

## BAB V

### PERANCANGAN UTAMA

#### V.1 PERENCANAAN UTAMA

Dalam penggambaran rencana garis kapal (*Lines Plan*), terlebih dahulu dibuat CSA (*Curve of Sectional Area*) dimana kurva tersebut akan menggambarkan besarnya luasan tiap-tiap *section* kapal yang direncanakan. Adapun data-data kapal rancangan yang diperlukan dalam penggambaran rencana garis ini adalah :

|   |   |          |
|---|---|----------|
| Panjang Antara Garis Tegak ( $L_{pp}$ ) | : | 125,93 m |
| Lebar (B)                               | : | 18.49 m  |
| Tinggi (H)                              | : | 11,63 m  |
| Sarat Air (T)                           | : | 8,61 m   |
| Koeffisien Blok ( $C_b$ )               | : | 0,76     |
| Koeffisien Tengah Kapal ( $C_m$ )       | : | 0,98     |
| Koeffisien Prismatik ( $C_p$ )          | : | 0,77     |
| Koeffisien Garis Air ( $C_w$ )          | : | 0,83     |

#### V.2 Pembuatan Rencana Garis (Metode RF.Scheltema Dheere)

Menurut Buku *Bouyancy dan Stability of Ship*, RF. Scheltema Dheere dan AR Baker (1969), dijelaskan metode untuk perancangan dan penggambaran bentuk badan kapal. Bentuk badan kapal menurut teknik perkapalan disebut dengan rencana garis (*lines plan*). Hal pertama yang harus direncanakan dalam pembuatan rencana garis adalah perhitungan curve of sectional area. *Curve of Sectional Area* merupakan suatu kurva yang menunjukkan besaran prosentase luasan melintang kapal pada setiap ordinat (*station*) sepanjang kapal.

Menurut RF. Scheltema Dheere dan AR Baker bahwa panjang kapal yang dipakai adalah LBP/LPP (*Length Between Perpendicular*) bukan LWL (*Length of Water Line*) ataupun L displasemen panjang kapal LPP tersebut dibagi menjadi 20

section sehingga penomorannya adalah dari station 0 sampai dengan station 20. Metode *RF. Scheltema Dheere* dan *AR Baker* tidak ditentukan secara pasti letak titik memanjang (*Longitudinal Center Of Buoyancy* atau LCB) seperti perencanaan rencana garis pada metode NSP Diagram. Namun demikian untuk mempermudah perhitungan untuk menentukan letak titik tekan memanjang LCB dapat diambil dari metode NSP diagram atau mengambil harga LCB dari kapal pembanding yang sejenis.

Langkah – langkah perhitungan rencana garis menurut *RF. Scheltema Dheere* dan *AR Baker* adalah sebagai berikut.

### V.2.1 Mencari L Displacement

$$\begin{aligned}
 L \text{ Displacement} &= \frac{1}{2}(lwl + lpp) \\
 &= \frac{1}{2}(129,71 + 125,93) \\
 &= 127,818 \text{ m} \\
 &= 419,345 \text{ feet} \\
 &= \frac{vd(\text{knot})}{\sqrt{l \text{ dist}(\text{ft})}} \\
 &= \frac{14,0}{419,345} \\
 &= 0,68
 \end{aligned}$$

$$\begin{aligned}
 h \text{ Displacement} &= \frac{l \text{ dist}}{20} \\
 &= \frac{127,818}{20} \\
 &= 6,3909 \text{ m}
 \end{aligned}$$

Didapat dari diafgram NSP:

$$\beta = 0,982$$

$$\sigma = 0,778$$

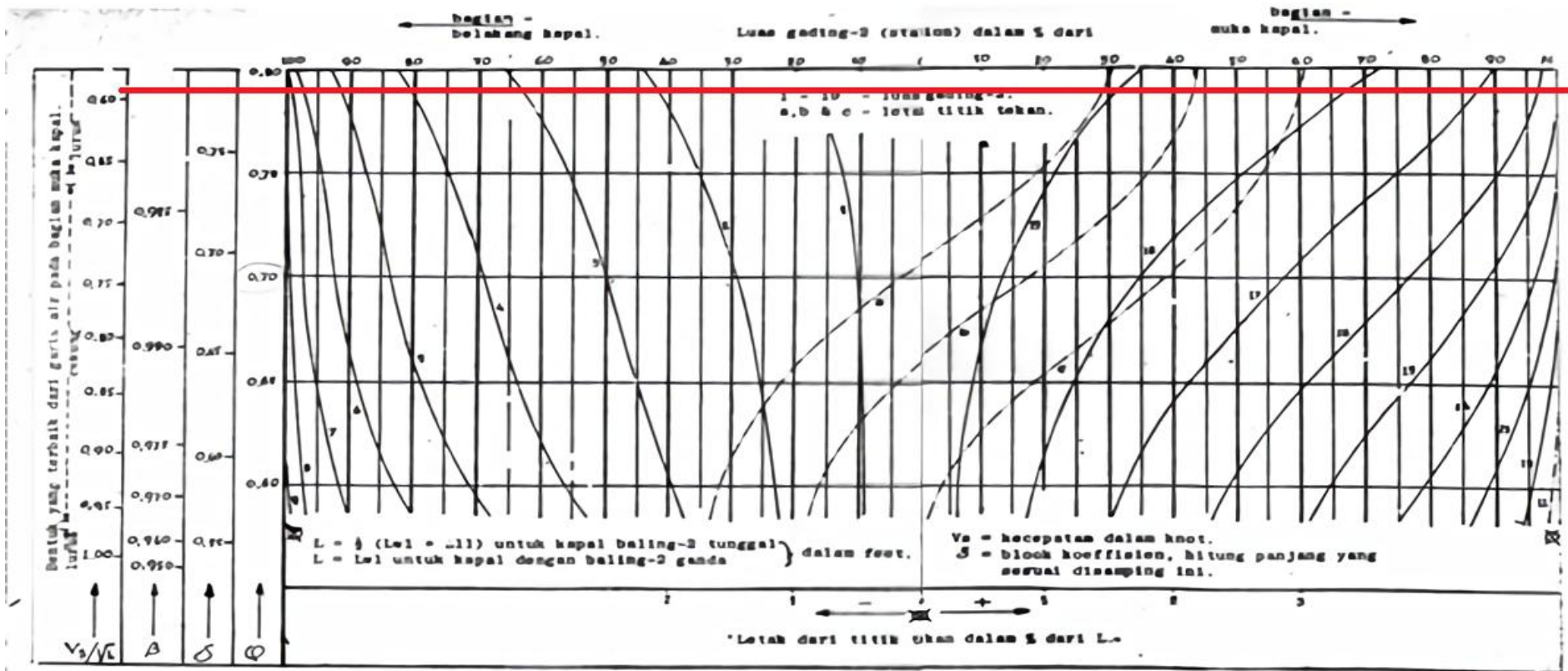
$$\varphi = 0,778$$

$$Am = B \times T \times \beta$$

$$Am = 156,355 \text{ m}^2$$



# DIAGRAM NSP



Gambar 2. Diagram NSP

### V.2.2 Curve Section Area ( L displacement)

Hasil dari pembacaan diagram Nsp dengan hasil koreksi volume dan koreksi LCB tertera pada tabel 5.1 sampai tabel 5.3 .

**Tabel 4. Hasil pembacaan diagram NSP**

| No. Station  | % Am | Luas     | faktor Simpson | Fungsi Luas | Lengan Momen | Fungsi Momen |
|--------------|------|----------|----------------|-------------|--------------|--------------|
| 0            | 0    | 0.0000   | 1              | 0.0000      | -10          | 0.0000       |
| 1            | 0.14 | 21.8897  | 4              | 87.5590     | -9           | -788.0309    |
| 2            | 0.4  | 62.5421  | 2              | 125.0843    | -8           | -1000.6741   |
| 3            | 0.6  | 93.8132  | 4              | 375.2528    | -7           | -2626.7696   |
| 4            | 0.78 | 121.9572 | 2              | 243.9143    | -6           | -1463.4859   |
| 5            | 0.9  | 140.7198 | 4              | 562.8792    | -5           | -2814.3960   |
| 6            | 0.96 | 150.1011 | 2              | 300.2022    | -4           | -1200.8089   |
| 7            | 0.99 | 154.7918 | 4              | 619.1671    | -3           | -1857.5013   |
| 8            | 1    | 156.3553 | 2              | 312.7107    | -2           | -625.4213    |
| 9            | 1    | 156.3553 | 4              | 625.4213    | -1           | -625.4213    |
| 10           | 1    | 156.3553 | 2              | 312.7107    | 0            | 0.0000       |
| 11           | 1    | 156.3553 | 4              | 625.4213    | 1            | 625.4213     |
| 12           | 1    | 156.3553 | 2              | 312.7107    | 2            | 625.4213     |
| 13           | 1    | 156.3553 | 4              | 625.4213    | 3            | 1876.2640    |
| 14           | 1    | 156.3553 | 2              | 312.7107    | 4            | 1250.8427    |
| 15           | 1    | 156.3553 | 4              | 625.4213    | 5            | 3127.1066    |
| 16           | 0.95 | 148.5376 | 2              | 297.0751    | 6            | 1782.4508    |
| 17           | 0.84 | 131.3385 | 4              | 525.3539    | 7            | 3677.4774    |
| 18           | 0.61 | 95.3768  | 2              | 190.7535    | 8            | 1526.0280    |
| 19           | 0.23 | 35.9617  | 4              | 143.8469    | 9            | 1294.6221    |
| 20           | 0    | 0.0000   | 1              | 0.0000      | 10           | 0.0000       |
| $\Sigma_1 =$ |      |          |                | 7223.616305 | $\Sigma_2 =$ | 2783.124897  |

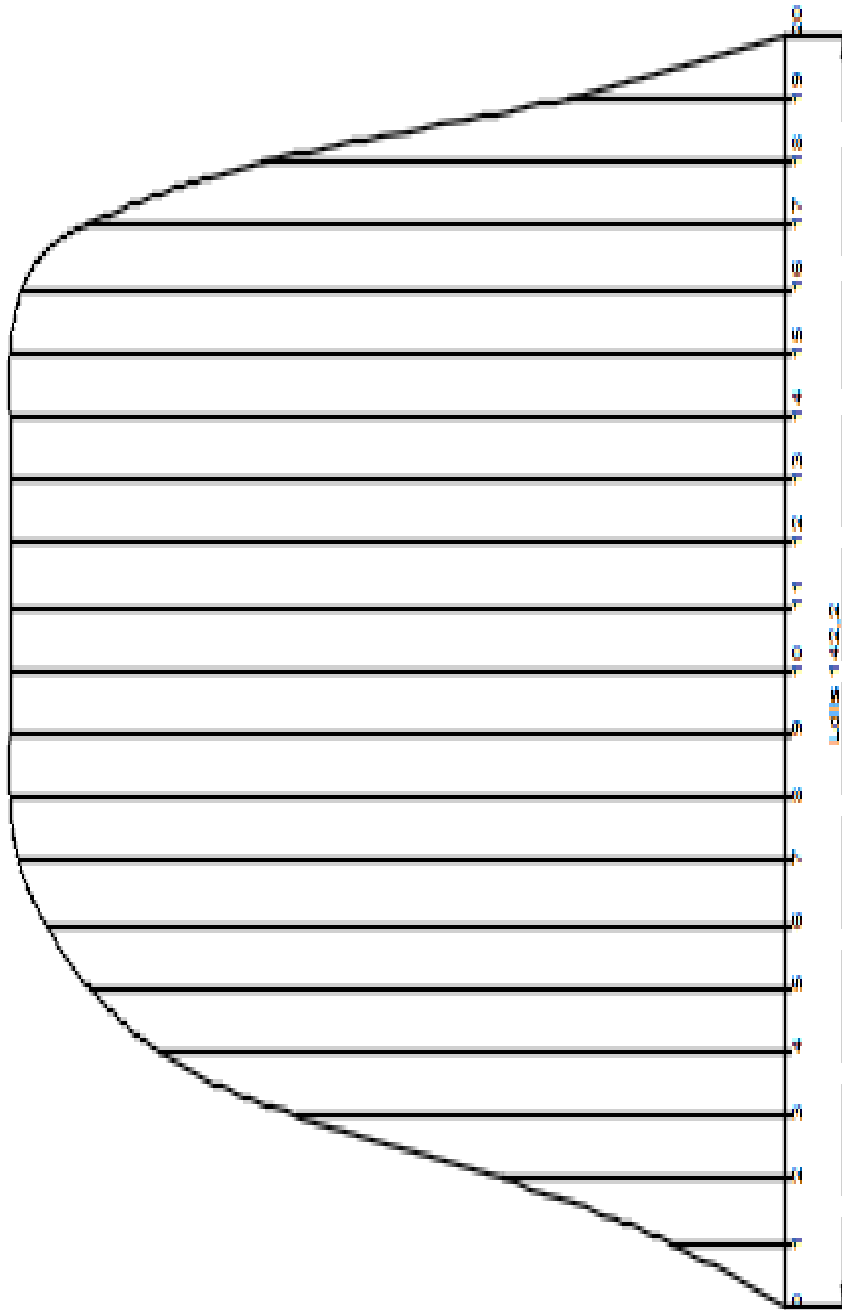
**Tabel 5. koreksi volume**

| Koreksi Volume  |  |              |            |
|---|--|--------------|------------|
| Vdisp   | $Lwl \times B \times T \times \delta disp$ | 16067.33602  | $m^3$      |
| Vsimp   | $1/3 \times hdisp \times \Sigma_1$         | 15388.46531  | $m^3$      |
| Ketentuan Nilai Koreksi                                   |  | <            | 0.5        |
| $Koreksi Vdisp. =  (Vsimp - Vdisp) / Vdisp  \times 100\%$ |  |              |            |
| Koreksi   | =  | -0.042251604 | (memenuhi) |

**Tabel 6. koreksi LCB**

| Koreksi LCB   |                                      |              |            |
|---|--------------------------------------|--------------|------------|
| LCB NSP   | $1,348\% \times Ldisp$               | 2.722522603  | m          |
| LCB Simp  | $(hdisp \times \Sigma_2) / \Sigma_1$ | 2.462294084  | m          |
| Ketentuan Nilai Koreksi                                       |                                      | <            | 0.1        |
| $Koreksi Vdisp. =  (LCBsimp - LCBNSP) / LCBNSP  \times 100\%$ |                                      |              |            |
| Koreksi   | =                                    | -0.095583603 | (memenuhi) |

Dari hasil perhitungan tabel diatas diperoleh gambar diagram CSA



Gambar 3. Diagram CSA

### V.2.3 Curve Section Area (LWL)

$$h_{lpp} = \frac{lpp}{20}$$

$$h_{lpp} = \frac{125,93}{20}$$

$$h_{lpp} = 6,296 \text{ m}$$

$$h' = \frac{1}{2}(lwl - lpp)$$

$$h' = \frac{1}{2}(129,71 - 125,93)$$

$$h' = 1,889 \text{ m}$$

$$z = \frac{h'}{h_{lpp}}$$

$$z = \frac{1,889}{6,296}$$

$$z = 0,300 \text{ m}$$

faktor *Simpson* & lengan momen untuk station 0, -1, & -2 tertera pada tabel 5.4

**Tabel 7. *Simpson* & Lengan momen**

| No. Station | faktor Simpson | Lengan Momen |
|-------------|----------------|--------------|
| -2          | 1 x Z = 0,30   | -10,60       |
| -1          | 4 x Z = 1,20   | -10,30       |
| 0           | 1 + Z = 1,30   | -10          |

Tabel 8. CSA

| No. Station | Luas   | faktor Simpson | Fungsi Luas | Lengan Momen | Fungsi Momen |
|-------------|--------|----------------|-------------|--------------|--------------|
| -2          | 0      | 0.43           | 0.0000      | -10.86       | 0.0000       |
| -1          | 4.41   | 1.72           | 7.5933      | -10.43       | -79.2017     |
| 0           | 8.97   | 1.43           | 12.8312     | -10          | -128.3122    |
| 1           | 29.29  | 4              | 117.1600    | -9           | -1054.4400   |
| 2           | 72.23  | 2              | 144.4600    | -8           | -1155.6800   |
| 3           | 101.06 | 4              | 404.2400    | -7           | -2829.6800   |
| 4           | 127.68 | 2              | 255.3600    | -6           | -1532.1600   |
| 5           | 143.26 | 4              | 573.0400    | -5           | -2865.2000   |
| 6           | 151.39 | 2              | 302.7800    | -4           | -1211.1200   |
| 7           | 155.46 | 4              | 621.8400    | -3           | -1865.5200   |
| 8           | 156.34 | 2              | 312.6800    | -2           | -625.3600    |
| 9           | 156.34 | 4              | 625.3600    | -1           | -625.3600    |
| 10          | 156.34 | 2              | 312.6800    | 0            | 0.0000       |
| 11          | 156.34 | 4              | 625.3600    | 1            | 625.3600     |
| 12          | 156.34 | 2              | 312.6800    | 2            | 625.3600     |
| 13          | 156.34 | 4              | 625.3600    | 3            | 1876.0800    |
| 14          | 156.34 | 2              | 312.6800    | 4            | 1250.7200    |
| 15          | 153.8  | 4              | 615.2000    | 5            | 3076.0000    |
| 16          | 147.99 | 2              | 295.9800    | 6            | 1775.8800    |
| 17          | 129.9  | 4              | 519.6000    | 7            | 3637.2000    |
| 18          | 93.93  | 2              | 187.8600    | 8            | 1502.8800    |
| 19          | 35.24  | 4              | 140.9600    | 9            | 1268.6400    |
| 20          | 0.0000 | 1              | 0.0000      | 10           | 0.0000       |
|             |        |                | 7318.111224 |              | 1745.287756  |

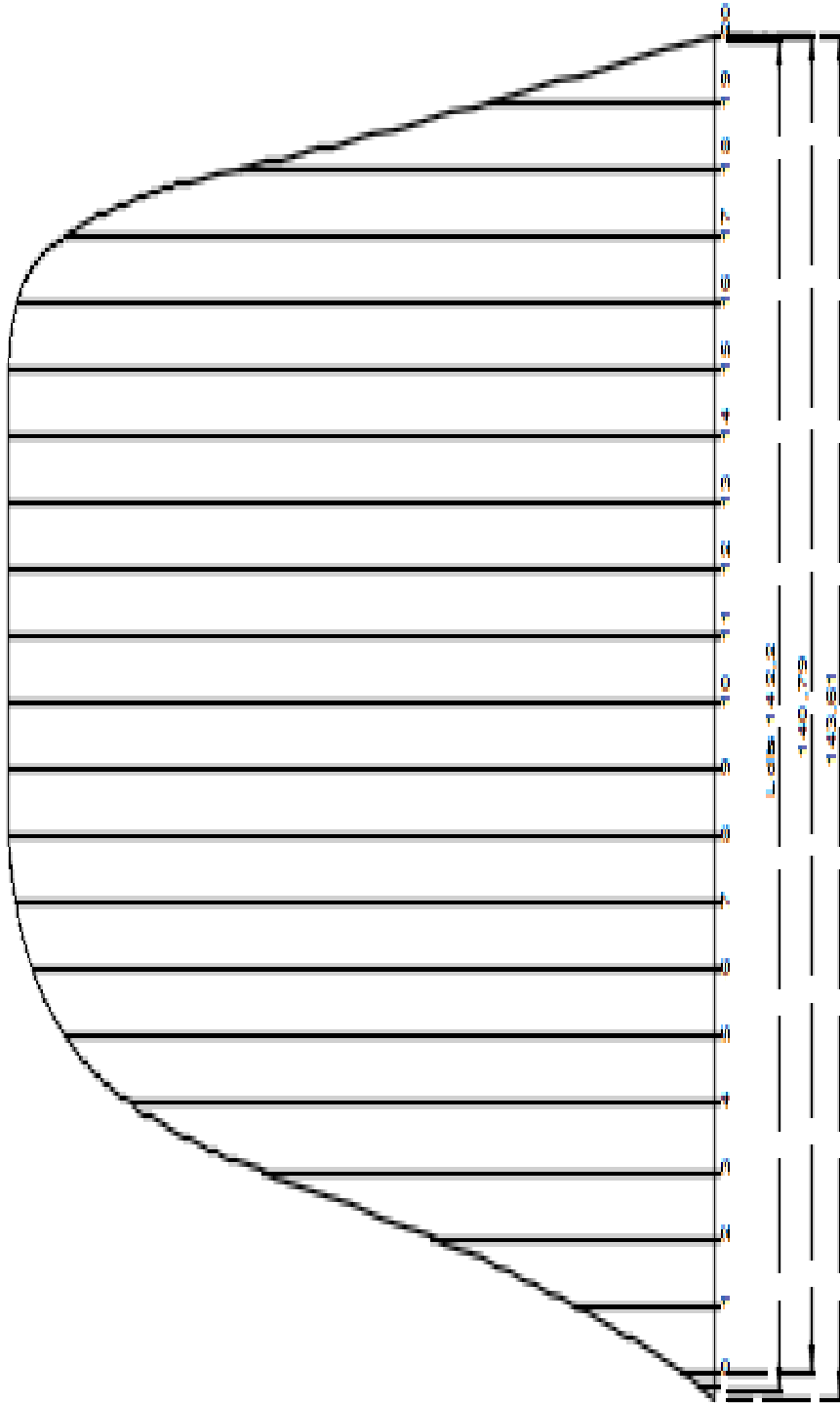
Tabel 9. Koreksi Volume

| Koreksi Volume  |  |              |            |
|---|--|--------------|------------|
| Vdisp   | $Lwl \times B \times T \times \delta wl$ | 15695.59817  | $m^3$      |
| Vsimp   | $1/3 \times h lpp \times \sum_1$         | 15359.37712  | $m^3$      |
| Ketentuan Nilai Koreksi                                   |  |              | < 0.5      |
| $Koreksi Vdisp. =  (Vsimp - Vdisp) / Vdisp  \times 100\%$ |  |              |            |
| Koreksi   | =  | -0.021421359 | (memenuhi) |

Tabel 10. Koreksi LCB

| Koreksi LCB   |                                  |              |            |
|---|----------------------------------|--------------|------------|
| LCB NSP   | $1,348\% \times Ldisp$           | 2.722522603  | m          |
| LCB Simp  | $(hdisp \times \sum_2) / \sum_1$ | 1.524157793  | m          |
| Ketentuan Nilai Koreksi                                       |                                  |              | < 0.1      |
| $Koreksi Vdisp. =  (LCBsimp - LCBNSP) / LCBNSP  \times 100\%$ |                                  |              |            |
| Koreksi   | =                                | -0.440167075 | (memenuhi) |





Gambar 4. Diagram CSA LWL

Penentuan sudut Masuk (angle of entrance)

*Penentuan sudut Masuk (angle of entrance)*

$$\varphi f = \varphi lpp + (1,4 - \varphi lpp) \times e\%$$

$$e = \frac{LCB}{L disp}$$

$$e = \frac{1,534622748}{127,818}$$

$$e = 0,01$$

$$\varphi lpp = \delta disp + \left( \frac{l disp}{lpp} \right)$$

$$\varphi lpp = 0,778 + \left( \frac{127,818}{125,93} \right)$$

$$\varphi lpp = 1,793$$

Maka:

$$\varphi f = 0,78$$

Angka dari  $\varphi f$  dimasukkan kedalam grafik "Angle of Entrance" dan didapat sudut

$$\varphi f = 20^\circ$$

**Tabel 11. A/2T**

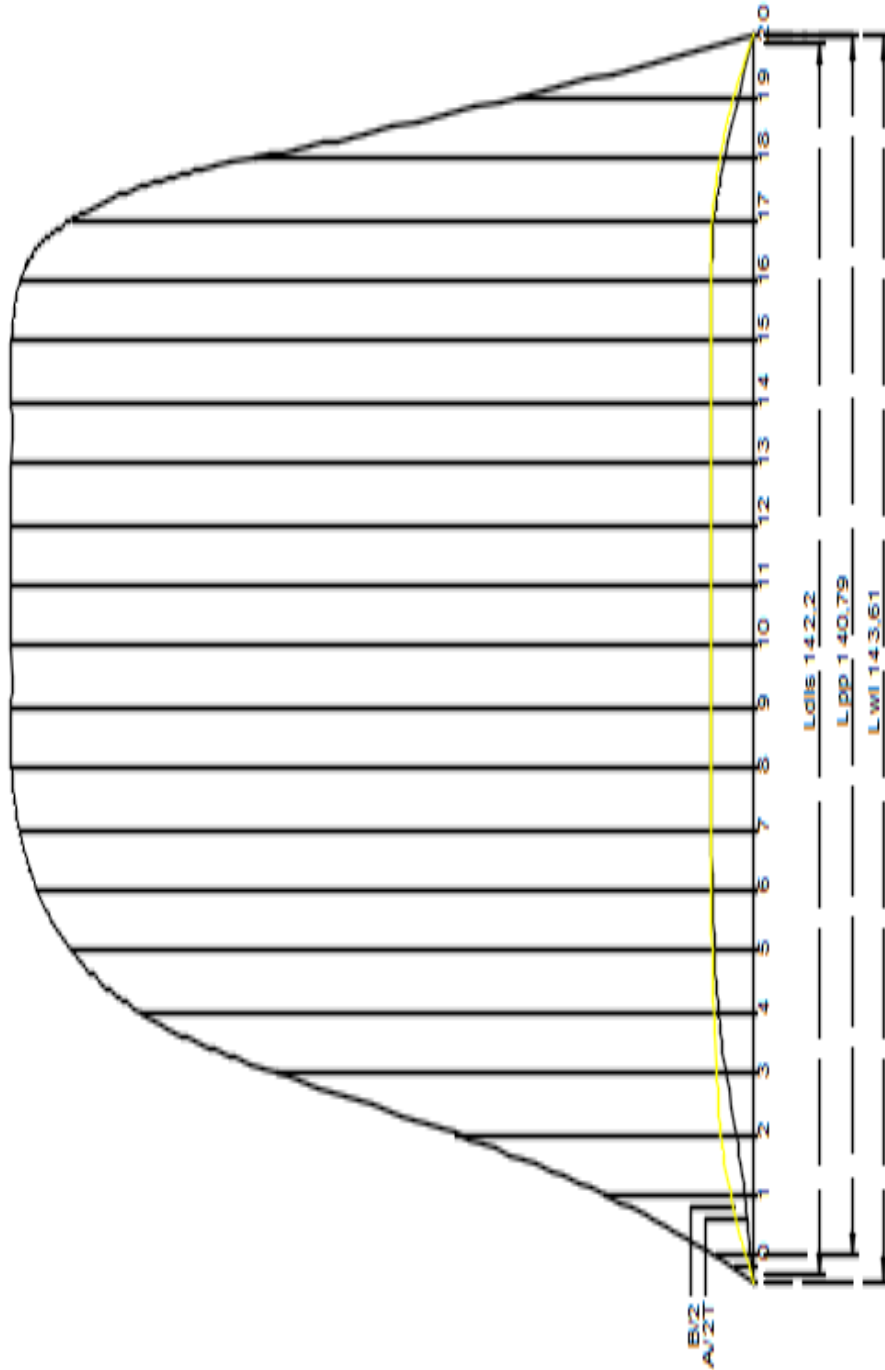
| No. Station | A (Luas) | A/2T |
|-------------|----------|------|
| -2          | 0        | 0.00 |
| -1          | 4.41     | 0.26 |
| 0           | 8.97     | 0.52 |
| 1           | 29.29    | 1.70 |
| 2           | 72.23    | 4.19 |
| 3           | 101.06   | 5.87 |
| 4           | 127.68   | 7.42 |
| 5           | 143.26   | 8.32 |
| 6           | 151.39   | 8.79 |
| 7           | 155.46   | 9.03 |
| 8           | 156.34   | 9.08 |
| 9           | 156.34   | 9.08 |
| 10          | 156.34   | 9.08 |
| 11          | 156.34   | 9.08 |
| 12          | 156.34   | 9.08 |
| 13          | 156.34   | 9.08 |
| 14          | 156.34   | 9.08 |
| 15          | 153.8    | 8.93 |
| 16          | 147.99   | 8.59 |
| 17          | 129.9    | 7.54 |
| 18          | 93.93    | 5.46 |
| 19          | 35.24    | 2.05 |
| 20          | 0        | 0.0  |

Tabel 12. B/2

| No. Station | B/2 | faktor Simpson | Fungsi Luas |
|-------------|-----|----------------|-------------|
| -2          | 0.0 | 0.43           | 0.0000      |
| -1          | 0.6 | 1.72           | 1.0331      |
| 0           | 1.2 | 1.43           | 1.6450      |
| 1           | 3.0 | 4              | 12.0800     |
| 2           | 4.8 | 2              | 9.5200      |
| 3           | 6.3 | 4              | 25.2000     |
| 4           | 7.6 | 2              | 15.2000     |
| 5           | 8.5 | 4              | 34.0000     |
| 6           | 9.1 | 2              | 18.2000     |
| 7           | 9.2 | 4              | 36.9887     |
| 8           | 9.2 | 2              | 18.4943     |
| 9           | 9.2 | 4              | 36.9887     |
| 10          | 9.2 | 2              | 18.4943     |
| 11          | 9.2 | 4              | 36.9887     |
| 12          | 9.2 | 2              | 18.4943     |
| 13          | 9.2 | 4              | 36.9887     |
| 14          | 9.2 | 2              | 18.4943     |
| 15          | 9.2 | 4              | 36.9887     |
| 16          | 9.2 | 2              | 18.4943     |
| 17          | 8.3 | 4              | 33.2000     |
| 18          | 6.2 | 2              | 12.4600     |
| 19          | 3.3 | 4              | 13.3600     |
| 20          | 0.0 | 1              | 0.0000      |
|             |     | $\Sigma_1 =$   | 452.2799812 |

Tabel 13. Koreksi CSA LWL

| Koreksi Area of Water Line                               |   |              |            |
|--|---|--------------|------------|
| $\alpha$   | $0,248 + 0,778 \delta w_l$                      | 0.84         |            |
| Awl  | $\alpha \times B \times Lwl$                    | 2013.300278  | $m^2$      |
| Awl Simp   | $2 \times (1/3 \times h_{lpp} \times \Sigma_1)$ | 1898.505935  | $m^2$      |
| Ketentuan Nilai Koreksi                                  |   |              | < 0.5      |
| $Koreksi Vdisp. =  (Awl simp - Awl) / Awl  \times 100\%$ |   |              |            |
| Koreksi  | =   | -0.057017994 | (memenuhi) |



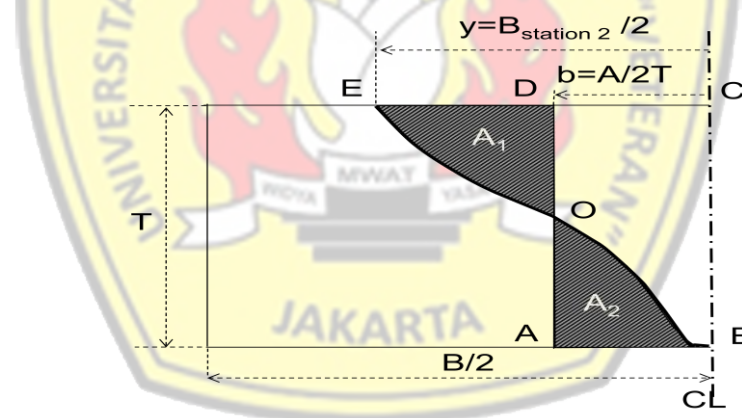
Gambar 5. Diagram B/2 dan A/2T

#### V.2.4 Pembuatan *body plan*

Setelah semua data-data untuk pembuatan *Body Plan* kapal telah selesai dilakukan, seperti Kurva Prismatik (CSA), Luasan Bidang Garis Air serta Jari-Jari Bilga, maka dilanjutkan dengan penggambaran *Body Plan* seperti yang terdapat dalam *Ikeda Masaharu* hal.58-63.

Karena bagian kiri dan kanan kapal adalah simetri maka gambar station 0 s/d 10 (bagian belakang dari midship) diletakkan sebelah kiri dan gambar station 10 s/d 20 (bagian depan dari midship) diletakkan sebelah kanan. Misalkan untuk station no.2 digambarkan dengan cara sebagai berikut:

- Gambar 4 persegi panjang dengan sisi  $B/2$  dan  $T$ .
- Ukurkan  $b = A/2T$ ,  $A$  adalah luas station 2 dari CSA, luas  $ABCD = A/2$
- Ukurkan  $y = B_{\text{station 2}} / 2$ , didapat dari gambar  $B/2$ .
- Buat lengkung  $EOB$  dimana luas  $A_1 = \text{luas } A_2$ . Luas dihitung dengan planimeter, Simpson atau excel.
- Demikian dibuatkan untuk tiap station (0 s/d 10 dan 10 s/d 20)

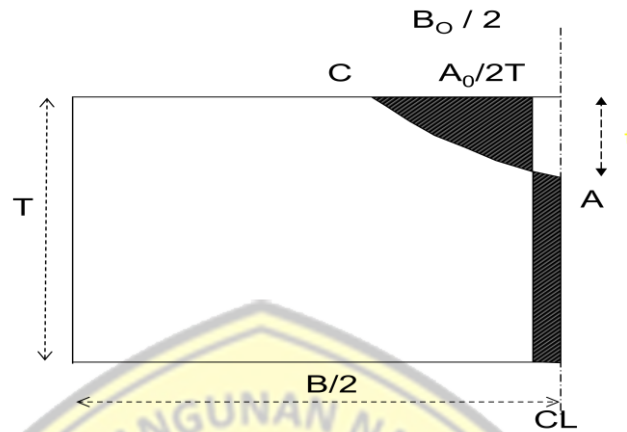


**Gambar 6. menghitung luas  $B/2$  dan  $A/2T$**

Penggambaran *body plan* pada station 0

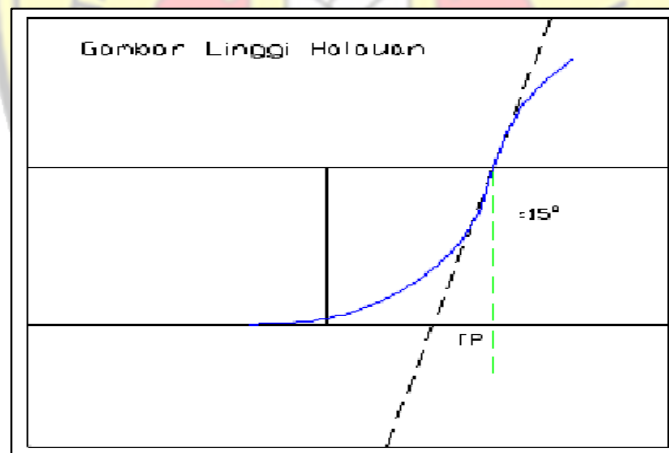
- Umumnya bentuk bodyplan pada station 0 = AP adalah cembung.
- Harga  $t$  diperoleh saat merancang buritan kapal,  $B_0/2$  diperoleh saat merancang setengah bidang garis air.
- Luas  $\Delta ABC = \frac{1}{2} \cdot AB \times BC$   
 $= \frac{1}{2} \cdot (B_0/2) \times t.$

- d. Supaya gambar bodyplan station AP berbentuk cembung, maka :  $\frac{1}{2}$  luas station 0 yaitu  $A_0 / 2$  harus lebih besar daripada luas  $\Delta ABC$ , maka :  $A_0 / 2 > \frac{1}{2} \cdot (B_0/2) \times t$ .

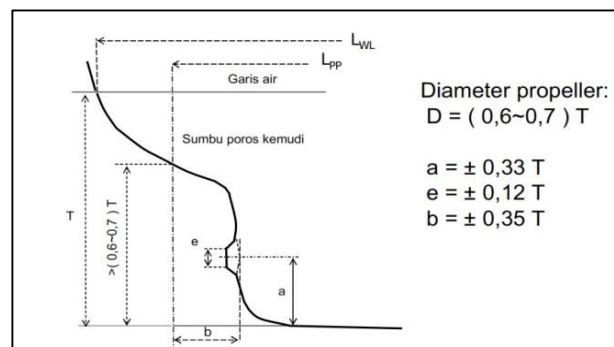


Gambar 7. menghitung luas  $B/2$  dan  $A/2T$

### V.2.5 Pembuatan Linggi Haluan dan Buritan



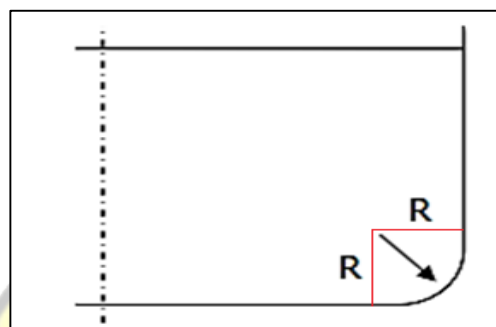
Gambar 8. Linggi Haluan



Gambar 9. Linggi Buritan

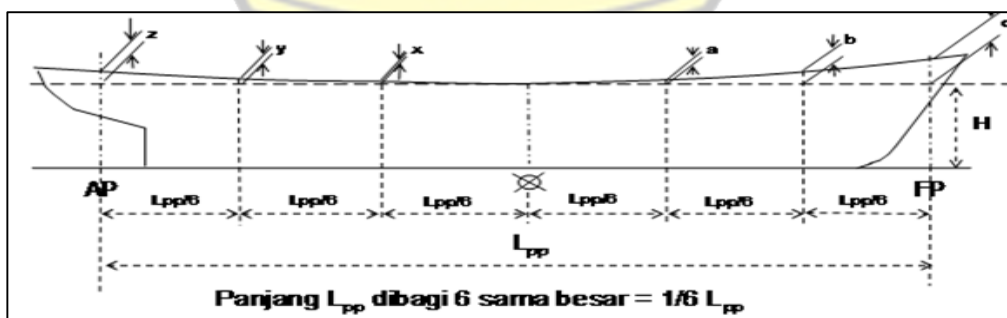
**Tabel 14. Penentuan, Diameter, Poros, dan Jarak Propeller**

|   |   |          |      |   |
|---|---|----------|------|---|
| D | Diameter Propeller                          | 0,7 x T  | 4,51 | m |
| a | Jarak Baseline ke Tengah Poros Propeller    | 0,34 x T | 2,13 | m |
| e | Poros Propeller                             | 0,13 x T | 0,84 | m |
| b | Jarak Sumbu Poros Kemudi Ke Poros Propeller | 0,34 x T | 2,19 | m |

**V.2.6 Penentuan radius bilga****Gambar 10. Radius Bilga**

$$R = \sqrt{\frac{1}{2} \cdot \{ (B \times T) - A_m \} / (1 - \frac{1}{4} \pi)}$$

$$R = 2,586 \text{ m}$$

**V.2.7 Perencanaan sheer line****Gambar 11. Perencanaan sheer line**

$$\frac{1}{6} l_{pp} = 20,988 \text{ m}$$

**Tabel 15. Perencanaan sheer line Depan midship**

| Depan Midship |                        |        |    |
|---------------|------------------------|--------|----|
| a             | $5.6 (L_{pp}/3 + 10)$  | 291.1  | mm |
| b             | $22.2 (L_{pp}/3 + 10)$ | 1153.9 | mm |
| c             | $50.0 (L_{pp}/3 + 10)$ | 2598.8 | mm |

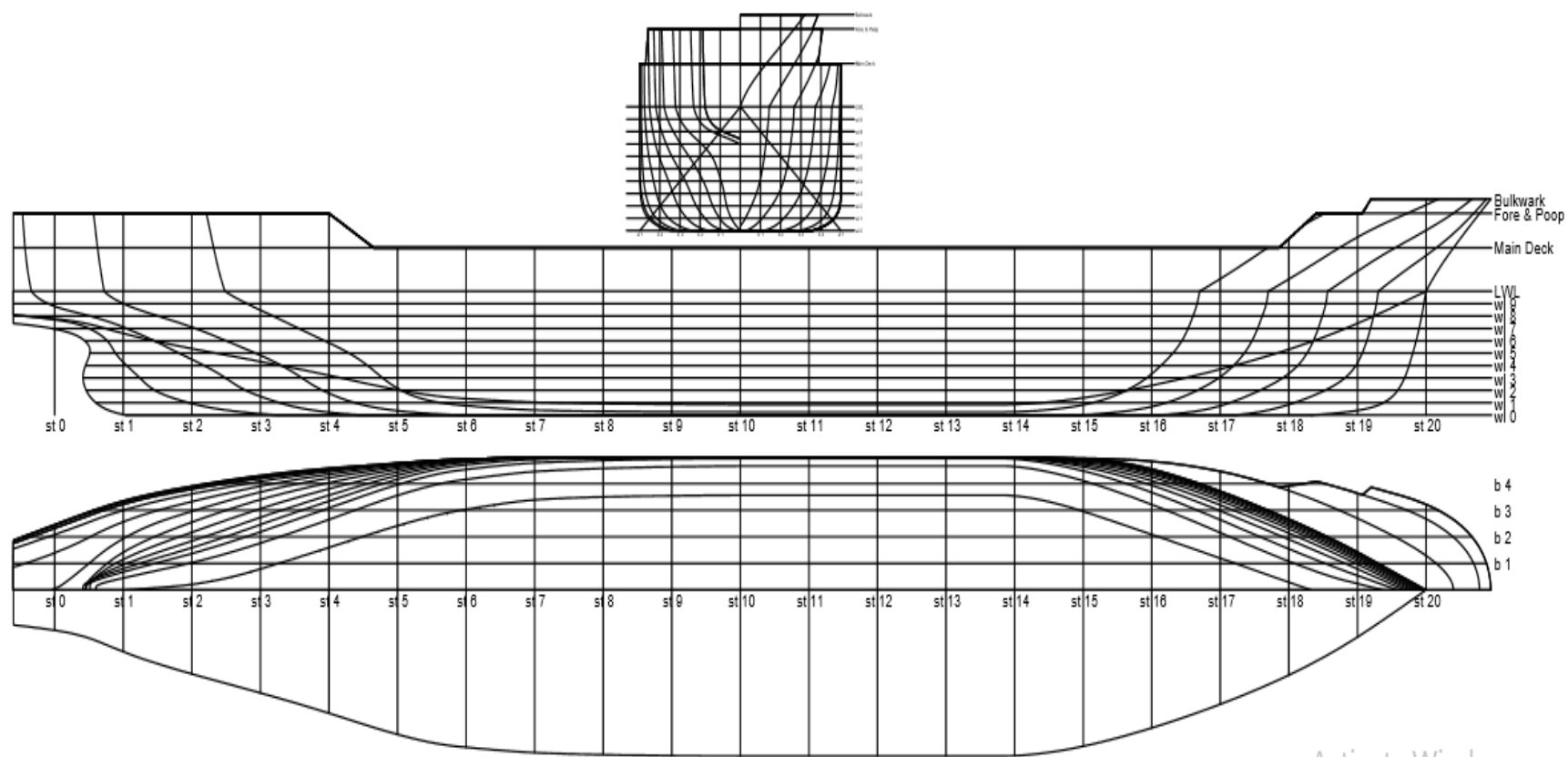
**Tabel 16. Perencanaan sheer line Belakang midship**

| Belakang Midship |                        |        |    |
|------------------|------------------------|--------|----|
| x                | $2.8 (L_{pp}/3 + 10)$  | 145.5  | mm |
| y                | $11.2 (L_{pp}/3 + 10)$ | 582.1  | mm |
| z                | $25.0 (L_{pp}/3 + 10)$ | 1299.4 | mm |

Hasil gambar lines plan pada yang sudah dibuat dengan rumus diatas tertera dibawah ini







Gambar 12. Lines Plan

Activate Windows

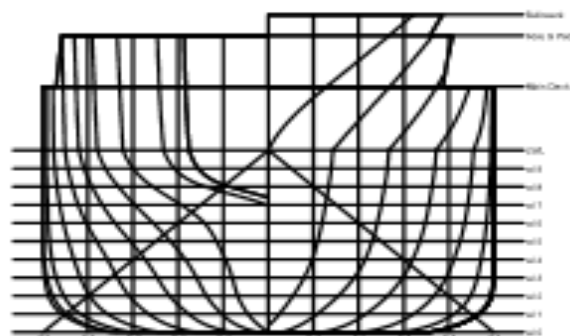
### V.3 Perhitungan Hidrostatik dan Bonjean

#### V.3.1 Perhitungan Kurva Hidrostatik

Kurva hidrostatik merupakan karakteristik dari sebuah kapal yang diperlukan dalam mendesain serta untuk pengoperasian kapal tersebut. Diagram hidrostatik ini menunjukkan karakter yang menyangkut kemampuan apung serta berbagai parameter dalam berbagai kondisi pada kapal tersebut. Adapun kurva-kurva yang digambarkan dalam diagram tersebut adalah meliputi :

- Luasan pada tiap-tiap garis air.
- Kurva displasemen.
- Titik tekan pada tiap luasan garis air.
- Kurva koefisien-koefisien kapal
- Momen inersia memanjang pada setiap luasan garis air.
- Momen inersia melintang pada setiap luasan garis air.
- $KM_T$  , Metacentra melintang diatas garis dasar.
- $KM_L$  , Metacentra memanjang diatas garis dasar.

Untuk memudahkan pembacaan, maka tiap kurva yang bersangkutan diberikan petunjuk serta skala ukuran antara gambar yang sesungguhnya dan juga untuk mempersingkat waktu pengerjaan, perhitungan tiap-tiap kurva telah dimasukkan kedalam tabel-tabel dengan gambar *body plan* yang sudah di dibagi 10 garis air berikut :



Gambar 13. Body plan 10 garis air

Tabel 17. ½ water lines

| <b>1/2 WATER LINES</b> |          |          |          |          |          |          |          |          |          |           |
|------------------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|-----------|
| <b>GA 0 m</b>          | <b>1</b> | <b>2</b> | <b>3</b> | <b>4</b> | <b>5</b> | <b>6</b> | <b>7</b> | <b>8</b> | <b>9</b> | <b>10</b> |
| 0                      | 0        | 0        | 0        | 0        | 0        | 0        | 1        | 2,98     | 3,79     | 5,76      |
| 0                      | 1,013    | 1,3      | 1,51     | 1,8      | 2,4      | 2,8      | 3,8      | 4,8      | 5,7      | 6,01      |
| 1,87                   | 2,05     | 2,8      | 3,04     | 3,9      | 4,2      | 4,9      | 5,8      | 6,5      | 6,9      | 7,4       |
| 2,79                   | 3,5      | 4,4      | 4,7      | 5,4      | 5,8      | 6,9      | 7,04     | 7,5      | 7,9      | 8,123     |
| 4,87                   | 5,034    | 5,9      | 6,534    | 6,889    | 7,34     | 7,89     | 8,23     | 8,589    | 8,57     | 8,745     |
| 5,089                  | 6,89     | 7,45     | 7,82     | 8,12     | 8,45     | 8,756    | 8,836    | 8,91     | 8,934    | 9,012     |
| 5,906                  | 7,89     | 8,687    | 8,701    | 9,106    | 9,34     | 9,38     | 9,38     | 9,38     | 9,38     | 9,38      |
| 6,987                  | 8,321    | 8,923    | 9,123    | 9,245    | 9,46     | 9,47     | 9,48     | 9,48     | 9,48     | 9,48      |
| 6,987                  | 8,623    | 9,123    | 9,243    | 9,2456   | 9,25     | 9,25     | 9,25     | 9,25     | 9,25     | 9,25      |
| 6,987                  | 8,568    | 9,103    | 9,218    | 9,2456   | 9,25     | 9,25     | 9,25     | 9,25     | 9,25     | 9,25      |
| 6,987                  | 8,617    | 9,142    | 9,235    | 9,25     | 9,25     | 9,25     | 9,25     | 9,25     | 9,25     | 9,25      |
| 6,987                  | 8,626    | 9,149    | 9,238    | 9,25     | 9,25     | 9,25     | 9,25     | 9,25     | 9,25     | 9,25      |
| 7,035                  | 8,626    | 9,149    | 9,238    | 9,25     | 9,25     | 9,25     | 9,25     | 9,25     | 9,25     | 9,25      |
| 7,1767                 | 8,781    | 9,45     | 9,238    | 9,25     | 9,25     | 9,25     | 9,25     | 9,25     | 9,25     | 9,25      |
| 7,278                  | 8,579    | 9,11     | 9,207    | 9,221    | 9,227    | 9,231    | 9,234    | 9,237    | 9,238    | 9,24      |
| 7,45                   | 7,678    | 8,4567   | 8,861    | 8,901    | 9,0125   | 9,21     | 9,203    | 9,025    | 9,027    | 9,219     |
| 5,89                   | 6,031    | 6,978    | 7,4754   | 7,78     | 7,997    | 8,12     | 8,19     | 8,289    | 8,573    | 8,89      |
| 3,98                   | 4,2124   | 4,99     | 5,632    | 6,012    | 6,4657   | 6,6325   | 6,785    | 6,8901   | 7,045    | 7,234     |
| 1,897                  | 2,011    | 3,0138   | 3,731    | 4,1      | 4,421    | 4,678    | 4,891    | 4,913    | 5,12     | 5,242     |
| 0                      | 1,04     | 1,45     | 2,76     | 3,15     | 3,44     | 2,53     | 5,65     | 2,893    | 2,678    | 3,0123    |
| 0                      | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0         |

Tabel 18. Aw ; OF ; IL(F) ; IT

| Garis Air 0                         |                |   |                |                         |              |               |                        |                               |
|-------------------------------------|----------------|---|----------------|-------------------------|--------------|---------------|------------------------|-------------------------------|
| Nomor Ordinat                       | Faktor simpson | Lengan Momen  | Luas Garis Air |                         | BM Memanjang |               | BM Melintang           |                               |
|                                     |                |   | 1/2 Ordinat    | Fungsi Luas 1/2 Ordinat | Momen        | Momen Inersia | (1/2 Ord) <sup>3</sup> | Fungsi (1/2 Ord) <sup>3</sup> |
| 1                                   | 2              | 3   | 4              | 5 = 2 x 4               | 6 = 3 x 5    | 7 = 3 x 6     | 8 = 4 <sup>3</sup>     | 9 = 2 x 8                     |
| AP                                  | 1              | -10   | 0              | 0                       | 0            | 0             | 0                      | 0                             |
| 1                                   | 4              | -9  | 0              | 0                       | 0            | 0             | 0                      | 0                             |
| 2                                   | 2              | -8  | 1,87           | 3,74                    | -29,92       | 239,36        | 6,539203               | 13,078406                     |
| 3                                   | 4              | -7  | 2,79           | 11,16                   | -78,12       | 546,84        | 21,717639              | 86,870556                     |
| 4                                   | 2              | -6  | 4,87           | 9,74                    | -58,44       | 350,64        | 115,5013               | 231,002606                    |
| 5                                   | 4              | -5  | 5,089          | 20,356                  | -101,78      | 508,9         | 131,79452              | 527,17808                     |
| 6                                   | 2              | -4  | 5,906          | 11,812                  | -47,248      | 188,992       | 206,00622              | 412,012435                    |
| 7                                   | 4              | -3  | 6,987          | 27,948                  | -83,844      | 251,532       | 341,09255              | 1364,37019                    |
| 8                                   | 2              | -2  | 6,987          | 13,974                  | -27,948      | 55,896        | 341,09255              | 682,185094                    |
| 9                                   | 4              | -1  | 6,987          | 27,948                  | -27,948      | 27,948        | 341,09255              | 1364,37019                    |
| 10                                  | 2              | 0   | 6,987          | 13,974                  | 0            | 0             | 341,09255              | 682,185094                    |
| 11                                  | 4              | 1   | 6,987          | 27,948                  | 27,948       | 27,948        | 341,09255              | 1364,37019                    |
| 12                                  | 2              | 2   | 7,035          | 14,07                   | 28,14        | 56,28         | 348,17077              | 696,341536                    |
| 13                                  | 4              | 3   | 7,1767         | 28,7068                 | 86,1204      | 258,3612      | 369,6361               | 1478,54439                    |
| 14                                  | 2              | 4   | 7,278          | 14,556                  | 58,224       | 232,896       | 385,51045              | 771,020898                    |
| 15                                  | 4              | 5   | 7,45           | 29,8                    | 149          | 745           | 413,49363              | 1653,9745                     |
| 16                                  | 2              | 6   | 5,89           | 11,78                   | 70,68        | 424,08        | 204,33647              | 408,672938                    |
| 17                                  | 4              | 7   | 3,98           | 15,92                   | 111,44       | 780,08        | 63,044792              | 252,179168                    |
| 18                                  | 2              | 8   | 1,897          | 3,794                   | 30,352       | 242,816       | 6,8265613              | 13,6531225                    |
| 19                                  | 4              | 9   | 0              | 0                       | 0            | 0             | 0                      | 0                             |
| FP                                  | 1              | 10  | 0              | 0                       | 0            | 0             | 0                      | 0                             |
| Σ                                   |                |   |                | 287,2268                | 106,656      | 4937,5692     | 3978,0404              | 12002,0094                    |
| h = LBP/Station = LPP/20 = 6,2965 m |                |   |                |                         |              |               |                        |                               |
| AW                                  | =              | $2/3 \times h \times \Sigma(5)$                       | =              | 1205,682364             |              |               |                        | m <sup>2</sup>                |
| OF                                  | =              | $[\Sigma(6) \times h] / \Sigma(5)$                    | =              | 2,338                   |              |               |                        | m                             |
| IL(O)                               | =              | $2/3 \times h^3 \times \Sigma(7)$                     | =              | 821711,868              |              |               |                        | m <sup>4</sup>                |
| IL(F)                               | =              | $IL(O) - Aw (OF)^2$                                   | =              | 815120,808              |              |               |                        | m <sup>4</sup>                |
| IT                                  | =              | $2/9 \times h \times \Sigma(9)$                       | =              | 16793,478               |              |               |                        | m <sup>4</sup>                |
| MSA                                 | =              | $2 \times 1/3 \times b \times \text{stata 10 fungsi}$ | =              | 2283,395177             |              |               |                        |                               |

Tabel 19. Aw ; OF ; IL(F) ; IT

| Aw ; OF ; IL(F) ; IT  |                |              |                |                 |              |               |                        |              |
|---|----------------|--------------|----------------|-----------------|--------------|---------------|------------------------|--------------|
| Garis Air 1   |                |              |                |                 |              |               |                        |              |
| Nomor Ordinat   | Faktor simpson | Lengan Momen | Luas Garis Air |                 | BM Memanjang |               | BM Melintang           |              |
|   |                |              | L/2 Ordina     | Fungsi Luas 1/2 | Momen        | Momen Inersia | (1/2 Ord) <sup>3</sup> | Fungsi (1/2) |
| 1   | 2              | 3            | 4              | 5 = 2 x 4       | 6 = 3 x 5    | 7 = 3 x 6     | 8 = 4 <sup>3</sup>     | 9 = 2 x 8    |
| AP  | 1              | -10          | 0              | 0               | 0            | 0             | 0                      | 0            |
| 1   | 4              | -9           | 1,013          | 4,052           | -36,468      | 328,212       | 1,039509               | 4,158037     |
| 2   | 2              | -8           | 2,05           | 4,1             | -32,8        | 262,4         | 8,615125               | 17,23025     |
| 3   | 4              | -7           | 3,5            | 14              | -98          | 686           | 42,875                 | 171,5        |
| 4   | 2              | -6           | 5,034          | 10,068          | -60,408      | 362,448       | 127,5674               | 255,1348     |
| 5   | 4              | -5           | 6,89           | 27,56           | -137,8       | 689           | 327,0828               | 1308,331     |
| 6   | 2              | -4           | 7,89           | 15,78           | -63,12       | 252,48        | 491,1691               | 982,3381     |
| 7   | 4              | -3           | 8,321          | 33,284          | -99,852      | 299,556       | 576,1381               | 2304,552     |
| 8   | 2              | -2           | 8,623          | 17,246          | -34,492      | 68,984        | 641,1729               | 1282,346     |
| 9   | 4              | -1           | 8,568          | 34,272          | -34,272      | 34,272        | 628,9822               | 2515,929     |
| 10  | 2              | 0            | 8,617          | 17,234          | 0            | 0             | 639,8354               | 1279,671     |
| 11  | 4              | 1            | 8,626          | 34,504          | 34,504       | 34,504        | 641,8423               | 2567,369     |
| 12  | 2              | 2            | 8,626          | 17,252          | 34,504       | 69,008        | 641,8423               | 1283,685     |
| 13  | 4              | 3            | 8,781          | 35,124          | 105,372      | 316,116       | 677,0674               | 2708,27      |
| 14  | 2              | 4            | 8,579          | 17,158          | 68,632       | 274,528       | 631,4079               | 1262,816     |
| 15  | 4              | 5            | 7,678          | 30,712          | 153,56       | 767,8         | 452,631                | 1810,524     |
| 16  | 2              | 6            | 6,031          | 12,062          | 72,372       | 434,232       | 219,3653               | 438,7307     |
| 17  | 4              | 7            | 4,2124         | 16,8496         | 117,9472     | 825,6304      | 74,74615               | 298,9846     |
| 18  | 2              | 8            | 2,011          | 4,022           | 32,176       | 257,408       | 8,132727               | 16,26545     |
| 19  | 4              | 9            | 1,04           | 4,16            | 37,44        | 336,96        | 1,124864               | 4,499456     |
| FP  | 1              | 10           | 0              | 0               | 0            | 0             | 0                      | 0            |
| Σ   |                |              |                | 349,4396        | 59,2952      | 6299,5384     | 6831,513               | 20507,83     |
| <p>h = LBP/Station = LPP/20 = 6,2965 m</p> <p>AW = <math>2/3 \times h \times \Sigma(5)</math> = 1466,830961 m<sup>2</sup></p> <p>OF = <math>[\Sigma(6) \times h] / \Sigma(5)</math> = 1,068 m</p> <p>IL(O) = <math>2/3 \times h^3 \times \Sigma(7)</math> = 1048371,224 m<sup>4</sup></p> <p>IL(F) = IL(O) - Aw (OF)<sup>2</sup> = 1046696,769 m<sup>4</sup></p> <p>IT = <math>2/9 \times h \times \Sigma(9)</math> = 28695,018 m<sup>4</sup></p> |                |              |                |                 |              |               |                        |              |

Tabel 20. Aw ; OF ; IL(F) ; IT

| Aw ; OF ; IL(F) ; IT  |                |              |                |                 |              |               |                        |              |
|---|----------------|--------------|----------------|-----------------|--------------|---------------|------------------------|--------------|
| Garis Air 2   |                |              |                |                 |              |               |                        |              |
| Nomor Ordinat   | Faktor simpson | Lengan Momen | Luas Garis Air |                 | BM Memanjang |               | BM Melintang           |              |
|   |                |              | 1/2 Ordina     | Fungsi Luas 1/2 | Momen        | Momen Inersia | (1/2 Ord) <sup>3</sup> | Fungsi (1/2) |
| 1   | 2              | 3            | 4              | 5 = 2 x 4       | 6 = 3 x 5    | 7 = 3 x 6     | 8 = 4 <sup>3</sup>     | 9 = 2 x 8    |
| AP  | 1              | -10          | 0              | 0               | 0            | 0             | 0                      | 0            |
| 1   | 4              | -9           | 1,3            | 5,2             | -46,8        | 421,2         | 2,197                  | 8,788        |
| 2   | 2              | -8           | 2,8            | 5,6             | -44,8        | 358,4         | 21,952                 | 43,904       |
| 3   | 4              | -7           | 4,4            | 17,6            | -123,2       | 862,4         | 85,184                 | 340,736      |
| 4   | 2              | -6           | 5,9            | 11,8            | -70,8        | 424,8         | 205,379                | 410,758      |
| 5   | 4              | -5           | 7,45           | 29,8            | -149         | 745           | 413,4936               | 1653,975     |
| 6   | 2              | -4           | 8,687          | 17,374          | -69,496      | 277,984       | 655,5555               | 1311,111     |
| 7   | 4              | -3           | 8,923          | 35,692          | -107,076     | 321,228       | 710,4486               | 2841,795     |
| 8   | 2              | -2           | 9,123          | 18,246          | -36,492      | 72,984        | 759,2993               | 1518,599     |
| 9   | 4              | -1           | 9,103          | 36,412          | -36,412      | 36,412        | 754,3165               | 3017,266     |
| 10  | 2              | 0            | 9,142          | 18,284          | 0            | 0             | 764,0533               | 1528,107     |
| 11  | 4              | 1            | 9,149          | 36,596          | 36,596       | 36,596        | 765,8097               | 3063,239     |
| 12  | 2              | 2            | 9,149          | 18,298          | 36,596       | 73,192        | 765,8097               | 1531,619     |
| 13  | 4              | 3            | 9,45           | 37,8            | 113,4        | 340,2         | 843,9086               | 3375,635     |
| 14  | 2              | 4            | 9,11           | 18,22           | 72,88        | 291,52        | 756,058                | 1512,116     |
| 15  | 4              | 5            | 8,4567         | 33,8268         | 169,134      | 845,67        | 604,7875               | 2419,15      |
| 16  | 2              | 6            | 6,978          | 13,956          | 83,736       | 502,416       | 339,7762               | 679,5523     |
| 17  | 4              | 7            | 4,99           | 19,96           | 139,72       | 978,04        | 124,2515               | 497,006      |
| 18  | 2              | 8            | 3,0138         | 6,0276          | 48,2208      | 385,7664      | 27,37432               | 54,74863     |
| 19  | 4              | 9            | 1,45           | 5,8             | 52,2         | 469,8         | 3,048625               | 12,1945      |
| FP  | 1              | 10           | 0              | 0               | 0            | 0             | 0                      | 0            |
| Σ   |                |              |                | 386,4924        | 68,4068      | 7443,6084     | 8599,654               | 25808,1      |
| <p>h = LBP/Station = LPP/20 = 6,2965 m</p> <p>AW = <math>\frac{2}{3} \times h \times \Sigma(5)</math> = 1622,366264 m<sup>2</sup></p> <p>OF = <math>\frac{[\Sigma(6) \times h]}{\Sigma(5)}</math> = 1,114 m</p> <p>IL(O) = <math>\frac{2}{3} \times h^3 \times \Sigma(7)</math> = 1238767,724 m<sup>4</sup></p> <p>IL(F) = IL(O) - Aw (OF)<sup>2</sup> = 1236752,776 m<sup>4</sup></p> <p>IT = <math>\frac{2}{9} \times h \times \Sigma(9)</math> = 36111,271 m<sup>4</sup></p> |                |              |                |                 |              |               |                        |              |

Tabel 21. Aw ; OF ; IL(F) ; IT

| Aw ; OF ; IL(F) ; IT  |                |              |                |                 |              |               |                        |              |
|---|----------------|--------------|----------------|-----------------|--------------|---------------|------------------------|--------------|
| Garis Air 3   |                |              |                |                 |              |               |                        |              |
| Nomor Ordinat   | Faktor simpson | Lengan Momen | Luas Garis Air |                 | BM Memanjang |               | BM Melintang           |              |
|   |                |              | 1/2 Ordinat    | Fungsi Luas 1/2 | Momen        | Momen Inersia | (1/2 Ord) <sup>3</sup> | Fungsi (1/2) |
| 1   | 2              | 3            | 4              | 5 = 2 x 4       | 6 = 3 x 5    | 7 = 3 x 6     | 8 = 4 <sup>3</sup>     | 9 = 2 x 8    |
| AP  | 1              | -10          | 0              | 0               | 0            | 0             | 0                      | 0            |
| 1   | 4              | -9           | 1,51           | 6,04            | -54,36       | 489,24        | 3,442951               | 13,7718      |
| 2   | 2              | -8           | 3,04           | 6,08            | -48,64       | 389,12        | 28,09446               | 56,18893     |
| 3   | 4              | -7           | 4,7            | 18,8            | -131,6       | 921,2         | 103,823                | 415,292      |
| 4   | 2              | -6           | 6,534          | 13,068          | -78,408      | 470,448       | 278,9571               | 557,9142     |
| 5   | 4              | -5           | 7,82           | 31,28           | -156,4       | 782           | 478,2118               | 1912,847     |
| 6   | 2              | -4           | 8,701          | 17,402          | -69,608      | 278,432       | 658,7301               | 1317,46      |
| 7   | 4              | -3           | 9,123          | 36,492          | -109,476     | 328,428       | 759,2993               | 3037,197     |
| 8   | 2              | -2           | 9,243          | 18,486          | -36,972      | 73,944        | 789,6577               | 1579,315     |
| 9   | 4              | -1           | 9,218          | 36,872          | -36,872      | 36,872        | 783,2675               | 3133,07      |
| 10  | 2              | 0            | 9,235          | 18,47           | 0            | 0             | 787,6091               | 1575,218     |
| 11  | 4              | 1            | 9,238          | 36,952          | 36,952       | 36,952        | 788,3769               | 3153,507     |
| 12  | 2              | 2            | 9,238          | 18,476          | 36,952       | 73,904        | 788,3769               | 1576,754     |
| 13  | 4              | 3            | 9,238          | 36,952          | 110,856      | 332,568       | 788,3769               | 3153,507     |
| 14  | 2              | 4            | 9,207          | 18,414          | 73,656       | 294,624       | 780,4668               | 1560,934     |
| 15  | 4              | 5            | 8,861          | 35,444          | 177,22       | 886,1         | 695,742                | 2782,968     |
| 16  | 2              | 6            | 7,4754         | 14,9508         | 89,7048      | 538,2288      | 417,7374               | 835,4747     |
| 17  | 4              | 7            | 5,632          | 22,528          | 157,696      | 1103,872      | 178,6438               | 714,5752     |
| 18  | 2              | 8            | 3,731          | 7,462           | 59,696       | 477,568       | 51,93687               | 103,8737     |
| 19  | 4              | 9            | 2,76           | 11,04           | 99,36        | 894,24        | 21,02458               | 84,0983      |
| FP  | 1              | 10           | 0              | 0               | 0            | 0             | 0                      | 0            |
| Σ   |                |              |                | 405,2088        | 119,7568     | 8407,7408     | 9160,75                | 27479,87     |
| <p>h = LBP/Station = LPP/20 = 6,2965 m</p> <p>AW = <math>\frac{2}{3} \times h \times \Sigma(5)</math> = 1700,931473 m<sup>2</sup></p> <p>OF = <math>[\Sigma(6) \times h] / \Sigma(5)</math> = 1,861 m</p> <p>IL(O) = <math>\frac{2}{3} \times h^3 \times \Sigma(7)</math> = 1399218,951 m<sup>4</sup></p> <p>IL(F) = IL(O) - Aw (OF)<sup>2</sup> = 1393328,780 m<sup>4</sup></p> <p>IT = <math>\frac{2}{9} \times h \times \Sigma(9)</math> = 38450,443 m<sup>4</sup></p> |                |              |                |                 |              |               |                        |              |

Tabel 22. Aw ; OF ; IL(F) ; IT

| Aw ; OF ; IL(F) ; IT   |                |              |                |                 |              |               |                        |              |
|--|----------------|--------------|----------------|-----------------|--------------|---------------|------------------------|--------------|
| Garis Air 4  |                |              |                |                 |              |               |                        |              |
| Nomor Ordinat  | Faktor simpson | Lengan Momen | Luas Garis Air |                 | BM Memanjang |               | BM Melintang           |              |
|  |                |              | L/2 Ordina     | Fungsi Luas 1/2 | Momen        | Momen Inersia | (1/2 Ord) <sup>3</sup> | Fungsi (1/2) |
| 1  | 2              | 3            | 4              | 5 = 2 x 4       | 6 = 3 x 5    | 7 = 3 x 6     | 8 = 4 <sup>3</sup>     | 9 = 2 x 8    |
| AP   | 1              | -10          | 0              | 0               | 0            | 0             | 0                      | 0            |
| 1  | 4              | -9           | 1,8            | 7,2             | -64,8        | 583,2         | 5,832                  | 23,328       |
| 2  | 2              | -8           | 3,9            | 7,8             | -62,4        | 499,2         | 59,319                 | 118,638      |
| 3  | 4              | -7           | 5,4            | 21,6            | -151,2       | 1058,4        | 157,464                | 629,856      |
| 4  | 2              | -6           | 6,889          | 13,778          | -82,668      | 496,008       | 326,9404               | 653,8807     |
| 5  | 4              | -5           | 8,12           | 32,48           | -162,4       | 812           | 535,3873               | 2141,549     |
| 6  | 2              | -4           | 9,106          | 18,212          | -72,848      | 291,392       | 755,0626               | 1510,125     |
| 7  | 4              | -3           | 9,245          | 36,98           | -110,94      | 332,82        | 790,1704               | 3160,682     |
| 8  | 2              | -2           | 9,2456         | 18,4912         | -36,9824     | 73,9648       | 790,3242               | 1580,648     |
| 9  | 4              | -1           | 9,2456         | 36,9824         | -36,9824     | 36,9824       | 790,3242               | 3161,297     |
| 10   | 2              | 0            | 9,25           | 18,5            | 0            | 0             | 791,4531               | 1582,906     |
| 11   | 4              | 1            | 9,25           | 37              | 37           | 37            | 791,4531               | 3165,813     |
| 12   | 2              | 2            | 9,25           | 18,5            | 37           | 74            | 791,4531               | 1582,906     |
| 13   | 4              | 3            | 9,25           | 37              | 111          | 333           | 791,4531               | 3165,813     |
| 14   | 2              | 4            | 9,221          | 18,442          | 73,768       | 295,072       | 784,0325               | 1568,065     |
| 15   | 4              | 5            | 8,901          | 35,604          | 178,02       | 890,1         | 705,2067               | 2820,827     |
| 16   | 2              | 6            | 7,78           | 15,56           | 93,36        | 560,16        | 470,911                | 941,8219     |
| 17   | 4              | 7            | 6,012          | 24,048          | 168,336      | 1178,352      | 217,2986               | 869,1944     |
| 18   | 2              | 8            | 4,1            | 8,2             | 65,6         | 524,8         | 68,921                 | 137,842      |
| 19   | 4              | 9            | 3,15           | 12,6            | 113,4        | 1020,6        | 31,25588               | 125,0235     |
| FP   | 1              | 10           | 0              | 0               | 0            | 0             | 0                      | 0            |
| Σ  |                |              |                | 418,9776        | 96,2632      | 9097,0512     | 9623,006               | 28815,19     |
| <p>h = LBP/Station = LPP/20 = 6,2965 m</p> <p>AW = <math>2/3 \times h \times \Sigma(5)</math> = 1758,72831 m<sup>2</sup></p> <p>OF = <math>[\Sigma(6) \times h] / \Sigma(5)</math> = 1,447 m</p> <p>IL(O) = <math>2/3 \times h^3 \times \Sigma(7)</math> = 1513934,211 m<sup>4</sup></p> <p>IL(F) = IL(O) - Aw (OF)<sup>2</sup> = 1510253,463 m<sup>4</sup></p> <p>IT = <math>2/9 \times h \times \Sigma(9)</math> = 40318,856 m<sup>4</sup></p> |                |              |                |                 |              |               |                        |              |



Tabel 23. Aw ; OF ; IL(F) ; IT

| Garis Air 5   |                |              |                |                         |              |               |                        |                               |
|---|----------------|--------------|----------------|-------------------------|--------------|---------------|------------------------|-------------------------------|
| Nomor Ordinat   | Faktor simpson | Lengan Momen | Luas Garis Air |                         | BM Memanjang |               | BM Melintang           |                               |
|   |                |              | 1/2 Ordinat    | Fungsi Luas 1/2 Ordinat | Momen        | Momen Inersia | (1/2 Ord) <sup>3</sup> | Fungsi (1/2 Ord) <sup>3</sup> |
| 1   | 2              | 3            | 4              | 5 = 2 x 4               | 6 = 3 x 5    | 7 = 3 x 6     | 8 = 4 <sup>3</sup>     | 9 = 2 x 8                     |
| AP  | 1              | -10          | 0              | 0                       | 0            | 0             | 0                      | 0                             |
| 1   | 4              | -9           | 2,4            | 9,6                     | -86,4        | 777,6         | 13,824                 | 55,296                        |
| 2   | 2              | -8           | 4,2            | 8,4                     | -67,2        | 537,6         | 74,088                 | 148,176                       |
| 3   | 4              | -7           | 5,8            | 23,2                    | -162,4       | 1136,8        | 195,112                | 780,448                       |
| 4   | 2              | -6           | 7,34           | 14,68                   | -88,08       | 528,48        | 395,4469               | 790,893808                    |
| 5   | 4              | -5           | 8,45           | 33,8                    | -169         | 845           | 603,35113              | 2413,4045                     |
| 6   | 2              | -4           | 9,34           | 18,68                   | -74,72       | 298,88        | 814,7805               | 1629,56101                    |
| 7   | 4              | -3           | 9,46           | 37,84                   | -113,52      | 340,56        | 846,59054              | 3386,36214                    |
| 8   | 2              | -2           | 9,25           | 18,5                    | -37          | 74            | 791,45313              | 1582,90625                    |
| 9   | 4              | -1           | 9,25           | 37                      | -37          | 37            | 791,45313              | 3165,8125                     |
| 10  | 2              | 0            | 9,25           | 18,5                    | 0            | 0             | 791,45313              | 1582,90625                    |
| 11  | 4              | 1            | 9,25           | 37                      | 37           | 37            | 791,45313              | 3165,8125                     |
| 12  | 2              | 2            | 9,25           | 18,5                    | 37           | 74            | 791,45313              | 1582,90625                    |
| 13  | 4              | 3            | 9,25           | 37                      | 111          | 333           | 791,45313              | 3165,8125                     |
| 14  | 2              | 4            | 9,227          | 18,454                  | 73,816       | 295,264       | 785,56398              | 1571,12796                    |
| 15  | 4              | 5            | 9,0125         | 36,05                   | 180,25       | 901,25        | 732,04172              | 2928,16688                    |
| 16  | 2              | 6            | 7,997          | 15,994                  | 95,964       | 575,784       | 511,42422              | 1022,84843                    |
| 17  | 4              | 7            | 6,4657         | 25,8628                 | 181,04       | 1267,2772     | 270,30038              | 1081,2015                     |
| 18  | 2              | 8            | 4,421          | 8,842                   | 70,736       | 565,888       | 86,40951               | 172,819021                    |
| 19  | 4              | 9            | 3,44           | 13,76                   | 123,84       | 1114,56       | 40,707584              | 162,830336                    |
| FP  | 1              | 10           | 0              | 0                       | 0            | 0             | 0                      | 0                             |
| $\Sigma$  |                |              |                | 431,6628                | 75,3256      | 9739,9432     | 10077,652              | 30226,4615                    |
| <p>h = LBP/Station = LPP/20 = 6,2965 m</p> <p>AW = <math>2/3 \times h \times \Sigma(5)</math> = 1811,976547 m<sup>2</sup></p> <p>OF = <math>[\Sigma(6) \times h] / \Sigma(5)</math> = 1,099 m</p> <p>IL(O) = <math>2/3 \times h^3 \times \Sigma(7)</math> = 1620924,506 m<sup>4</sup></p> <p>IL(F) = IL(O) - Aw (OF)<sup>2</sup> = 1618737,012 m<sup>4</sup></p> <p>IT = <math>2/9 \times h \times \Sigma(9)</math> = 42293,537 m<sup>4</sup></p> |                |              |                |                         |              |               |                        |                               |

Tabel 24. Aw ; OF ; IL(F) ; IT

| Aw ; OF ; IL(F) ; IT   |                |              |                |                 |              |               |                        |              |
|--|----------------|--------------|----------------|-----------------|--------------|---------------|------------------------|--------------|
| Garis Air 6  |                |              |                |                 |              |               |                        |              |
| Nomor Ordinat  | Faktor simpson | Lengan Momen | Luas Garis Air |                 | BM Memanjang |               | BM Melintang           |              |
|  |                |              | L/2 Ordina     | Fungsi Luas 1/2 | Momen        | Momen Inersia | (1/2 Ord) <sup>3</sup> | Fungsi (1/2) |
| 1  | 2              | 3            | 4              | 5 = 2 x 4       | 6 = 3 x 5    | 7 = 3 x 6     | 8 = 4 <sup>3</sup>     | 9 = 2 x 8    |
| AP   | 1              | -10          | 0              | 0               | 0            | 0             | 0                      | 0            |
| 1  | 4              | -9           | 2,8            | 11,2            | -100,8       | 907,2         | 21,952                 | 87,808       |
| 2  | 2              | -8           | 4,9            | 9,8             | -78,4        | 627,2         | 117,649                | 235,298      |
| 3  | 4              | -7           | 6,9            | 27,6            | -193,2       | 1352,4        | 328,509                | 1314,036     |
| 4  | 2              | -6           | 7,89           | 15,78           | -94,68       | 568,08        | 491,1691               | 982,3381     |
| 5  | 4              | -5           | 8,756          | 35,024          | -175,12      | 875,6         | 671,3009               | 2685,204     |
| 6  | 2              | -4           | 9,38           | 18,76           | -75,04       | 300,16        | 825,2937               | 1650,587     |
| 7  | 4              | -3           | 9,47           | 37,88           | -113,64      | 340,92        | 849,2781               | 3397,112     |
| 8  | 2              | -2           | 9,25           | 18,5            | -37          | 74            | 791,4531               | 1582,906     |
| 9  | 4              | -1           | 9,25           | 37              | -37          | 37            | 791,4531               | 3165,813     |
| 10   | 2              | 0            | 9,25           | 18,5            | 0            | 0             | 791,4531               | 1582,906     |
| 11   | 4              | 1            | 9,25           | 37              | 37           | 37            | 791,4531               | 3165,813     |
| 12   | 2              | 2            | 9,25           | 18,5            | 37           | 74            | 791,4531               | 1582,906     |
| 13   | 4              | 3            | 9,25           | 37              | 111          | 333           | 791,4531               | 3165,813     |
| 14   | 2              | 4            | 9,231          | 18,462          | 73,848       | 295,392       | 786,5861               | 1573,172     |
| 15   | 4              | 5            | 9,21           | 36,84           | 184,2        | 921           | 781,23                 | 3124,92      |
| 16   | 2              | 6            | 8,12           | 16,24           | 97,44        | 584,64        | 535,3873               | 1070,775     |
| 17   | 4              | 7            | 6,6325         | 26,53           | 185,71       | 1299,97       | 291,764                | 1167,056     |
| 18   | 2              | 8            | 4,678          | 9,356           | 74,848       | 598,784       | 102,3719               | 204,7437     |
| 19   | 4              | 9            | 2,53           | 10,12           | 91,08        | 819,72        | 16,19428               | 64,77711     |
| FP   | 1              | 10           | 0              | 0               | 0            | 0             | 0                      | 0            |
| Σ  |                |              |                | 440,092         | -12,754      | 10046,066     | 10551,21               | 31739,21     |
| <p>h = LBP/Station = LPP/20 = 6,2965 m</p> <p>AW = <math>2/3 \times h \times \Sigma(5)</math> = 1847,359519 m<sup>2</sup></p> <p>OF = <math>[\Sigma(6) \times h] / \Sigma(5)</math> = -0,182 m</p> <p>IL(O) = <math>2/3 \times h^3 \times \Sigma(7)</math> = 1671869,562 m<sup>4</sup></p> <p>IL(F) = IL(O) - Aw (OF)<sup>2</sup> = 1671808,050 m<sup>4</sup></p> <p>IT = <math>2/9 \times h \times \Sigma(9)</math> = 44410,203 m<sup>4</sup></p> |                |              |                |                 |              |               |                        |              |

Tabel 25. Aw ; OF ; IL(F) ; IT

| Aw ; OF ; IL(F) ; IT  |                |              |                |                 |              |               |                        |              |
|---|----------------|--------------|----------------|-----------------|--------------|---------------|------------------------|--------------|
| Garis Air 7   |                |              |                |                 |              |               |                        |              |
| Nomor Ordinat   | Faktor Simpson | Lengan Momen | Luas Garis Air |                 | BM Memanjang |               | BM Melintang           |              |
|   |                |              | 1/2 Ordina     | Fungsi Luas 1/2 | Momen        | Momen Inersia | (1/2 Ord) <sup>3</sup> | Fungsi (1/2) |
| 1   | 2              | 3            | 4              | 5 = 2 x 4       | 6 = 3 x 5    | 7 = 3 x 6     | 8 = 4 <sup>3</sup>     | 9 = 2 x 8    |
| AP  | 1              | -10          | 1              | 1               | -10          | 100           | 1                      | 1            |
| 1   | 4              | -9           | 3,8            | 15,2            | -136,8       | 1231,2        | 54,872                 | 219,488      |
| 2   | 2              | -8           | 5,8            | 11,6            | -92,8        | 742,4         | 195,112                | 390,224      |
| 3   | 4              | -7           | 7,04           | 28,16           | -197,12      | 1379,84       | 348,9137               | 1395,655     |
| 4   | 2              | -6           | 8,23           | 16,46           | -98,76       | 592,56        | 557,4418               | 1114,884     |
| 5   | 4              | -5           | 8,836          | 35,344          | -176,72      | 883,6         | 689,8698               | 2759,479     |
| 6   | 2              | -4           | 9,38           | 18,76           | -75,04       | 300,16        | 825,2937               | 1650,587     |
| 7   | 4              | -3           | 9,48           | 37,92           | -113,76      | 341,28        | 851,9714               | 3407,886     |
| 8   | 2              | -2           | 9,25           | 18,5            | -37          | 74            | 791,4531               | 1582,906     |
| 9   | 4              | -1           | 9,25           | 37              | -37          | 37            | 791,4531               | 3165,813     |
| 10  | 2              | 0            | 9,25           | 18,5            | 0            | 0             | 791,4531               | 1582,906     |
| 11  | 4              | 1            | 9,25           | 37              | 37           | 37            | 791,4531               | 3165,813     |
| 12  | 2              | 2            | 9,25           | 18,5            | 37           | 74            | 791,4531               | 1582,906     |
| 13  | 4              | 3            | 9,25           | 37              | 111          | 333           | 791,4531               | 3165,813     |
| 14  | 2              | 4            | 9,234          | 18,468          | 73,872       | 295,488       | 787,3532               | 1574,706     |
| 15  | 4              | 5            | 9,203          | 36,812          | 184,06       | 920,3         | 779,45                 | 3117,8       |
| 16  | 2              | 6            | 8,19           | 16,38           | 98,28        | 589,68        | 549,3533               | 1098,707     |
| 17  | 4              | 7            | 6,785          | 27,14           | 189,98       | 1329,86       | 312,3558               | 1249,423     |
| 18  | 2              | 8            | 4,891          | 9,782           | 78,256       | 626,048       | 117,0019               | 234,0038     |
| 19  | 4              | 9            | 5,65           | 22,6            | 203,4        | 1830,6        | 180,3621               | 721,4485     |
| FP  | 1              | 10           | 0              | 0               | 0            | 0             | 0                      | 0            |
| Σ   |                |              |                | 462,126         | 37,848       | 11718,016     | 10818,71               | 32460        |
| <p>h = LBP/Station = LPP/20 = 6,2965 m</p> <p>AW = <math>\frac{2}{3} \times h \times \Sigma(5)</math> = 1939,850906 m<sup>2</sup></p> <p>OF = <math>\frac{[\Sigma(6) \times h]}{\Sigma(5)}</math> = 0,516 m</p> <p>IL(O) = <math>\frac{2}{3} \times h^3 \times \Sigma(7)</math> = 1950116,023 m<sup>4</sup></p> <p>IL(F) = IL(O) - Aw (OF)<sup>2</sup> = 1949600,163 m<sup>4</sup></p> <p>IT = <math>\frac{2}{9} \times h \times \Sigma(9)</math> = 45418,751 m<sup>4</sup></p> |                |              |                |                 |              |               |                        |              |

Tabel 26. Aw ; OF ; IL(F) ; IT

| Aw ; OF ; IL(F) ; IT  |                |              |                |                 |              |               |                        |              |
|---|----------------|--------------|----------------|-----------------|--------------|---------------|------------------------|--------------|
| Garis Air 8   |                |              |                |                 |              |               |                        |              |
| Nomor Ordinat   | Faktor simpson | Lengan Momen | Luas Garis Air |                 | BM Memanjang |               | BM Melintang           |              |
|   |                |              | 1/2 Ordinat    | Fungsi Luas 1/2 | Momen        | Momen Inersia | (1/2 Ord) <sup>3</sup> | Fungsi (1/2) |
| 1   | 2              | 3            | 4              | 5 = 2 x 4       | 6 = 3 x 5    | 7 = 3 x 6     | 8 = 4 <sup>3</sup>     | 9 = 2 x 8    |
| AP  | 1              | -10          | 2,98           | 2,98            | -29,8        | 298           | 26,46359               | 26,46359     |
| 1   | 4              | -9           | 4,8            | 19,2            | -172,8       | 1555,2        | 110,592                | 442,368      |
| 2   | 2              | -8           | 6,5            | 13              | -104         | 832           | 274,625                | 549,25       |
| 3   | 4              | -7           | 7,5            | 30              | -210         | 1470          | 421,875                | 1687,5       |
| 4   | 2              | -6           | 8,589          | 17,178          | -103,068     | 618,408       | 633,6184               | 1267,237     |
| 5   | 4              | -5           | 8,91           | 35,64           | -178,2       | 891           | 707,348                | 2829,392     |
| 6   | 2              | -4           | 9,38           | 18,76           | -75,04       | 300,16        | 825,2937               | 1650,587     |
| 7   | 4              | -3           | 9,48           | 37,92           | -113,76      | 341,28        | 851,9714               | 3407,886     |
| 8   | 2              | -2           | 9,25           | 18,5            | -37          | 74            | 791,4531               | 1582,906     |
| 9   | 4              | -1           | 9,25           | 37              | -37          | 37            | 791,4531               | 3165,813     |
| 10  | 2              | 0            | 9,25           | 18,5            | 0            | 0             | 791,4531               | 1582,906     |
| 11  | 4              | 1            | 9,25           | 37              | 37           | 37            | 791,4531               | 3165,813     |
| 12  | 2              | 2            | 9,25           | 18,5            | 37           | 74            | 791,4531               | 1582,906     |
| 13  | 4              | 3            | 9,25           | 37              | 111          | 333           | 791,4531               | 3165,813     |
| 14  | 2              | 4            | 9,237          | 18,474          | 73,896       | 295,584       | 788,1209               | 1576,242     |
| 15  | 4              | 5            | 9,025          | 36,1            | 180,5        | 902,5         | 735,0919               | 2940,368     |
| 16  | 2              | 6            | 8,289          | 16,578          | 99,468       | 596,808       | 569,5166               | 1139,033     |
| 17  | 4              | 7            | 6,8901         | 27,5604         | 192,9228     | 1350,4596     | 327,097                | 1308,388     |
| 18  | 2              | 8            | 4,913          | 9,826           | 78,608       | 628,864       | 118,5879               | 237,1758     |
| 19  | 4              | 9            | 2,893          | 11,572          | 104,148      | 937,332       | 24,21282               | 96,85126     |
| FP  | 1              | 10           | 0              | 0               | 0            | 0             | 0                      | 0            |
| Σ   |                |              |                | 461,2884        | -146,125     | 11572,5956    | 11138,92               | 33308,05     |
| <p>h = LBP/Station = LPP/20 = 6,2965 m</p> <p>AW = <math>\frac{2}{3} \times h \times \Sigma(5)</math> = 1936,33494 m<sup>2</sup></p> <p>OF = <math>\frac{[\Sigma(6) \times h]}{\Sigma(5)}</math> = -1,995 m</p> <p>IL(O) = <math>\frac{2}{3} \times h^3 \times \Sigma(7)</math> = 1925915,113 m<sup>4</sup></p> <p>IL(F) = IL(O) - Aw (OF)<sup>2</sup> = 1918211,684 m<sup>4</sup></p> <p>IT = <math>\frac{2}{9} \times h \times \Sigma(9)</math> = 46605,358 m<sup>4</sup></p> |                |              |                |                 |              |               |                        |              |

Tabel 27. Aw ; OF ; IL(F) ; IT

| Aw ; OF ; IL(F) ; IT  |                |              |                |                 |              |               |                        |              |
|---|----------------|--------------|----------------|-----------------|--------------|---------------|------------------------|--------------|
| Garis Air 9   |                |              |                |                 |              |               |                        |              |
| Nomor Ordinat   | Faktor simpson | Lengan Momen | Luas Garis Air |                 | BM Memanjang |               | BM Melintang           |              |
|   |                |              | L/2 Ordina     | Fungsi Luas 1/2 | Momen        | Momen Inersia | (1/2 Ord) <sup>3</sup> | Fungsi (1/2) |
| 1   | 2              | 3            | 4              | 5 = 2 x 4       | 6 = 3 x 5    | 7 = 3 x 6     | 8 = 4 <sup>3</sup>     | 9 = 2 x 8    |
| AP  | 1              | -10          | 3,79           | 3,79            | -37,9        | 379           | 54,43994               | 54,43994     |
| 1   | 4              | -9           | 5,7            | 22,8            | -205,2       | 1846,8        | 185,193                | 740,772      |
| 2   | 2              | -8           | 6,9            | 13,8            | -110,4       | 883,2         | 328,509                | 657,018      |
| 3   | 4              | -7           | 7,9            | 31,6            | -221,2       | 1548,4        | 493,039                | 1972,156     |
| 4   | 2              | -6           | 8,57           | 17,14           | -102,84      | 617,04        | 629,4228               | 1258,846     |
| 5   | 4              | -5           | 8,934          | 35,736          | -178,68      | 893,4         | 713,0793               | 2852,317     |
| 6   | 2              | -4           | 9,38           | 18,76           | -75,04       | 300,16        | 825,2937               | 1650,587     |
| 7   | 4              | -3           | 9,48           | 37,92           | -113,76      | 341,28        | 851,9714               | 3407,886     |
| 8   | 2              | -2           | 9,25           | 18,5            | -37          | 74            | 791,4531               | 1582,906     |
| 9   | 4              | -1           | 9,25           | 37              | -37          | 37            | 791,4531               | 3165,813     |
| 10  | 2              | 0            | 9,25           | 18,5            | 0            | 0             | 791,4531               | 1582,906     |
| 11  | 4              | 1            | 9,25           | 37              | 37           | 37            | 791,4531               | 3165,813     |
| 12  | 2              | 2            | 9,25           | 18,5            | 37           | 74            | 791,4531               | 1582,906     |
| 13  | 4              | 3            | 9,25           | 37              | 111          | 333           | 791,4531               | 3165,813     |
| 14  | 2              | 4            | 9,238          | 18,476          | 73,904       | 295,616       | 788,3769               | 1576,754     |
| 15  | 4              | 5            | 9,027          | 36,108          | 180,54       | 902,7         | 735,5807               | 2942,323     |
| 16  | 2              | 6            | 8,573          | 17,146          | 102,876      | 617,256       | 630,084                | 1260,168     |
| 17  | 4              | 7            | 7,045          | 28,18           | 197,26       | 1380,82       | 349,6576               | 1398,63      |
| 18  | 2              | 8            | 5,12           | 10,24           | 81,92        | 655,36        | 134,2177               | 268,4355     |
| 19  | 4              | 9            | 2,678          | 10,712          | 96,408       | 867,672       | 19,20577               | 76,82308     |
| FP  | 1              | 10           | 0              | 0               | 0            | 0             | 0                      | 0            |
| Σ   |                |              |                | 468,908         | -201,112     | 12083,704     | 11467,58               | 34286,49     |
| <p>h = LBP/Station = LPP/20 = 6,2965 m</p> <p>AW = <math>\frac{2}{3} \times h \times \Sigma(5)</math> = 1968,31948 m<sup>2</sup></p> <p>OF = <math>\frac{[\Sigma(6) \times h]}{\Sigma(5)}</math> = -2,701 m</p> <p>IL(O) = <math>\frac{2}{3} \times h^3 \times \Sigma(7)</math> = 2010973,939 m<sup>4</sup></p> <p>IL(F) = IL(O) - Aw (OF)<sup>2</sup> = 1996619,220 m<sup>4</sup></p> <p>IT = <math>\frac{2}{9} \times h \times \Sigma(9)</math> = 47974,417 m<sup>4</sup></p> |                |              |                |                 |              |               |                        |              |

Tabel 28. Aw ; OF ; IL(F) ; IT

| Garis Air 10   |                |              |                |                         |              |               |                        |                               |
|--|----------------|--------------|----------------|-------------------------|--------------|---------------|------------------------|-------------------------------|
| Nomor Ordinat  | Faktor simpson | Lengan Momen | Luas Garis Air |                         | BM Memanjang |               | BM Melintang           |                               |
|  |                |              | 1/2 Ordinat    | Fungsi Luas 1/2 Ordinat | Momen        | Momen Inersia | (1/2 Ord) <sup>3</sup> | Fungsi (1/2 Ord) <sup>3</sup> |
| 1  | 2              | 3            | 4              | 5 = 2 x 4               | 6 = 3 x 5    | 7 = 3 x 6     | 8 = 4 <sup>3</sup>     | 9 = 2 x 8                     |
| AP   | 1              | -10          | 5,76           | 5,76                    | -57,6        | 576           | 191,10298              | 191,102976                    |
| 1  | 4              | -9           | 6,01           | 24,04                   | -216,36      | 1947,24       | 217,0818               | 868,327204                    |
| 2  | 2              | -8           | 7,4            | 14,8                    | -118,4       | 947,2         | 405,224                | 810,448                       |
| 3  | 4              | -7           | 8,123          | 32,492                  | -227,44      | 1592,108      | 535,98096              | 2143,92383                    |
| 4  | 2              | -6           | 8,745          | 17,49                   | -104,94      | 629,64        | 668,77409              | 1337,54819                    |
| 5  | 4              | -5           | 9,012          | 36,048                  | -180,24      | 901,2         | 731,91989              | 2927,67956                    |
| 6  | 2              | -4           | 9,38           | 18,76                   | -75,04       | 300,16        | 825,29367              | 1650,58734                    |
| 7  | 4              | -3           | 9,48           | 37,92                   | -113,76      | 341,28        | 851,97139              | 3407,88557                    |
| 8  | 2              | -2           | 9,25           | 18,5                    | -37          | 74            | 791,45313              | 1582,90625                    |
| 9  | 4              | -1           | 9,25           | 37                      | -37          | 37            | 791,45313              | 3165,8125                     |
| 10   | 2              | 0            | 9,25           | 18,5                    | 0            | 0             | 791,45313              | 1582,90625                    |
| 11   | 4              | 1            | 9,25           | 37                      | 37           | 37            | 791,45313              | 3165,8125                     |
| 12   | 2              | 2            | 9,25           | 18,5                    | 37           | 74            | 791,45313              | 1582,90625                    |
| 13   | 4              | 3            | 9,25           | 37                      | 111          | 333           | 791,45313              | 3165,8125                     |
| 14   | 2              | 4            | 9,24           | 18,48                   | 73,92        | 295,68        | 788,88902              | 1577,77805                    |
| 15   | 4              | 5            | 9,219          | 36,876                  | 184,38       | 921,9         | 783,52245              | 3134,0898                     |
| 16   | 2              | 6            | 8,89           | 17,78                   | 106,68       | 640,08        | 702,59537              | 1405,19074                    |
| 17   | 4              | 7            | 7,234          | 28,936                  | 202,552      | 1417,864      | 378,56069              | 1514,24276                    |
| 18   | 2              | 8            | 5,242          | 10,484                  | 83,872       | 670,976       | 144,04263              | 288,085265                    |
| 19   | 4              | 9            | 3,0123         | 12,0492                 | 108,443      | 975,9852      | 27,333463              | 109,333854                    |
| FP   | 1              | 10           | 0              | 0                       | 0            | 0             | 0                      | 0                             |
| $\Sigma$   |                |              |                | 478,4152                | -222,94      | 12712,3132    | 11973,678              | 35503,0455                    |
| <p>h = LBP/Station = LPP/20 = 6,2965 m</p> <p>AW = <math>2/3 \times h \times \Sigma(5)</math> = 2008,227538 m<sup>2</sup></p> <p>OF = <math>[\Sigma(6) \times h] / \Sigma(5)</math> = -2,934 m</p> <p>IL(O) = <math>2/3 \times h^3 \times \Sigma(7)</math> = 2115587,286 m<sup>4</sup></p> <p>IL(F) = IL(O) - Aw (OF)<sup>2</sup> = 2098298,421 m<sup>4</sup></p> <p>IT = <math>2/9 \times h \times \Sigma(9)</math> = 49676,650 m<sup>4</sup></p> |                |              |                |                         |              |               |                        |                               |

Tabel 29.  $\Delta$  ,  $\nabla$  , KB

| <b><math>\Delta</math> , <math>\nabla</math> , KB</b> |                          |                                       |                     |           |                    |                     |
|---|--------------------------|---------------------------------------|---------------------|-----------|--------------------|---------------------|
| <b>Garis air 0 s/d 2</b>                              |                          |                                       |                     |           |                    |                     |
| <b>( 0.00 - 0.678 meter)</b>                          |                          |                                       |                     |           |                    |                     |
| <b>NO.</b>  | <b>G.A</b>               | <b>Simpson</b>                        | <b>Lengan Momen</b> | <b>AW</b> | <b>Fungsi (AW)</b> | <b>Fungsi Momen</b> |
| 1   | 2                        |                                       | 3                   | 4         | 5 = 2 x 4          | 6 = 3 x 5           |
| 0   | 1                        |                                       | 0                   | 1205,682  | 1205,68236         | 0                   |
| 1   | 4                        |                                       | 1                   | 1466,831  | 5867,32384         | 5867,323844         |
| 2   | 1                        |                                       | 2                   | 1622,366  | 1622,36626         | 3244,732529         |
| $\Sigma$  |                          |                                       |                     |           | 8695,37247         | 9112,056373         |
| $h_1 =$   | Jarak Garis Air = T/Ga = |                                       |                     | 0,861     | m                  |                     |
| $\nabla$  | =                        | $\Sigma(5) \times 1/3 \times h_1$     | =                   | 2495,572  | $m^3$              |                     |
| $\Delta$  | =                        | $\nabla \times 1.025$                 | =                   | 2557,961  | ton                |                     |
| Momen   | =                        | $\Sigma(6) \times 1/3 \times (h_1)^2$ | =                   | 2251,653  | ton - meter        |                     |
| KB  | =                        | Momen/ $\nabla$                       | =                   | 0,902     | meter              |                     |
| KB  | =                        | $(\Sigma_6 \times h_1) / \Sigma_5$    | =                   | 0,902     | meter              |                     |

Tabel 30.  $\Delta$  ,  $\nabla$  , KB

| <b><math>\Delta</math> , <math>\nabla</math> , KB</b> |                          |                                       |                     |           |                    |                     |
|---|--------------------------|---------------------------------------|---------------------|-----------|--------------------|---------------------|
| <b>Garis air 2 s/d 4</b>                              |                          |                                       |                     |           |                    |                     |
| <b>( 0,678 - 2,72meter)</b>                           |                          |                                       |                     |           |                    |                     |
| <b>NO.</b>  | <b>G.A</b>               | <b>Simpson</b>                        | <b>Lengan Momen</b> | <b>AW</b> | <b>Fungsi (AW)</b> | <b>Fungsi Momen</b> |
| 1   | 2                        |                                       | 3                   | 4         | 5 = 2 x 4          | 6 = 3 x 5           |
| 2   | 1                        |                                       | 2                   | 1622,366  | 1622,366264        | 3244,732529         |
| 3   | 4                        |                                       | 3                   | 1700,931  | 6803,725891        | 20411,17767         |
| 4   | 1                        |                                       | 4                   | 1758,728  | 1758,728306        | 7034,913222         |
| $\Sigma$  |                          |                                       |                     |           | 10184,82046        | 30690,82342         |
| $h_1 =$   | Jarak Garis Air = T/Ga = |                                       |                     | 0,861     | m                  |                     |
| $\nabla$  | =                        | $\Sigma(5) \times 1/3 \times h_1$     | =                   | 2923,043  | $m^3$              |                     |
| $\Delta$  | =                        | $\nabla \times 1.025$                 | =                   | 2996,120  | ton                |                     |
| Momen   | =                        | $\Sigma(6) \times 1/3 \times (h_1)^2$ | =                   | 7583,917  | ton - meter        |                     |
| KB  | =                        | Momen/ $\nabla$                       | =                   | 2,595     | meter              |                     |
| KB  | =                        | $(\Sigma_6 \times h_1) / \Sigma_5$    | =                   | 2,595     | meter              |                     |

Tabel 31.  $\Delta$ ,  $\nabla$ , KB

| $\Delta$ , $\nabla$ , KB                  |                                       |         |              |             |             |              |
|---|---------------------------------------|---------|--------------|-------------|-------------|--------------|
| Garis air 4 s/d 6<br>(2,72 - 4,068 meter) |                                       |         |              |             |             |              |
| NO.                                       | G.A                                   | Simpson | Lengan Momen | AW          | Fungsi (AW) | Fungsi Momen |
| 1   | 2                                     |         | 3            | 4           | 5 = 2 x 4   | 6 = 3 x 5    |
| 4   | 1                                     |         | 4            | 1709.382    | 1709.382    | 6837.528861  |
| 5   | 4                                     |         | 5            | 1755.766    | 7023.066    | 35115.32864  |
| 6   | 1                                     |         | 6            | 1799.548    | 1799.548    | 10797.28857  |
| $\Sigma$                                  |                                       |         |              |             | 10532       | 52750.14607  |
| $h_1 =$                                   | Jarak Garis Air = $T/Ga =$            |         |              | 0.861       | m           |              |
| $\nabla =$                                | $\Sigma(5) \times 1/3 \times h_1$     |         |              | = 3022.683  | $m^3$       |              |
| $\Delta =$                                | $\nabla \times 1.025$                 |         |              | = 3098.250  | ton         |              |
| Momen =                                   | $\Sigma(6) \times 1/3 \times (h_1)^2$ |         |              | = 13034.930 | ton - meter |              |
| KB =                                      | Momen/ $\nabla$                       |         |              | = 4.312     | meter       |              |
| KB =                                      | $(\Sigma_6 \times h_1) / \Sigma_5$    |         |              | = 4.312     | meter       |              |

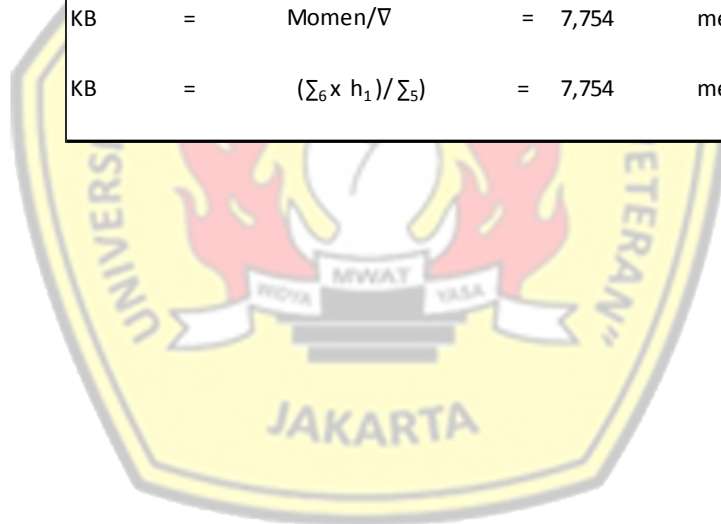
Tabel 32.  $\Delta$ ,  $\nabla$ , KB

| $\Delta$ , $\nabla$ , KB                   |                                       |         |              |             |             |              |
|--|---------------------------------------|---------|--------------|-------------|-------------|--------------|
| Garis air 6 s/d 8<br>(4.068 - 5.424 meter) |                                       |         |              |             |             |              |
| NO.  | G.A                                   | Simpson | Lengan Momen | AW          | Fungsi (AW) | Fungsi Momen |
| 1  | 2                                     |         | 3            | 4           | 5 = 2 x 4   | 6 = 3 x 5    |
| 6  | 1                                     |         | 6            | 1847,36     | 1847,35952  | 11084,15711  |
| 7  | 4                                     |         | 7            | 1939,851    | 7759,40362  | 54315,82537  |
| 8  | 1                                     |         | 8            | 1936,335    | 1936,33494  | 15490,67952  |
| $\Sigma$                                   |                                       |         |              |             | 11543,0981  | 80890,662    |
| $h_1 =$                                    | Jarak Garis Air = $T/Ga =$            |         |              | 0,861       | m           |              |
| $\nabla =$                                 | $\Sigma(5) \times 1/3 \times h_1$     |         |              | = 3312,869  | $m^3$       |              |
| $\Delta =$                                 | $\nabla \times 1.025$                 |         |              | = 3395,691  | ton         |              |
| Momen =                                    | $\Sigma(6) \times 1/3 \times (h_1)^2$ |         |              | = 19988,649 | ton - meter |              |
| KB =                                       | Momen/ $\nabla$                       |         |              | = 6,034     | meter       |              |
| KB =                                       | $(\Sigma_6 \times h_1) / \Sigma_5$    |         |              | = 6,034     | meter       |              |



Tabel 33.  $\Delta$  ,  $\nabla$  , KB

| $\Delta$ , $\nabla$ , KB                    |                          |                                       |              |             |             |              |
|---|--------------------------|---------------------------------------|--------------|-------------|-------------|--------------|
| Garis air 8 s/d 10<br>( 5.424 - 6.78 meter) |                          |                                       |              |             |             |              |
| NO.   | G.A                      | Simpson                               | Lengan Momen | AW          | Fungsi (AW) | Fungsi Momen |
| 1   | 2                        |                                       | 3            | 4           | 5 = 2 x 4   | 6 = 3 x 5    |
| 8   | 1                        |                                       | 8            | 1936,335    | 1936,33494  | 15490,67952  |
| 9   | 4                        |                                       | 9            | 1968,319    | 7873,277925 | 70859,50133  |
| 10  | 1                        |                                       | 10           | 2008,228    | 2008,227538 | 20082,27538  |
| $\Sigma$                                    |                          |                                       |              |             | 11817,8404  | 106432,4562  |
| $h_1 =$                                     | Jarak Garis Air = T/Ga = |                                       |              | 0,861       | m           |              |
| $\nabla$                                    | =                        | $\Sigma(5) \times 1/3 \times h_1$     |              | = 3391,720  | $m^3$       |              |
| $\Delta$                                    | =                        | $\nabla \times 1.025$                 |              | = 3476,513  | ton         |              |
| Momen                                       | =                        | $\Sigma(6) \times 1/3 \times (h_1)^2$ |              | = 26300,205 | ton - meter |              |
| KB  | =                        | Momen/ $\nabla$                       |              | = 7,754     | meter       |              |
| KB  | =                        | $(\Sigma_6 \times h_1) / \Sigma_5$    |              | = 7,754     | meter       |              |



Tabel 34. Titik Bouyancy Horizontal (OB)

| TITIK BOUYANCY HORIZONTAL (OB)                               |                |              |             |  |             |                    |           |             |            |
|--|----------------|--------------|-------------|--|-------------|--------------------|-----------|-------------|------------|
| Antara Garis Air 0 - 2                                       |                |              |             |  |             |                    |           |             |            |
| (0.00 - 0.678 meter)   |                |              |             |  |             |                    |           |             |            |
| Nomor Ordinat  | Faktor Simpson | Lengan Momen | G.A. 0      | G.A. 1   | G.A. 2      | Fungsi 1/2 Ordinat | Luas      | Fungsi Luas | OB         |
|  |                |              | 1/2 Ordinat | 1/2 Ordinat  | 1/2 Ordinat |                    |           |             | Momen      |
|  |                |              | 1           | 4  | 1           |                    |           |             |            |
| 1  | 2              | 3            | 4           | 5  | 6           | 7=4+5+6            | 8 = 7 x a | 9 = 2 x 8   | 10 = 3 x 9 |
| AP   | 1              | -10          | 0           | 0  | 0           | 0                  | 0         | 0           | 0          |
| 1  | 4              | -9           | 0           | 1,013  | 1,3         | 5,352              | 3,072048  | 12,288      | -110,594   |
| 2  | 2              | -8           | 1,87        | 2,05   | 2,8         | 12,87              | 7,38738   | 14,775      | -118,198   |
| 3  | 4              | -7           | 2,79        | 3,5  | 4,4         | 21,19              | 12,16306  | 48,652      | -340,566   |
| 4  | 2              | -6           | 4,87        | 5,034  | 5,9         | 30,906             | 17,74004  | 35,48009    | -212,881   |
| 5  | 4              | -5           | 5,089       | 6,89   | 7,45        | 40,099             | 23,01683  | 92,0673     | -460,337   |
| 6  | 2              | -4           | 5,906       | 7,89   | 8,687       | 46,153             | 26,49182  | 52,98364    | -211,935   |
| 7  | 4              | -3           | 6,987       | 8,321  | 8,923       | 49,194             | 28,23736  | 112,9494    | -338,848   |
| 8  | 2              | -2           | 6,987       | 8,623  | 9,123       | 50,602             | 29,04555  | 58,0911     | -116,182   |
| 9  | 4              | -1           | 6,987       | 8,568  | 9,103       | 50,362             | 28,90779  | 115,6312    | -115,631   |
| 10   | 2              | 0            | 6,987       | 8,617  | 9,142       | 50,597             | 29,04268  | 58,08536    | 0,000      |
| 11   | 4              | 1            | 6,987       | 8,626  | 9,149       | 50,64              | 29,06736  | 116,2694    | 116,2694   |
| 12   | 2              | 2            | 7,035       | 8,626  | 9,149       | 50,688             | 29,09491  | 58,18982    | 116,3796   |
| 13   | 4              | 3            | 7,1767      | 8,781  | 9,45        | 51,7507            | 29,7049   | 118,8196    | 356,459    |
| 14   | 2              | 4            | 7,278       | 8,579  | 9,11        | 50,704             | 29,1041   | 58,20819    | 232,8328   |
| 15   | 4              | 5            | 7,45        | 7,678  | 8,4567      | 46,6187            | 26,75913  | 107,037     | 535,1827   |
| 16   | 2              | 6            | 5,89        | 6,031  | 6,978       | 36,992             | 21,23341  | 42,467      | 254,801    |
| 17   | 4              | 7            | 3,98        | 4,2124   | 4,99        | 25,8196            | 14,82045  | 59,282      | 414,973    |
| 18   | 2              | 8            | 1,897       | 2,011  | 3,0138      | 12,9548            | 7,436055  | 14,87211    | 118,9769   |
| 19   | 4              | 9            | 0           | 1,04   | 1,45        | 5,61               | 3,22014   | 12,88056    | 115,925    |
| FP   | 1              | 10           | 0           | 0  | 0           | 0                  | 0         | 0           | 0          |
|  |                |              |             |  |             |                    | Σ         | 1189,028    | 236,628    |
| Jarak antara Garis Air<br>$h_1 = T/GA = 0,861$ m             |                |              |             | $\nabla = 1/3 \times h \times \Sigma(9) = 2495,572 \text{ m}^3$            |             |                    |           |             |            |
| Jarak Antara penampang vertikal<br>$h = lpp/sta. = 6,2965$ m |                |              |             | $\Delta = \nabla \times 1.025 = 2557,961 \text{ ton}$                      |             |                    |           |             |            |
| $a = 2/3 \times h_1 = 0,574$ m                               |                |              |             | $OB = \frac{[\Sigma(10) \times h]}{\Sigma(9)} = 1,253 \text{ m}$           |             |                    |           |             |            |
|  |                |              |             | $MSA = 2 \times 1/3 \times b \times sta \text{ 10 fungsi area} = 29,04268$ |             |                    |           |             |            |

Tabel 35. Titik Bouyancy Horizontal (OB)

| TITIK BOUYANCY HORIZONTAL (OB)                               |                |              |             |        |  |         |             |        |                    |           |             |            |
|--|----------------|--------------|-------------|--------|--|---------|-------------|--------|--------------------|-----------|-------------|------------|
| Antara Garis Air 2 - 4<br>(0,678 - 2,72meter)                |                |              |             |        |  |         |             |        |                    |           |             |            |
| Nomor Ordinat  | Faktor Simpson | Lengan Momen | G.A. 2      |        | G.A. 3   |         | G.A. 4      |        | Fungsi 1/2 Ordinat | Luas      | Fungsi Luas | OB         |
|  |                |              | 1/2 Ordinat |        | 1/2 Ordinat  |         | 1/2 Ordinat |        |                    |           |             | Momen      |
|  |                |              | 1           | 4      | 4  | 1       | 1           |        |                    |           |             |            |
| 1  | 2              | 3            | 4           |        | 5  |         | 6           |        | 7=4+5+6            | 8 = 7 x a | 9 = 2 x 8   | 10 = 3 x 9 |
| AP   | 1              | -10          | 0           | 0      | 0  | 0       | 0           | 0      | 0                  | 0         | 0           | 0          |
| 1  | 4              | -9           | 1,3         | 1,3    | 1,51   | 6,04    | 1,8         | 1,8    | 9,14               | 5,24636   | 20,985      | -188,869   |
| 2  | 2              | -8           | 2,8         | 2,8    | 3,04   | 12,16   | 3,9         | 3,9    | 18,86              | 10,82564  | 21,651      | -173,210   |
| 3  | 4              | -7           | 4,4         | 4,4    | 4,7  | 18,8    | 5,4         | 5,4    | 28,6               | 16,4164   | 65,666      | -459,659   |
| 4  | 2              | -6           | 5,9         | 5,9    | 6,534  | 26,136  | 6,889       | 6,889  | 38,925             | 22,34295  | 44,6859     | -268,115   |
| 5  | 4              | -5           | 7,45        | 7,45   | 7,82   | 31,28   | 8,12        | 8,12   | 46,85              | 26,8919   | 107,5676    | -537,838   |
| 6  | 2              | -4           | 8,687       | 8,687  | 8,701  | 34,804  | 9,106       | 9,106  | 52,597             | 30,190678 | 60,38136    | -241,525   |
| 7  | 4              | -3           | 8,923       | 8,923  | 9,123  | 36,492  | 9,245       | 9,245  | 54,66              | 31,37484  | 125,4994    | -376,498   |
| 8  | 2              | -2           | 9,123       | 9,123  | 9,243  | 36,972  | 9,2456      | 9,2456 | 55,3406            | 31,765504 | 63,53101    | -127,062   |
| 9  | 4              | -1           | 9,103       | 9,103  | 9,218  | 36,872  | 9,2456      | 9,2456 | 55,2206            | 31,696624 | 126,7865    | -126,786   |
| 10   | 2              | 0            | 9,142       | 9,142  | 9,235  | 36,94   | 9,25        | 9,25   | 55,332             | 31,760568 | 63,52114    | 0,000      |
| 11   | 4              | 1            | 9,149       | 9,149  | 9,238  | 36,952  | 9,25        | 9,25   | 55,351             | 31,771474 | 127,0859    | 127,0859   |
| 12   | 2              | 2            | 9,149       | 9,149  | 9,238  | 36,952  | 9,25        | 9,25   | 55,351             | 31,771474 | 63,54295    | 127,0859   |
| 13   | 4              | 3            | 9,45        | 9,45   | 9,238  | 36,952  | 9,25        | 9,25   | 55,652             | 31,944248 | 127,777     | 383,331    |
| 14   | 2              | 4            | 9,11        | 9,11   | 9,207  | 36,828  | 9,221       | 9,221  | 55,159             | 31,661266 | 63,32253    | 253,2901   |
| 15   | 4              | 5            | 8,4567      | 8,4567 | 8,861  | 35,444  | 8,901       | 8,901  | 52,8017            | 30,308176 | 121,233     | 606,1635   |
| 16   | 2              | 6            | 6,978       | 6,978  | 7,4754   | 29,9016 | 7,78        | 7,78   | 44,6596            | 25,63461  | 51,269      | 307,615    |
| 17   | 4              | 7            | 4,99        | 4,99   | 5,632  | 22,528  | 6,012       | 6,012  | 33,53              | 19,24622  | 76,985      | 538,894    |
| 18   | 2              | 8            | 3,0138      | 3,0138 | 3,731  | 14,924  | 4,1         | 4,1    | 22,0378            | 12,649697 | 25,29939    | 202,3952   |
| 19   | 4              | 9            | 1,45        | 1,45   | 2,76   | 11,04   | 3,15        | 3,15   | 15,64              | 8,97736   | 35,90944    | 323,185    |
| FP   | 1              | 10           | 0           | 0      | 0  | 0       | 0           | 0      | 0                  | 0         | 0           | 0          |
|  |                |              |             |        |  |         |             |        |                    | Σ         | 1392,699    | 369,482    |
| Jarak antara Garis Air<br>$h_1 = T/GA = 0,861$ m             |                |              |             |        | $\nabla = 1/3 \times h \times \Sigma(9) = 2923,043 \text{ m}^3$            |         |             |        |                    |           |             |            |
| Jarak Antara penampang vertikal<br>$h = lpp/sta. = 6,2965$ m |                |              |             |        | $\Delta = \nabla \times 1.025 = 2996,120 \text{ ton}$                      |         |             |        |                    |           |             |            |
| $a = 2/3 \times h_1 = 0,574$ m                               |                |              |             |        | $OB = \frac{[\Sigma(10) \times h]}{\Sigma(9)} = 1,670 \text{ m}$           |         |             |        |                    |           |             |            |
|  |                |              |             |        | $MSA = 2 \times 1/3 \times b \times sta \text{ 10 fungsi area} = 31,76057$ |         |             |        |                    |           |             |            |

Tabel 36. Titik Bouyancy Horizontal (OB)

| TITIK BOUYANCY HORIZONTAL (OB)                               |                |              |             |        |  |         |             |        |                    |           |             |            |
|--|----------------|--------------|-------------|--------|--|---------|-------------|--------|--------------------|-----------|-------------|------------|
| Antara Garis Air 4 - 6                                       |                |              |             |        |  |         |             |        |                    |           |             |            |
| (2,72 - 4,068 meter)   |                |              |             |        |  |         |             |        |                    |           |             |            |
| Nomor Ordinat  | Faktor Simpson | Lengan Momen | G.A. 4      |        | G.A. 5   |         | G.A. 6      |        | Fungsi 1/2 Ordinat | Luas      | Fungsi Luas | OB         |
|  |                |              | 1/2 Ordinat |        | 1/2 Ordinat  |         | 1/2 Ordinat |        |                    |           |             | Momen      |
|  |                |              | 1           | 4      | 4  | 1       | 1           | 6      |                    |           |             |            |
| 1  | 2              | 3            | 4           |        | 5  |         | 6           |        | 7=4+5+6            | 8 = 7 x a | 9 = 2 x 8   | 10 = 3 x 9 |
| AP   | 1              | -10          | 0           | 0      | 0  | 0       | 0           | 0      | 0                  | 0         | 0           | 0          |
| 1  | 4              | -9           | 1,8         | 1,8    | 2,4  | 9,6     | 2,8         | 2,8    | 14,2               | 8,1508    | 32,603      | -293,429   |
| 2  | 2              | -8           | 3,9         | 3,9    | 4,2  | 16,8    | 4,9         | 4,9    | 25,6               | 14,6944   | 29,389      | -235,110   |
| 3  | 4              | -7           | 5,4         | 5,4    | 5,8  | 23,2    | 6,9         | 6,9    | 35,5               | 20,377    | 81,508      | -570,556   |
| 4  | 2              | -6           | 6,889       | 6,889  | 7,34   | 29,36   | 7,89        | 7,89   | 44,139             | 25,335786 | 50,67157    | -304,029   |
| 5  | 4              | -5           | 8,12        | 8,12   | 8,45   | 33,8    | 8,756       | 8,756  | 50,676             | 29,088024 | 116,3521    | -581,76    |
| 6  | 2              | -4           | 9,106       | 9,106  | 9,34   | 37,36   | 9,38        | 9,38   | 55,846             | 32,055604 | 64,11121    | -256,445   |
| 7  | 4              | -3           | 9,245       | 9,245  | 9,46   | 37,84   | 9,47        | 9,47   | 56,555             | 32,46257  | 129,8503    | -389,551   |
| 8  | 2              | -2           | 9,2456      | 9,2456 | 9,25   | 37      | 9,25        | 9,25   | 55,4956            | 31,854474 | 63,70895    | -127,418   |
| 9  | 4              | -1           | 9,2456      | 9,2456 | 9,25   | 37      | 9,25        | 9,25   | 55,4956            | 31,854474 | 127,4179    | -127,418   |
| 10   | 2              | 0            | 9,25        | 9,25   | 9,25   | 37      | 9,25        | 9,25   | 55,5               | 31,857    | 63,714      | 0,000      |
| 11   | 4              | 1            | 9,25        | 9,25   | 9,25   | 37      | 9,25        | 9,25   | 55,5               | 31,857    | 127,428     | 127,428    |
| 12   | 2              | 2            | 9,25        | 9,25   | 9,25   | 37      | 9,25        | 9,25   | 55,5               | 31,857    | 63,714      | 127,428    |
| 13   | 4              | 3            | 9,25        | 9,25   | 9,25   | 37      | 9,25        | 9,25   | 55,5               | 31,857    | 127,428     | 382,284    |
| 14   | 2              | 4            | 9,221       | 9,221  | 9,227  | 36,908  | 9,231       | 9,231  | 55,36              | 31,77664  | 63,55328    | 254,2131   |
| 15   | 4              | 5            | 8,901       | 8,901  | 9,0125   | 36,05   | 9,21        | 9,21   | 54,161             | 31,088414 | 124,354     | 621,7683   |
| 16   | 2              | 6            | 7,78        | 7,78   | 7,997  | 31,988  | 8,12        | 8,12   | 47,888             | 27,487712 | 54,975      | 329,853    |
| 17   | 4              | 7            | 6,012       | 6,012  | 6,4657   | 25,8628 | 6,6325      | 6,6325 | 38,5073            | 22,10319  | 88,413      | 618,889    |
| 18   | 2              | 8            | 4,1         | 4,1    | 4,421  | 17,684  | 4,678       | 4,678  | 26,462             | 15,189188 | 30,37838    | 243,027    |
| 19   | 4              | 9            | 3,15        | 3,15   | 3,44   | 13,76   | 2,53        | 2,53   | 19,44              | 11,15856  | 44,63424    | 401,7082   |
| FP   | 1              | 10           | 0           | 0      | 0  | 0       | 0           | 0      | 0                  | 0         | 0           | 0          |
|  |                |              |             |        |  |         |             |        |                    | Σ         | 1484,204    | 220,882    |
| Jarak antara Garis Air<br>$h_1 = T/GA = 0,861$ m             |                |              |             |        | $\nabla = 1/3 \times h \times \Sigma(9) = 3115,096 \text{ m}^3$          |         |             |        |                    |           |             |            |
| Jarak Antara penampang vertikal<br>$h = lpp/sta. = 6,2965$ m |                |              |             |        | $\Delta = \nabla \times 1.025 = 3192,974 \text{ ton}$                    |         |             |        |                    |           |             |            |
| $a = 2/3 \times h_1 = 0,574$ m                               |                |              |             |        | $OB = \frac{[\Sigma(10) \times h]}{\Sigma(9)} = 0,937 \text{ m}$         |         |             |        |                    |           |             |            |
|  |                |              |             |        | $MSA = 2 \times 1/3 \times b \times sta \text{ 10 fungsi area} = 31,857$ |         |             |        |                    |           |             |            |

Tabel 37. Titik Bouyancy Horizontal (OB)

| TITIK BOUYANCY HORIZONTAL (OB)  |                    |              |             |             |   |                    |                         |             |          |          |
|---------------------------------|--------------------|--------------|-------------|-------------|---|--------------------|-------------------------|-------------|----------|----------|
| Antara Garis Air 6 - 8          |                    |              |             |             |   |                    |                         |             |          |          |
| ( 4.068 - 5.424 meter)          |                    |              |             |             |   |                    |                         |             |          |          |
| Nomor Ordinat                   | Faktor Simpson     | Lengan Momen | G.A. 6      | G.A. 7      | G.A. 8                                    | Fungsi 1/2 Ordinat | Luas                    | Fungsi Luas | OB       |          |
|                                 |                    |              | 1/2 Ordinat | 1/2 Ordinat | 1/2 Ordinat                               |                    |                         |             | Momen    |          |
|                                 |                    |              | 1           | 4           | 1   |                    |                         |             |          |          |
| 1                               | 2                  | 3            | 4           | 5           | 6   | 7=4+5+6            | 8=7 x a                 | 9=2 x 8     | 10=3 x 9 |          |
| AP                              | 1                  | -10          | 0           | 1           | 2,98                                      |                    |                         |             |          |          |
|                                 |                    |              | 0           | 4           | 2,98                                      |                    | 6,98                    | 4,00652     | 4,00652  | -40,0652 |
| 1                               | 4                  | -9           | 2,8         | 3,8         | 4,8                                       |                    | 22,8                    | 13,0872     | 52,349   | -471,139 |
|                                 |                    |              | 2,8         | 15,2        | 4,8                                       |                    |                         |             |          |          |
| 2                               | 2                  | -8           | 4,9         | 5,8         | 6,5                                       |                    | 34,6                    | 19,8604     | 39,721   | -317,766 |
|                                 |                    |              | 4,9         | 23,2        | 6,5                                       |                    |                         |             |          |          |
| 3                               | 4                  | -7           | 6,9         | 7,04        | 7,5                                       |                    | 42,56                   | 24,42944    | 97,718   | -684,024 |
|                                 |                    |              | 6,9         | 28,16       | 7,5                                       |                    |                         |             |          |          |
| 4                               | 2                  | -6           | 7,89        | 8,23        | 8,589                                     |                    | 49,399                  | 28,35503    | 56,71005 | -340,26  |
|                                 |                    |              | 7,89        | 32,92       | 8,589                                     |                    |                         |             |          |          |
| 5                               | 4                  | -5           | 8,756       | 8,836       | 8,91                                      |                    | 53,01                   | 30,42774    | 121,711  | -608,555 |
|                                 |                    |              | 8,756       | 35,344      | 8,91                                      |                    |                         |             |          |          |
| 6                               | 2                  | -4           | 9,38        | 9,38        | 9,38                                      |                    | 56,28                   | 32,30472    | 64,60944 | -258,438 |
|                                 |                    |              | 9,38        | 37,52       | 9,38                                      |                    |                         |             |          |          |
| 7                               | 4                  | -3           | 9,47        | 9,48        | 9,48                                      |                    | 56,87                   | 32,64338    | 130,5735 | -391,721 |
|                                 |                    |              | 9,47        | 37,92       | 9,48                                      |                    |                         |             |          |          |
| 8                               | 2                  | -2           | 9,25        | 9,25        | 9,25                                      |                    | 55,5                    | 31,857      | 63,714   | -127,428 |
|                                 |                    |              | 9,25        | 37          | 9,25                                      |                    |                         |             |          |          |
| 9                               | 4                  | -1           | 9,25        | 9,25        | 9,25                                      |                    | 55,5                    | 31,857      | 127,428  | -127,428 |
|                                 |                    |              | 9,25        | 37          | 9,25                                      |                    |                         |             |          |          |
| 10                              | 2                  | 0            | 9,25        | 9,25        | 9,25                                      |                    | 55,5                    | 31,857      | 63,714   | 0,000    |
|                                 |                    |              | 9,25        | 37          | 9,25                                      |                    |                         |             |          |          |
| 11                              | 4                  | 1            | 9,25        | 9,25        | 9,25                                      |                    | 55,5                    | 31,857      | 127,428  | 127,428  |
|                                 |                    |              | 9,25        | 37          | 9,25                                      |                    |                         |             |          |          |
| 12                              | 2                  | 2            | 9,25        | 9,25        | 9,25                                      |                    | 55,5                    | 31,857      | 63,714   | 127,428  |
|                                 |                    |              | 9,25        | 37          | 9,25                                      |                    |                         |             |          |          |
| 13                              | 4                  | 3            | 9,25        | 9,25        | 9,25                                      |                    | 55,5                    | 31,857      | 127,428  | 382,284  |
|                                 |                    |              | 9,25        | 37          | 9,25                                      |                    |                         |             |          |          |
| 14                              | 2                  | 4            | 9,231       | 9,234       | 9,237                                     |                    | 55,404                  | 31,8019     | 63,60379 | 254,4152 |
|                                 |                    |              | 9,231       | 36,936      | 9,237                                     |                    |                         |             |          |          |
| 15                              | 4                  | 5            | 9,21        | 9,203       | 9,025                                     |                    | 55,047                  | 31,59698    | 126,388  | 631,9396 |
|                                 |                    |              | 9,21        | 36,812      | 9,025                                     |                    |                         |             |          |          |
| 16                              | 2                  | 6            | 8,12        | 8,19        | 8,289                                     |                    | 49,169                  | 28,22301    | 56,446   | 338,676  |
|                                 |                    |              | 8,12        | 32,76       | 8,289                                     |                    |                         |             |          |          |
| 17                              | 4                  | 7            | 6,6325      | 6,785       | 6,8901                                    |                    | 40,6626                 | 23,34033    | 93,361   | 653,529  |
|                                 |                    |              | 6,6325      | 27,14       | 6,8901                                    |                    |                         |             |          |          |
| 18                              | 2                  | 8            | 4,678       | 4,891       | 4,913                                     |                    | 29,155                  | 16,73497    | 33,46994 | 267,7595 |
|                                 |                    |              | 4,678       | 19,564      | 4,913                                     |                    |                         |             |          |          |
| 19                              | 4                  | 9            | 2,53        | 5,65        | 2,893                                     |                    | 28,023                  | 16,0852     | 64,34081 | 579,0673 |
|                                 |                    |              | 2,53        | 22,6        | 2,893                                     |                    |                         |             |          |          |
| FP                              | 1                  | 10           | 0           | 0           | 0   |                    | 0                       | 0           | 0        | 0        |
|                                 |                    |              | 0           | 0           | 0   |                    |                         |             |          |          |
|                                 |                    |              |             |             |   |                    | Σ                       | 1578,434    |          | -4,298   |
| Jarak antara Garis Air          |                    |              |             |             |   |                    |                         |             |          |          |
| $h_1 =$                         | $T/GA =$           | 0,861        | m           | $\nabla =$  | $1/3 \times h \times \Sigma(9)$           | =                  | 3312,869 m <sup>3</sup> |             |          |          |
| Jarak Antara penampang vertikal |                    |              |             |             |   |                    |                         |             |          |          |
| $h =$                           | $lpp/sta. =$       | 6,2965       | m           | $\Delta =$  | $\nabla \times 1.025$                     | =                  | 3395,691 ton            |             |          |          |
| $a =$                           | $2/3 \times h_1 =$ | 0,574        | m           | $OB =$      | $\frac{[\Sigma(10) \times h]}{\Sigma(9)}$ | =                  | -0,017 m                |             |          |          |
|                                 |                    |              |             | $MSA =$     | $2 \times 1/3 \times b \times sta$        | $10$               | fungsi area =           | 31,857      |          |          |

Tabel 38. Titik Bouyancy Horizontal (OB)

| TITIK BOUYANCY HORIZONTAL (OB)  |                    |              |             |   |             |                                     |           |                        |            |
|---------------------------------|--------------------|--------------|-------------|---|-------------|-------------------------------------|-----------|------------------------|------------|
| Antara Garis Air 8 - 10         |                    |              |             |   |             |                                     |           |                        |            |
| ( 5.424 - 6.78 meter)           |                    |              |             |   |             |                                     |           |                        |            |
| Nomor Ordinat                   | Faktor Simpson     | Lengan Momen | G.A. 8      | G.A. 9  | G.A. 10     | Fungsi 1/2 Ordinat                  | Luas      | Fungsi Luas            | OB         |
|                                 |                    |              | 1/2 Ordinat | 1/2 Ordinat   | 1/2 Ordinat |                                     |           |                        | Momen      |
|                                 |                    |              | 1           | 4   | 1           |                                     |           |                        |            |
| 1                               | 2                  | 3            | 4           | 5   | 6           | 7=4+5+6                             | 8 = 7 x a | 9 = 2 x 8              | 10 = 3 x 9 |
| AP                              | 1                  | -10          | 2,98        | 3,79  | 5,76        |                                     |           |                        |            |
|                                 |                    |              | 2,98        | 15,16   | 5,76        | 23,9                                | 13,7186   | 13,7186                | -137,186   |
| 1                               | 4                  | -9           | 4,8         | 5,7   | 6,01        |                                     |           |                        |            |
|                                 |                    |              | 4,8         | 22,8  | 6,01        | 33,61                               | 19,29214  | 77,169                 | -694,517   |
| 2                               | 2                  | -8           | 6,5         | 6,9   | 7,4         |                                     |           |                        |            |
|                                 |                    |              | 6,5         | 27,6  | 7,4         | 41,5                                | 23,821    | 47,642                 | -381,136   |
| 3                               | 4                  | -7           | 7,5         | 7,9   | 8,123       |                                     |           |                        |            |
|                                 |                    |              | 7,5         | 31,6  | 8,123       | 47,223                              | 27,106002 | 108,424                | -758,968   |
| 4                               | 2                  | -6           | 8,589       | 8,57  | 8,745       |                                     |           |                        |            |
|                                 |                    |              | 8,589       | 34,28   | 8,745       | 51,614                              | 29,626436 | 59,25287               | -355,517   |
| 5                               | 4                  | -5           | 8,91        | 8,934   | 9,012       |                                     |           |                        |            |
|                                 |                    |              | 8,91        | 35,736  | 9,012       | 53,658                              | 30,799692 | 123,1988               | -615,994   |
| 6                               | 2                  | -4           | 9,38        | 9,38  | 9,38        |                                     |           |                        |            |
|                                 |                    |              | 9,38        | 37,52   | 9,38        | 56,28                               | 32,30472  | 64,60944               | -258,438   |
| 7                               | 4                  | -3           | 9,48        | 9,48  | 9,48        |                                     |           |                        |            |
|                                 |                    |              | 9,48        | 37,92   | 9,48        | 56,88                               | 32,64912  | 130,5965               | -391,789   |
| 8                               | 2                  | -2           | 9,25        | 9,25  | 9,25        |                                     |           |                        |            |
|                                 |                    |              | 9,25        | 37  | 9,25        | 55,5                                | 31,857    | 63,714                 | -127,428   |
| 9                               | 4                  | -1           | 9,25        | 9,25  | 9,25        |                                     |           |                        |            |
|                                 |                    |              | 9,25        | 37  | 9,25        | 55,5                                | 31,857    | 127,428                | -127,428   |
| 10                              | 2                  | 0            | 9,25        | 9,25  | 9,25        |                                     |           |                        |            |
|                                 |                    |              | 9,25        | 37  | 9,25        | 55,5                                | 31,857    | 63,714                 | 0,000      |
| 11                              | 4                  | 1            | 9,25        | 9,25  | 9,25        |                                     |           |                        |            |
|                                 |                    |              | 9,25        | 37  | 9,25        | 55,5                                | 31,857    | 127,428                | 127,428    |
| 12                              | 2                  | 2            | 9,25        | 9,25  | 9,25        |                                     |           |                        |            |
|                                 |                    |              | 9,25        | 37  | 9,25        | 55,5                                | 31,857    | 63,714                 | 127,428    |
| 13                              | 4                  | 3            | 9,25        | 9,25  | 9,25        |                                     |           |                        |            |
|                                 |                    |              | 9,25        | 37  | 9,25        | 55,5                                | 31,857    | 127,428                | 382,284    |
| 14                              | 2                  | 4            | 9,237       | 9,238   | 9,24        |                                     |           |                        |            |
|                                 |                    |              | 9,237       | 36,952  | 9,24        | 55,429                              | 31,816246 | 63,63249               | 254,53     |
| 15                              | 4                  | 5            | 9,025       | 9,027   | 9,219       |                                     |           |                        |            |
|                                 |                    |              | 9,025       | 36,108  | 9,219       | 54,352                              | 31,198048 | 124,792                | 623,961    |
| 16                              | 2                  | 6            | 8,289       | 8,573   | 8,89        |                                     |           |                        |            |
|                                 |                    |              | 8,289       | 34,292  | 8,89        | 51,471                              | 29,544354 | 59,089                 | 354,532    |
| 17                              | 4                  | 7            | 6,8901      | 7,045   | 7,234       |                                     |           |                        |            |
|                                 |                    |              | 6,8901      | 28,18   | 7,234       | 42,3041                             | 24,282553 | 97,130                 | 679,911    |
| 18                              | 2                  | 8            | 4,913       | 5,12  | 5,242       |                                     |           |                        |            |
|                                 |                    |              | 4,913       | 20,48   | 5,242       | 30,635                              | 17,58449  | 35,16898               | 281,3518   |
| 19                              | 4                  | 9            | 2,893       | 2,678   | 3,0123      |                                     |           |                        |            |
|                                 |                    |              | 2,893       | 10,712  | 3,0123      | 16,6173                             | 9,5383302 | 38,15332               | 343,3799   |
| FP                              | 1                  | 10           | 0           | 0   | 0           |                                     |           |                        |            |
|                                 |                    |              | 0           | 0   | 0           | 0                                   | 0         | 0                      | 0          |
|                                 |                    |              |             |   |             |                                     | Σ         | 1616,003               | -673,595   |
| Jarak antara Garis Air          |                    |              |             |   |             |                                     |           |                        |            |
| $h_1 =$                         | $T/GA =$           | 0,861        | m           | $\nabla =$  |             | $1/3 \times h \times \Sigma(9)$     | =         | 3391,72 m <sup>3</sup> |            |
| Jarak Antara penampang vertikal |                    |              |             |   |             |                                     |           |                        |            |
| $h =$                           | $lpp/sta. =$       | 6,2965       | m           | $\Delta =$  |             | $\nabla \times 1.025$               | =         | 3476,513 ton           |            |
| $a =$                           | $2/3 \times h_1 =$ | 0,574        | m           | $OB =$  |             | $[\Sigma(10) \times h] / \Sigma(9)$ | =         | -2,625 m               |            |
|                                 |                    |              |             | $MSA = 2 \times 1/3 \times b \times sta \ 10 \text{ fungsi area} =$ |             |                                     |           |                        |            |
|                                 |                    |              |             | 31,857  |             |                                     |           |                        |            |

**Tabel 39. Displacement moulded, KB, OB, momen  $\Delta$ KB momen  $\Delta$  OB**

| Garis Air 0 - 2<br>( 0.00 - 0.678 meter) |   |   |          |       |       |                     |                     |
|--|---|---|----------|-------|-------|---------------------|---------------------|
| GA                                       |   |   | $\Delta$ | KB    | OB    | Momen. $\Delta$ .KB | Momen. $\Delta$ .OB |
|  |   |   | Ton      | Meter | Meter | Ton-Meter           | Ton-Meter           |
| 0  | - | 2 | 2557,961 | 0,902 | 1,253 | 2307,944            | 3205,290            |

| Garis Air 2 - 4<br>( 0,678 - 2,72meter) |   |   |          |       |       |                     |                     |
|---|---|---|----------|-------|-------|---------------------|---------------------|
| GA                                      |   |   | $\Delta$ | KB    | OB    | Momen. $\Delta$ .KB | Momen. $\Delta$ .OB |
|   |   |   | Ton      | Meter | Meter | Ton-Meter           | Ton-Meter           |
| 0                                       | - | 2 | 2557,961 | 0,902 | 1,253 | 2307,944            | 3205,290            |
| 2                                       | - | 4 | 2996,120 | 2,595 | 1,670 | 7773,515            | 5004,890            |
| $\Sigma$                                |   |   | 5554,081 | 3,497 | 2,924 | 10081,459           | 8210,180            |

| Garis Air 4 - 6<br>( 2,72 - 4,068 meter) |   |   |          |       |       |                     |                     |
|--|---|---|----------|-------|-------|---------------------|---------------------|
| GA                                       |   |   | $\Delta$ | KB    | OB    | Momen. $\Delta$ .KB | Momen. $\Delta$ .OB |
|  |   |   | Ton      | Meter | Meter | Ton-Meter           | Ton-Meter           |
| 0  | - | 2 | 2557,961 | 0,902 | 1,253 | 2307,944            | 3205,290            |
| 2  | - | 4 | 2996,120 | 2,595 | 1,670 | 7773,515            | 5004,890            |
| 4  | - | 6 | 3192,974 | 4,312 | 0,937 | 13768,201           | 2991,996            |
| $\Sigma$                                 |   |   | 8747,054 | 7,809 | 3,861 | 23849,660           | 11202,176           |

| Garis Air 6 - 8<br>( 4.068 - 5.424 meter) |   |   |           |        |        |                     |                     |
|---|---|---|-----------|--------|--------|---------------------|---------------------|
| GA  |   |   | $\Delta$  | KB     | OB     | Momen. $\Delta$ .KB | Momen. $\Delta$ .OB |
|   |   |   | Ton       | Meter  | Meter  | Ton-Meter           | Ton-Meter           |
| 0   | - | 2 | 2557,961  | 0,902  | 1,253  | 2307,944            | 3205,290            |
| 2   | - | 4 | 2996,120  | 2,595  | 1,670  | 7773,515            | 5004,890            |
| 4   | - | 6 | 3192,974  | 4,312  | 0,937  | 13768,201           | 2991,996            |
| 6   | - | 8 | 3395,691  | 6,034  | -0,017 | 20488,365           | -58,215             |
| $\Sigma$                                  |   |   | 12142,745 | 13,842 | 3,843  | 44338,025           | 11143,961           |

| Garis Air 8 - 10<br>( 5.424 - 6.78 meter) |   |    |           |          |          |                     |                     |
|---|---|----|-----------|----------|----------|---------------------|---------------------|
| GA  |   |    | $\Delta$  | KB       | OB       | Momen. $\Delta$ .KB | Momen. $\Delta$ .OB |
|   |   |    | Ton       | Meter    | Meter    | Ton-Meter           | Ton-Meter           |
| 0   | - | 2  | 2557,961  | 0,902    | 1,253    | 2307,944            | 3205,290            |
| 2   | - | 4  | 2996,120  | 2,595    | 1,670    | 7773,515            | 5004,890            |
| 4   | - | 6  | 3192,974  | 4,312    | 0,937    | 13768,201           | 2991,996            |
| 6   | - | 8  | 3395,691  | 6,034    | -0,017   | 20488,365           | -58,215             |
| 8   | - | 10 | 3476,5132 | 7,754238 | -2,62456 | 26957,71009         | -9124,306411        |
| $\Sigma$                                  |   |    | 15619,259 | 21,597   | 1,219    | 71295,735           | 2019,655            |

Tabel 40. Permukaan Basah dan Displacement

| PERMUKAAN BASAH & DISPLASEMEN KULIT |                |               |         |                   |         |                   |         |                   |         |                   |         |                   |         |                   |        |                   |        |                   |         |                   |        |                    |         |      |
|-------------------------------------|----------------|---------------|---------|-------------------|---------|-------------------|---------|-------------------|---------|-------------------|---------|-------------------|---------|-------------------|--------|-------------------|--------|-------------------|---------|-------------------|--------|--------------------|---------|------|
| STATION                             | FAKTOR SIMPSON | GARIS AIR 0 m |         | s/d GARIS AIR 1 m |         | s/d GARIS AIR 2 m |         | s/d GARIS AIR 3 m |         | s/d GARIS AIR 4 m |         | s/d GARIS AIR 5 m |         | s/d GARIS AIR 6 m |        | s/d GARIS AIR 7 m |        | s/d GARIS AIR 8 m |         | s/d GARIS AIR 9 m |        | s/d GARIS AIR 10 m |         |      |
|                                     |                | 1/2 Lengk     | FUNGSI  | 1/2 Lengk         | FUNGSI  | 1/2 Lengk         | FUNGSI  | 1/2 Lengk         | FUNGSI  | 1/2 Lengk         | FUNGSI  | 1/2 Lengk         | FUNGSI  | 1/2 Lengk         | FUNGSI | 1/2 Lengk         | FUNGSI | 1/2 Lengk         | FUNGSI  | 1/2 Lengk         | FUNGSI | 1/2 Lengk          | FUNGSI  |      |
| 0                                   | 1              | 0             | 0       | 0                 | 0       | 0                 | 0       | 0                 | 0       | 0                 | 0       | 0                 | 0       | 0                 | 0      | 0                 | 1      | 1                 | 2,98    | 2,98              | 3,79   | 3,79               | 5,76    | 5,76 |
| 1                                   | 4              | 0             | 0       | 1,013             | 4,052   | 1,3               | 5,2     | 1,51              | 6,04    | 1,8               | 7,2     | 2,4               | 9,6     | 2,8               | 11,2   | 3,8               | 15,2   | 4,8               | 19,2    | 5,7               | 22,8   | 6,01               | 24,04   |      |
| 2                                   | 2              | 1,87          | 3,74    | 2,05              | 4,1     | 2,8               | 5,6     | 3,04              | 6,08    | 3,9               | 7,8     | 4,2               | 8,4     | 4,9               | 9,8    | 5,8               | 11,6   | 6,5               | 13      | 6,9               | 13,8   | 7,4                | 14,8    |      |
| 3                                   | 4              | 2,79          | 11,16   | 3,5               | 14      | 4,4               | 17,6    | 4,7               | 18,8    | 5,4               | 21,6    | 5,8               | 23,2    | 6,9               | 27,6   | 7,04              | 28,16  | 7,5               | 30      | 7,9               | 31,6   | 8,123              | 32,492  |      |
| 4                                   | 2              | 4,87          | 9,74    | 5,034             | 10,068  | 5,9               | 11,8    | 6,534             | 13,068  | 6,889             | 13,778  | 7,34              | 14,68   | 7,89              | 15,78  | 8,23              | 16,46  | 8,589             | 17,178  | 8,57              | 17,14  | 8,745              | 17,49   |      |
| 5                                   | 4              | 5,089         | 20,356  | 6,89              | 27,56   | 7,45              | 29,8    | 7,82              | 31,28   | 8,12              | 32,48   | 8,45              | 33,8    | 8,756             | 35,024 | 8,836             | 35,344 | 8,91              | 35,64   | 8,934             | 35,736 | 9,012              | 36,048  |      |
| 6                                   | 2              | 5,906         | 11,812  | 7,89              | 15,78   | 8,687             | 17,374  | 8,701             | 17,402  | 9,106             | 18,212  | 9,34              | 18,68   | 9,38              | 18,76  | 9,38              | 18,76  | 9,38              | 18,76   | 9,38              | 18,76  | 9,38               | 18,76   |      |
| 7                                   | 4              | 6,987         | 27,948  | 8,321             | 33,284  | 8,923             | 35,692  | 9,123             | 36,492  | 9,245             | 36,98   | 9,46              | 37,84   | 9,47              | 37,88  | 9,48              | 37,92  | 9,48              | 37,92   | 9,48              | 37,92  | 9,48               | 37,92   |      |
| 8                                   | 2              | 6,987         | 13,974  | 8,623             | 17,246  | 9,123             | 18,246  | 9,243             | 18,486  | 9,2456            | 18,4912 | 9,25              | 18,5    | 9,25              | 18,5   | 9,25              | 18,5   | 9,25              | 18,5    | 9,25              | 18,5   | 9,25               | 18,5    |      |
| 9                                   | 4              | 6,987         | 27,948  | 8,568             | 34,272  | 9,103             | 36,412  | 9,218             | 36,872  | 9,2456            | 36,9824 | 9,25              | 37      | 9,25              | 37     | 9,25              | 37     | 9,25              | 37      | 9,25              | 37     | 9,25               | 37      |      |
| 10                                  | 2              | 6,987         | 13,974  | 8,617             | 17,234  | 9,142             | 18,284  | 9,235             | 18,47   | 9,25              | 18,5    | 9,25              | 18,5    | 9,25              | 18,5   | 9,25              | 18,5   | 9,25              | 18,5    | 9,25              | 18,5   | 9,25               | 18,5    |      |
| 11                                  | 4              | 6,987         | 27,948  | 8,626             | 34,504  | 9,149             | 36,596  | 9,238             | 36,952  | 9,25              | 37      | 9,25              | 37      | 9,25              | 37     | 9,25              | 37     | 9,25              | 37      | 9,25              | 37     | 9,25               | 37      |      |
| 12                                  | 2              | 7,035         | 14,07   | 8,626             | 17,252  | 9,149             | 18,298  | 9,238             | 18,476  | 9,25              | 18,5    | 9,25              | 18,5    | 9,25              | 18,5   | 9,25              | 18,5   | 9,25              | 18,5    | 9,25              | 18,5   | 9,25               | 18,5    |      |
| 13                                  | 4              | 7,1767        | 28,7068 | 8,781             | 35,124  | 9,45              | 37,8    | 9,238             | 36,952  | 9,25              | 37      | 9,25              | 37      | 9,25              | 37     | 9,25              | 37     | 9,25              | 37      | 9,25              | 37     | 9,25               | 37      |      |
| 14                                  | 2              | 7,278         | 14,556  | 8,579             | 17,158  | 9,11              | 18,22   | 9,207             | 18,414  | 9,221             | 18,442  | 9,227             | 18,454  | 9,231             | 18,462 | 9,234             | 18,468 | 9,237             | 18,474  | 9,238             | 18,476 | 9,24               | 18,48   |      |
| 15                                  | 4              | 7,45          | 29,8    | 7,678             | 30,712  | 8,4567            | 33,8268 | 8,861             | 35,444  | 8,901             | 35,604  | 9,0125            | 36,05   | 9,21              | 36,84  | 9,203             | 36,812 | 9,025             | 36,1    | 9,027             | 36,108 | 9,219              | 36,876  |      |
| 16                                  | 2              | 5,89          | 11,78   | 6,031             | 12,062  | 6,978             | 13,956  | 7,4754            | 14,9508 | 7,78              | 15,56   | 7,997             | 15,994  | 8,12              | 16,24  | 8,19              | 16,38  | 8,289             | 16,578  | 8,573             | 17,146 | 8,89               | 17,78   |      |
| 17                                  | 4              | 3,98          | 15,92   | 4,2124            | 16,8496 | 4,99              | 19,96   | 5,632             | 22,528  | 6,012             | 24,048  | 6,4657            | 25,8628 | 6,6325            | 26,53  | 6,785             | 27,14  | 6,8901            | 27,5604 | 7,045             | 28,18  | 7,234              | 28,936  |      |
| 18                                  | 2              | 1,897         | 3,794   | 2,011             | 4,022   | 3,0138            | 6,0276  | 3,731             | 7,462   | 4,1               | 8,2     | 4,421             | 8,842   | 4,678             | 9,356  | 4,891             | 9,782  | 4,913             | 9,826   | 5,12              | 10,24  | 5,242              | 10,484  |      |
| 19                                  | 4              | 0             | 0       | 1,04              | 4,16    | 1,45              | 5,8     | 2,76              | 11,04   | 3,15              | 12,6    | 3,44              | 13,76   | 2,53              | 10,12  | 5,65              | 22,6   | 2,893             | 11,572  | 2,678             | 10,712 | 3,0123             | 12,0492 |      |
| 20                                  | 1              | 0             | 0       | 0                 | 0       | 0                 | 0       | 0                 | 0       | 0                 | 0       | 0                 | 0       | 0                 | 0      | 0                 | 0      | 0                 | 0       | 0                 | 0      | 0                  | 0       |      |
| Σ                                   |                | 287,2268      |         | 345,3876          |         | 381,2924          |         | 399,1688          |         | 411,7776          |         | 422,0628          |         | 428,892           |        | 445,926           |        | 439,1084          |         | 442,318           |        | 448,6152           |         |      |



**Tabel 41. Permukaan Basah dan Displasement**

| Garis Air | Permukaan basah (m <sup>2</sup> )    | Faktor Kulit | Δ Kulit  | Δ Tambahan |
|-----------|--------------------------------------|--------------|----------|------------|
|           | $\frac{2}{3} \times h \times \Sigma$ |              |          |            |
| 1         | 2                                    | 3            | 4=2x3    | 5=2+4      |
| 0         | 1205,682364                          | 0,023        | 27,31172 | 1232,994   |
| s/d 1     | 1449,822016                          | 0,023        | 32,84209 | 1482,664   |
| s/d 2     | 1600,538398                          | 0,023        | 36,2562  | 1636,795   |
| s/d 3     | 1675,577566                          | 0,023        | 37,95602 | 1713,534   |
| s/d 4     | 1728,505106                          | 0,023        | 39,15496 | 1767,660   |
| s/d 5     | 1771,678947                          | 0,023        | 40,13296 | 1811,812   |
| s/d 6     | 1800,345652                          | 0,023        | 40,78233 | 1841,128   |
| s/d 7     | 1871,848706                          | 0,023        | 42,40205 | 1914,251   |
| s/d 8     | 1843,230694                          | 0,023        | 41,75378 | 1884,984   |
| s/d 9     | 1856,703525                          | 0,023        | 42,05898 | 1898,763   |
| s/d 10    | 1883,137071                          | 0,023        | 42,65776 | 1925,795   |

**Tabel 42. Am dan Cm**

| GARIS AIR  | 1/2 ORDINAT | SIMPSON | FUNGSI PRODUCT |
|--|-------------|---------|----------------|
| 0 m  | 6,987       | 1       | 6,987          |
| 0,689 m  | 8,617       | 4       | 34,468         |
| 1,378 m  | 9,142       | 1       | 9,142          |
| $\Sigma$   |             |         | 50,597         |
| $Am = 2 \times \frac{1}{3} \times hwl \times \Sigma$ |             |         | 29,042678      |
| $Cm = Am / (Bxt)$                                    |             |         | 0,182430142    |

**Tabel 43. Am dan Cm**

| GARIS AIR  | FUNGSI | SIMPSON | FUNGSI PRODUCT |
|--|--------|---------|----------------|
| 1,378 m  | 9,142  | 1       | 9,142          |
| 2,067 m  | 9,235  | 4       | 36,94          |
| 2,756 m  | 9,25   | 1       | 9,25           |
| $\Sigma$   |        |         | 55,332         |
| $Am = 2 \times \frac{1}{3} \times hwl \times \Sigma$ |        |         | 31,760568      |
| $Cm = Am / (Bxt)$                                    |        |         | 0,199502434    |

**Tabel 44. Am dan Cm**

| GARIS AIR                                    | FUNGSI | SIMPSON | FUNGSI PRODUCT |
|--|--------|---------|----------------|
| 2,756 m                                      | 9,25   | 1       | 9,25           |
| 3,445 m                                      | 9,25   | 4       | 37             |
| 4,134 m                                      | 9,25   | 1       | 9,25           |
| $\Sigma$                                     |        |         | 55,5           |
| $Am = 2 \times 1/3 \times hwl \times \Sigma$ |        |         | 31,857         |
| $Cm = Am / (Bxt)$                            |        |         | 0,200108167    |

**Tabel 45. Am dan Cm**

| GARIS AIR                                    | FUNGSI | SIMPSON | FUNGSI PRODUCT |
|--|--------|---------|----------------|
| 4,134 m                                      | 9,25   | 1       | 9,25           |
| 4,823 m                                      | 9,25   | 4       | 37             |
| 5,512 m                                      | 9,25   | 1       | 9,25           |
| $\Sigma$                                     |        |         | 55,5           |
| $Am = 2 \times 1/3 \times hwl \times \Sigma$ |        |         | 31,857         |
| $Cm = Am / (Bxt)$                            |        |         | 0,200108167    |

**Tabel 46. Am dan Cm**

| GARIS AIR                                    | FUNGSI | SIMPSON | FUNGSI PRODUCT |
|--|--------|---------|----------------|
| 5,512 m                                      | 9,25   | 1       | 9,25           |
| 6,201 m                                      | 9,25   | 4       | 37             |
| 6,89 m                                       | 9,25   | 1       | 9,25           |
| $\Sigma$                                     |        |         | 55,5           |
| $Am = 2 \times 1/3 \times hwl \times \Sigma$ |        |         | 31,857         |
| $Cm = Am / (Bxt)$                            |        |         | 0,200108167    |

Tabel 47. Hydrostatic Curve

| Bidang Garis Air               |                         |                             | Tengah Kapal (O)      |                  |                        | Displasemen (Δ)             |                            |                              |                           | Momen Inersia          |                       |                              |  |               |                     |
|--------------------------------|-------------------------|-----------------------------|-----------------------|------------------|------------------------|-----------------------------|----------------------------|------------------------------|---------------------------|------------------------|-----------------------|------------------------------|--|---------------|---------------------|
| Garis Air                      | Luas Bidang GA          | Koef. Bidang GA             | TPC                   | Am               | B x T                  | Koef. O                     | Δ Bersih (tanpa kulit dll) | 1.025 x L x B x T            | Koef. Blok                | Koef. Prismatik        | Momen Inersia Memanja | MTC                          | MSA                                      | c mid         | FUNCTION OF WATER L |
|                                | m <sup>2</sup>          |                             | Ton/cm                | m <sup>2</sup>   | m <sup>2</sup>         |                             | Ton                        | Ton                          |                           |                        | m <sup>4</sup>        | Ton-m/cm                     |  |               |                     |
|                                |                         | $\frac{Aw}{x B}$            | $\frac{Lwl}{100}$     |                  |                        | $\frac{Am}{B x T}$          |                            |                              | $\frac{\Delta}{\square}$  | $\frac{CB}{CM}$        |                       | $\frac{IL x 1.025}{100 x L}$ |  | MSA / (B x d) |                     |
| 0                              | 1205,682364             | 0,503                       | 12,358                | 0                | 159,1989               | 0                           | 0                          | 20549,11541                  | 0                         | 0                      | 815120,8              | 1052143,674                  | 0  | 0             | 287,2268            |
| 2                              | 1622,366264             | 0,676                       | 16,629                | 29,043           | 159,1989               | 0,182                       | 2557,961                   | 20549,11541                  | 0,124                     | 0,682                  | 1236753               | 1596378,839                  | 29,042678                                | 1,824301424   | 386,4924            |
| 4                              | 1758,728306             | 0,733                       | 18,027                | 60,803           | 159,1989               | 0,382                       | 5554,081                   | 20549,11541                  | 0,270                     | 0,708                  | 1510253               | 1949408,740                  | 60,803246                                | 3,819325762   | 418,9776            |
| 6                              | 1847,359519             | 0,770                       | 18,935                | 92,660           | 159,1989               | 0,582                       | 8747,054                   | 20549,11541                  | 0,426                     | 0,731                  | 1671808               | 2157940,575                  | 92,660246                                | 5,820407427   | 440,092             |
| 8                              | 1936,335                | 0,807                       | 19,847                | 124,517          | 159,1989               | 0,782                       | 12142,745                  | 20549,11541                  | 0,591                     | 0,755                  | 1918212               | 2475994,073                  | 124,517246                               | 7,821489093   | 461,2884            |
| 10                             | 2008,227538             | 0,837                       | 20,584                | 156,374          | 159,1989               | 0,982                       | 15619,259                  | 20549,11541                  | 0,760                     | 0,774                  | 2098298               | 2708446,881                  | 156,374246                               | 9,822570759   | 478,4152            |
| <b>Simbol</b>                  | <b>Aw</b>               | <b>Cw</b>                   | <b>TPC</b>            | <b>Am</b>        |                        | <b>Cm</b>                   | <b>Δ</b>                   | $\square$                    | <b>CB</b>                 | <b>CP</b>              | <b>IL(f)</b>          | <b>MTC</b>                   |  | <b>c mid</b>  | <b>fw</b>           |
| Titik Melintang                |                         |                             |                       | Titik Memanjang  |                        |                             |                            | Perubahan Δ Karena Trim 1 cm |                           | Displasemen Seluruhnya |                       |                              | Displacement Due To Trim One Centrimetre |               |                     |
| Titik Tekan Diatas Garis Dasar | Momen Inersia Melintang | MT Diatas Titik Tekan       | MT Diatas Garis Dasar | Titik Terhadap O | Titik Apung Terhadap O | ML Diatas Titik Tekan       | ML Diatas Garis Dasar      | Aw x OF                      | $\frac{1.025xAwO}{F Lwl}$ | Permukaan Basah        | Δ Kulit dll           | Δ Seluruhnya                 | $DDT = \otimes_F x \frac{TPC}{Lpp}$      |               |                     |
| m                              | m <sup>4</sup>          | m                           | m                     | m                | m                      | m                           | m                          |                              | Ton                       | m <sup>2</sup>         | Ton                   | Ton                          |  |               |                     |
|                                |                         | $\frac{IT x 1.025}{\Delta}$ | KB + BMT              |                  |                        | $\frac{IL x 1.025}{\Delta}$ | KB + BML                   |                              |                           |                        |                       |                              |  |               |                     |
| 0                              | 16793,478               | 0                           | 0                     | 1,253            | 2,3380897              | 0                           | 0                          | 2818,994                     | 48,158                    | 1205,682               | 27,312                | 27,312                       | 0,229450358                              |               |                     |
| 0,902                          | 36111,271               | 14,470                      | 15,372                | 1,253            | 1,11444214             | 495,579                     | 496,481                    | 1808,033                     | 30,887                    | 1600,538               | 36,256                | 2594,217                     | 0,147163834                              |               |                     |
| 2,595                          | 40318,856               | 7,441                       | 10,035                | 1,670            | 1,44666741             | 278,716                     | 281,310                    | 2544,295                     | 43,465                    | 1728,505               | 39,155                | 5593,236                     | 0,207091423                              |               |                     |
| 4,312                          | 44410,203               | 5,204                       | 9,516                 | 0,937            | -0,1824745             | 195,906                     | 200,218                    | -337,096                     | -5,759                    | 1800,346               | 40,782                | 8787,837                     | -0,027437733                             |               |                     |
| 6,034                          | 46605,35802             | 3,934                       | 9,968                 | -0,017           | -1,9945815             | 161,921                     | 167,955                    | -3862,1779                   | -65,979                   | 1843,231               | 41,754                | 12184,499                    | -0,314359752                             |               |                     |
| 7,754237804                    | 49676,65025             | 3,260                       | 11,014                | -2,62456         | -2,9341126             | 137,699                     | 145,453                    | -5892,36578                  | -100,661                  | 1883,137               | 42,658                | 15661,916                    | -0,479605727                             |               |                     |
| <b>KB</b>                      | <b>IT</b>               | <b>BMT</b>                  | <b>KMT</b>            | <b>OB</b>        | <b>OF</b>              | <b>BML</b>                  | <b>KML</b>                 |                              |                           | <b>Aws</b>             | <b>Δa</b>             | <b>Δ</b>                     | <b>DDT</b>                               |               |                     |



Gambar 14. Hydrostatic curve

## V.2.2 Perhitungan Kurva Bonjean

Kurva Bonjean adalah kurva yang dibentuk dari luasan tiap-tiap ordinat garis air yang terbenam pada kondisi sarat air yang telah ditentukan dan diteruskan sampai ke bangunan atas (*Super Structure*) kapal. Kegunaan kurva bonjean tersebut dapat digunakan untuk perencanaan, seperti :

- perhitungan peluncuran kapal.
- perhitungan rencana kapasitas dan lain sebagainya.

Pada kurva Bonjean juga digambarkan bentuk dari ceruk haluan dan ceruk buritan kapal. Berikut tabel 5.41 sampai 5.47 perhitungan kurva Bonjean

**Tabel 48. Fungsi ½ Ordinat dan Luas**

( 0.00 - 1.356 meter)

| STATI<br>ON | SIMPS<br>ON | Lengan<br>momen | GA 0 m      |      | GA 0.678 m  |        | GA 1.356m   |       | Fungsi 1/2<br>Ordinat | Luas              |
|-------------|-------------|-----------------|-------------|------|-------------|--------|-------------|-------|-----------------------|-------------------|
|             |             |                 | 1/2 Ordinat |      | 1/2 Ordinat |        | 1/2 Ordinat |       |                       |                   |
|             |             |                 | 1           | 4    | 4           | 5      | 1           | 6     |                       |                   |
| 1           | 2           | 3               |             | 4    |             | 5      |             | 6     | 7=4+5+6               | 2 x 1/3 x h w x f |
| AP          | 1           | -10             | 0           | 0    | 0           | 0      | 0           | 0     | 0                     | 0.0000            |
| 1           | 4           | -9              | 0           | 0    | 0.83        | 3.32   | 1.253       | 1.253 | 4.573                 | 2.6249            |
| 2           | 2           | -8              | 0.39        | 0.39 | 1.9         | 7.6    | 2.539       | 2.539 | 10.529                | 6.0436            |
| 3           | 4           | -7              | 1.47        | 1.47 | 3.261       | 13.044 | 4.047       | 4.047 | 18.561                | 10.6540           |
| 4           | 2           | -6              | 2.96        | 2.96 | 4.9         | 19.6   | 5.706       | 5.706 | 28.266                | 16.2247           |
| 5           | 4           | -5              | 4.47        | 4.47 | 6.578       | 26.312 | 7.324       | 7.324 | 38.106                | 21.8728           |
| 6           | 2           | -4              | 5.61        | 5.61 | 7.693       | 30.772 | 8.383       | 8.383 | 44.765                | 25.6951           |
| 7           | 4           | -3              | 6.26        | 6.26 | 8.235       | 32.94  | 8.84        | 8.84  | 48.04                 | 27.5750           |
| 8           | 2           | -2              | 6.27        | 6.27 | 8.455       | 33.82  | 9.013       | 9.013 | 49.103                | 28.1851           |
| 9           | 4           | -1              | 6.27        | 6.27 | 8.568       | 34.272 | 9.103       | 9.103 | 49.645                | 28.4962           |
| 10          | 2           | 0               | 6.27        | 6.27 | 8.617       | 34.468 | 9.142       | 9.142 | 49.88                 | 28.6311           |
| 11          | 4           | 1               | 6.27        | 6.27 | 8.626       | 34.504 | 9.149       | 9.149 | 49.923                | 28.6558           |
| 12          | 2           | 2               | 6.6         | 6.6  | 8.626       | 34.504 | 9.149       | 9.149 | 50.253                | 28.8452           |
| 13          | 4           | 3               | 6.55        | 6.55 | 8.626       | 34.504 | 9.149       | 9.149 | 50.203                | 28.8165           |
| 14          | 2           | 4               | 6.54        | 6.54 | 8.579       | 34.316 | 9.11        | 9.11  | 49.966                | 28.6805           |
| 15          | 4           | 5               | 5.47        | 5.47 | 7.596       | 30.384 | 8.281       | 8.281 | 44.135                | 25.3335           |
| 16          | 2           | 6               | 3.86        | 3.86 | 5.943       | 23.772 | 6.785       | 6.785 | 34.417                | 19.7554           |
| 17          | 4           | 7               | 2.21        | 2.21 | 3.985       | 15.94  | 4.88        | 4.88  | 23.03                 | 13.2192           |
| 18          | 2           | 8               | 0.54        | 0.54 | 1.995       | 7.98   | 2.859       | 2.859 | 11.379                | 6.5315            |
| 19          | 4           | 9               | 0           | 0    | 0.445       | 1.78   | 1.002       | 1.002 | 2.782                 | 1.5969            |
| FP          | 1           | 10              | 0           | 0    | 0           | 0      | 0           | 0     | 0                     | 0.0000            |

Tabel 49. Fungsi 1/2 Ordinat dan Luas

GA 1,356 - 2,756 m

| STATI<br>ON | SIMPS<br>ON | Lengan<br>momen | GA 1,356 m  |       | GA 2,034 m  |        | GA 2,712 m  |       | Fungsi 1/2<br>Ordinat | Luas                         |
|-------------|-------------|-----------------|-------------|-------|-------------|--------|-------------|-------|-----------------------|------------------------------|
|             |             |                 | 1/2 Ordinat |       | 1/2 Ordinat |        | 1/2 Ordinat |       |                       |                              |
|             |             |                 | 1           | 4     | 4           | 5      | 1           | 6     |                       |                              |
| 1           | 2           | 3               |             |       |             |        |             |       | 7=4+5+6               | 2 x 1/3 x h <sub>w</sub> x E |
| AP          | 1           | -10             | 0           | 0     | 0           | 0      | 0           | 0     | 0                     | 0.0000                       |
| 1           | 4           | -9              | 1.253       | 1.253 | 1.482       | 5.928  | 1.753       | 1.753 | 8.934                 | 5.1281                       |
| 2           | 2           | -8              | 2.539       | 2.539 | 2.943       | 11.772 | 3.408       | 3.408 | 17.719                | 10.1707                      |
| 3           | 4           | -7              | 4.047       | 4.047 | 4.551       | 18.204 | 5.051       | 5.051 | 27.302                | 15.6713                      |
| 4           | 2           | -6              | 5.706       | 5.706 | 6.184       | 24.736 | 6.593       | 6.593 | 37.035                | 21.2581                      |
| 5           | 4           | -5              | 7.324       | 7.324 | 7.704       | 30.816 | 7.971       | 7.971 | 46.111                | 26.4677                      |
| 6           | 2           | -4              | 8.383       | 8.383 | 8.701       | 34.804 | 8.875       | 8.875 | 52.062                | 29.8836                      |
| 7           | 4           | -3              | 8.84        | 8.84  | 9.08        | 36.32  | 9.188       | 9.188 | 54.348                | 31.1958                      |
| 8           | 2           | -2              | 9.013       | 9.013 | 9.177       | 36.708 | 9.235       | 9.235 | 54.956                | 31.5447                      |
| 9           | 4           | -1              | 9.103       | 9.103 | 9.218       | 36.872 | 9.242       | 9.242 | 55.217                | 31.6946                      |
| 10          | 2           | 0               | 9.142       | 9.142 | 9.235       | 36.94  | 9.245       | 9.245 | 55.327                | 31.7577                      |
| 11          | 4           | 1               | 9.149       | 9.149 | 9.238       | 36.952 | 9.245       | 9.245 | 55.346                | 31.7686                      |
| 12          | 2           | 2               | 9.149       | 9.149 | 9.238       | 36.952 | 9.245       | 9.245 | 55.346                | 31.7686                      |
| 13          | 4           | 3               | 9.149       | 9.149 | 9.238       | 36.952 | 9.245       | 9.245 | 55.346                | 31.7686                      |
| 14          | 2           | 4               | 9.11        | 9.11  | 9.207       | 36.828 | 9.221       | 9.221 | 55.159                | 31.6613                      |
| 15          | 4           | 5               | 8.281       | 8.281 | 8.563       | 34.252 | 8.717       | 8.717 | 51.25                 | 29.4175                      |
| 16          | 2           | 6               | 6.785       | 6.785 | 7.281       | 29.124 | 7.596       | 7.596 | 43.505                | 24.9719                      |
| 17          | 4           | 7               | 4.88        | 4.88  | 5.501       | 22.004 | 5.912       | 5.912 | 32.796                | 18.8249                      |
| 18          | 2           | 8               | 2.859       | 2.859 | 3.518       | 14.072 | 3.961       | 3.961 | 20.892                | 11.9920                      |
| 19          | 4           | 9               | 1.002       | 1.002 | 1.46        | 5.84   | 1.792       | 1.792 | 8.634                 | 4.9559                       |
| FP          | 1           | 10              | 0           | 0     | 0           | 0      | 0           | 0     | 0                     | 0.0000                       |

Tabel 50. Fungsi 1/2 Ordinat dan Luas

GA 2,712 - 4,134 m

| STATI<br>ON | SIMPS<br>ON | Lengan<br>momen | GA 2,712 m  |       | GA 3,39 m   |        | GA 4,068 m  |       | Fungsi 1/2<br>Ordinat | Luas                         |
|-------------|-------------|-----------------|-------------|-------|-------------|--------|-------------|-------|-----------------------|------------------------------|
|             |             |                 | 1/2 Ordinat |       | 1/2 Ordinat |        | 1/2 Ordinat |       |                       |                              |
|             |             |                 | 1           | 4     | 4           | 5      | 1           | 6     |                       |                              |
| 1           | 2           | 3               |             |       |             |        |             |       | 7=4+5+6               | 2 x 1/3 x h <sub>w</sub> x E |
| AP          | 1           | -10             | 0           | 0     | 0           | 0      | 0           | 0     | 0                     | 0.0000                       |
| 1           | 4           | -9              | 1.753       | 1.753 | 2.13        | 8.52   | 2.621       | 2.621 | 12.894                | 7.4012                       |
| 2           | 2           | -8              | 3.408       | 3.408 | 4.016       | 16.064 | 4.718       | 4.718 | 24.19                 | 13.8851                      |
| 3           | 4           | -7              | 5.051       | 5.051 | 5.657       | 22.628 | 6.287       | 6.287 | 33.966                | 19.4965                      |
| 4           | 2           | -6              | 6.593       | 6.593 | 7.037       | 28.148 | 7.464       | 7.464 | 42.205                | 24.2257                      |
| 5           | 4           | -5              | 7.971       | 7.971 | 8.203       | 32.812 | 8.403       | 8.403 | 49.186                | 28.2328                      |
| 6           | 2           | -4              | 8.875       | 8.875 | 8.969       | 35.876 | 9.019       | 9.019 | 53.77                 | 30.8640                      |
| 7           | 4           | -3              | 9.188       | 9.188 | 9.217       | 36.868 | 9.222       | 9.222 | 55.278                | 31.7296                      |
| 8           | 2           | -2              | 9.235       | 9.235 | 9.245       | 36.98  | 9.245       | 9.245 | 55.46                 | 31.8340                      |
| 9           | 4           | -1              | 9.242       | 9.242 | 9.245       | 36.98  | 9.245       | 9.245 | 55.467                | 31.8381                      |
| 10          | 2           | 0               | 9.245       | 9.245 | 9.245       | 36.98  | 9.245       | 9.245 | 55.47                 | 31.8398                      |
| 11          | 4           | 1               | 9.245       | 9.245 | 9.245       | 36.98  | 9.245       | 9.245 | 55.47                 | 31.8398                      |
| 12          | 2           | 2               | 9.245       | 9.245 | 9.245       | 36.98  | 9.245       | 9.245 | 55.47                 | 31.8398                      |
| 13          | 4           | 3               | 9.245       | 9.245 | 9.245       | 36.98  | 9.245       | 9.245 | 55.47                 | 31.8398                      |
| 14          | 2           | 4               | 9.221       | 9.221 | 9.227       | 36.908 | 9.231       | 9.231 | 55.36                 | 31.7766                      |
| 15          | 4           | 5               | 8.717       | 8.717 | 8.848       | 35.392 | 8.945       | 8.945 | 53.054                | 30.4530                      |
| 16          | 2           | 6               | 7.596       | 7.596 | 7.855       | 31.42  | 8.045       | 8.045 | 47.061                | 27.0130                      |
| 17          | 4           | 7               | 5.912       | 5.912 | 6.211       | 24.844 | 6.429       | 6.429 | 37.185                | 21.3442                      |
| 18          | 2           | 8               | 3.961       | 3.961 | 4.253       | 17.012 | 4.463       | 4.463 | 25.436                | 14.6003                      |
| 19          | 4           | 9               | 1.792       | 1.792 | 2.021       | 8.084  | 2.196       | 2.196 | 12.072                | 6.9293                       |
| FP          | 1           | 10              | 0           | 0     | 0           | 0      | 0           | 0     | 0                     | 0.0000                       |

Tabel 51. Fungsi 1/2 Ordinat dan Luas

GA 4,068 - 5,512 m

| STATI<br>ON | SIMPSON | Lengan<br>momen | GA 4,068 m  |       | GA 4,746 m  |        | GA 5,424 m  |       | Fungsi 1/2<br>Ordinat | Luas                     |
|-------------|---------|-----------------|-------------|-------|-------------|--------|-------------|-------|-----------------------|--------------------------|
|             |         |                 | 1/2 Ordinat |       | 1/2 Ordinat |        | 1/2 Ordinat |       |                       |                          |
|             |         |                 | 1           | 4     | 4           | 5      | 1           | 6     |                       |                          |
| 1           | 2       | 3               |             | 4     |             | 5      |             | 6     | 7=4+5+6               | 2 x 1/3 x hwl x $\Sigma$ |
| AP          | 1       | -10             | 0           | 0     | 0.9         | 3.6    | 2.59        | 2.59  | 6.19                  | 3.5531                   |
| 1           | 4       | -9              | 2.621       | 2.621 | 3.573       | 14.292 | 4.739       | 4.739 | 21.652                | 12.4282                  |
| 2           | 2       | -8              | 4.718       | 4.718 | 5.476       | 21.904 | 6.148       | 6.148 | 32.77                 | 18.8100                  |
| 3           | 4       | -7              | 6.287       | 6.287 | 6.812       | 27.248 | 7.227       | 7.227 | 40.762                | 23.3974                  |
| 4           | 2       | -6              | 7.464       | 7.464 | 7.796       | 31.184 | 8.037       | 8.037 | 46.685                | 26.7972                  |
| 5           | 4       | -5              | 8.403       | 8.403 | 8.554       | 34.216 | 8.664       | 8.664 | 51.283                | 29.4364                  |
| 6           | 2       | -4              | 9.019       | 9.019 | 9.049       | 36.196 | 9.071       | 9.071 | 54.286                | 31.1602                  |
| 7           | 4       | -3              | 9.222       | 9.222 | 9.222       | 36.888 | 9.222       | 9.222 | 55.332                | 31.7606                  |
| 8           | 2       | -2              | 9.245       | 9.245 | 9.245       | 36.98  | 9.245       | 9.245 | 55.47                 | 31.8398                  |
| 9           | 4       | -1              | 9.245       | 9.245 | 9.245       | 36.98  | 9.245       | 9.245 | 55.47                 | 31.8398                  |
| 10          | 2       | 0               | 9.245       | 9.245 | 9.245       | 36.98  | 9.245       | 9.245 | 55.47                 | 31.8398                  |
| 11          | 4       | 1               | 9.245       | 9.245 | 9.245       | 36.98  | 9.245       | 9.245 | 55.47                 | 31.8398                  |
| 12          | 2       | 2               | 9.245       | 9.245 | 9.245       | 36.98  | 9.245       | 9.245 | 55.47                 | 31.8398                  |
| 13          | 4       | 3               | 9.245       | 9.245 | 9.245       | 36.98  | 9.245       | 9.245 | 55.47                 | 31.8398                  |
| 14          | 2       | 4               | 9.231       | 9.231 | 9.234       | 36.936 | 9.237       | 9.237 | 55.404                | 31.8019                  |
| 15          | 4       | 5               | 8.945       | 8.945 | 9.01        | 36.04  | 9.058       | 9.058 | 54.043                | 31.0207                  |
| 16          | 2       | 6               | 8.045       | 8.045 | 8.176       | 32.704 | 8.275       | 8.275 | 49.024                | 28.1398                  |
| 17          | 4       | 7               | 6.429       | 6.429 | 6.586       | 26.344 | 6.712       | 6.712 | 39.485                | 22.6644                  |
| 18          | 2       | 8               | 4.463       | 4.463 | 4.624       | 18.496 | 4.76        | 4.76  | 27.719                | 15.9107                  |
| 19          | 4       | 9               | 2.196       | 2.196 | 2.339       | 9.356  | 2.467       | 2.467 | 14.019                | 8.0469                   |
| FP          | 1       | 10              | 0           | 0     | 0           | 0      | 0           | 0     | 0                     | 0.0000                   |

Tabel 52. Fungsi 1/2 Ordinat dan Luas

GA 5,424 - 6,89 m

| STATI<br>ON | SIMPSON | Lengan<br>momen | GA 5,424 m  |       | GA 6,102 m  |        | GA 6,78 m   |       | Fungsi 1/2<br>Ordinat | Luas                     |
|-------------|---------|-----------------|-------------|-------|-------------|--------|-------------|-------|-----------------------|--------------------------|
|             |         |                 | 1/2 Ordinat |       | 1/2 Ordinat |        | 1/2 Ordinat |       |                       |                          |
|             |         |                 | 1           | 4     | 4           | 5      | 1           | 6     |                       |                          |
| 1           | 2       | 3               |             | 4     |             | 5      |             | 6     | 7=4+5+6               | 2 x 1/3 x hwl x $\Sigma$ |
| AP          | 1       | -10             | 2.59        | 2.59  | 3.86        | 15.44  | 4.3         | 4.3   | 22.33                 | 12.8174                  |
| 1           | 4       | -9              | 4.739       | 4.739 | 5.546       | 22.184 | 5.964       | 5.964 | 32.887                | 18.8771                  |
| 2           | 2       | -8              | 6.148       | 6.148 | 6.683       | 26.732 | 7.01        | 7.01  | 39.89                 | 22.8969                  |
| 3           | 4       | -7              | 7.227       | 7.227 | 7.555       | 30.22  | 7.767       | 7.767 | 45.214                | 25.9528                  |
| 4           | 2       | -6              | 8.037       | 8.037 | 8.219       | 32.876 | 8.338       | 8.338 | 49.251                | 28.2701                  |
| 5           | 4       | -5              | 8.664       | 8.664 | 8.748       | 34.992 | 8.804       | 8.804 | 52.46                 | 30.1120                  |
| 6           | 2       | -4              | 9.071       | 9.071 | 9.089       | 36.356 | 9.101       | 9.101 | 54.528                | 31.2991                  |
| 7           | 4       | -3              | 9.222       | 9.222 | 9.222       | 36.888 | 9.222       | 9.222 | 55.332                | 31.7606                  |
| 8           | 2       | -2              | 9.245       | 9.245 | 9.245       | 36.98  | 9.245       | 9.245 | 55.47                 | 31.8398                  |
| 9           | 4       | -1              | 9.245       | 9.245 | 9.245       | 36.98  | 9.245       | 9.245 | 55.47                 | 31.8398                  |
| 10          | 2       | 0               | 9.245       | 9.245 | 9.245       | 36.98  | 9.245       | 9.245 | 55.47                 | 31.8398                  |
| 11          | 4       | 1               | 9.245       | 9.245 | 9.245       | 36.98  | 9.245       | 9.245 | 55.47                 | 31.8398                  |
| 12          | 2       | 2               | 9.245       | 9.245 | 9.245       | 36.98  | 9.245       | 9.245 | 55.47                 | 31.8398                  |
| 13          | 4       | 3               | 9.245       | 9.245 | 9.245       | 36.98  | 9.245       | 9.245 | 55.47                 | 31.8398                  |
| 14          | 2       | 4               | 9.237       | 9.237 | 9.238       | 36.952 | 9.24        | 9.24  | 55.429                | 31.8162                  |
| 15          | 4       | 5               | 9.058       | 9.058 | 9.095       | 36.38  | 9.125       | 9.125 | 54.563                | 31.3192                  |
| 16          | 2       | 6               | 8.275       | 8.275 | 8.353       | 33.412 | 8.411       | 8.411 | 50.098                | 28.7563                  |
| 17          | 4       | 7               | 6.712       | 6.712 | 6.817       | 27.268 | 6.877       | 6.877 | 40.857                | 23.4519                  |
| 18          | 2       | 8               | 4.76        | 4.76  | 4.878       | 19.512 | 4.934       | 4.934 | 29.206                | 16.7642                  |
| 19          | 4       | 9               | 2.467       | 2.467 | 2.578       | 10.312 | 2.642       | 2.642 | 15.421                | 8.8517                   |
| FP          | 1       | 10              | 0           | 0     | 0           | 0      | 0           | 0     | 0                     | 0.0000                   |

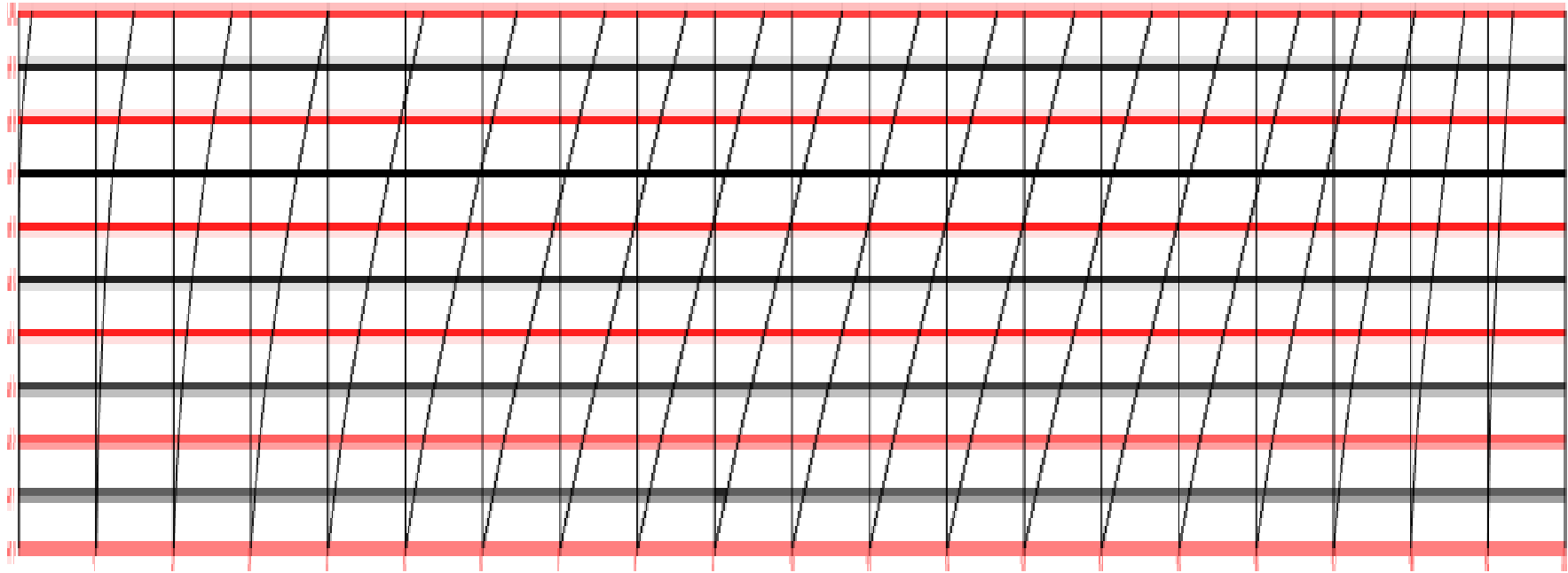
**Tabel 53. Bonjean curve**

| STATION | GARIS AIR   |                 |                 |                 |                |
|---------|-------------|-----------------|-----------------|-----------------|----------------|
|         | 0 - 1,356 m | 1,356 - 2,712 m | 2,712 - 4,068 m | 4,068 - 5,424 m | 5,424 - 6,78 m |
| AP      | 0.000       | 0.000           | 0.000           | 3.553           | 12.817         |
| 1       | 2.625       | 5.128           | 7.401           | 12.428          | 18.877         |
| 2       | 6.044       | 10.171          | 13.885          | 18.810          | 22.897         |
| 3       | 10.654      | 15.671          | 19.496          | 23.397          | 25.953         |
| 4       | 16.225      | 21.258          | 24.226          | 26.797          | 28.270         |
| 5       | 21.873      | 26.468          | 28.233          | 29.436          | 30.112         |
| 6       | 25.695      | 29.884          | 30.864          | 31.160          | 31.299         |
| 7       | 27.575      | 31.196          | 31.730          | 31.761          | 31.761         |
| 8       | 28.185      | 31.545          | 31.834          | 31.840          | 31.840         |
| 9       | 28.496      | 31.695          | 31.838          | 31.840          | 31.840         |
| 10      | 28.631      | 31.758          | 31.840          | 31.840          | 31.840         |
| 11      | 28.656      | 31.769          | 31.840          | 31.840          | 31.840         |
| 12      | 28.845      | 31.769          | 31.840          | 31.840          | 31.840         |
| 13      | 28.817      | 31.769          | 31.840          | 31.840          | 31.840         |
| 14      | 28.680      | 31.661          | 31.777          | 31.802          | 31.816         |
| 15      | 25.333      | 29.418          | 30.453          | 31.021          | 31.319         |
| 16      | 19.755      | 24.972          | 27.013          | 28.140          | 28.756         |
| 17      | 13.219      | 18.825          | 21.344          | 22.664          | 23.452         |
| 18      | 6.532       | 11.992          | 14.600          | 15.911          | 16.764         |
| 19      | 1.597       | 4.956           | 6.929           | 8.047           | 8.852          |
| FP      | 0.000       | 0.000           | 0.000           | 0.000           | 0.000          |

**Tabel 54. Bonjean curve**

| STATION | TOTAL AREA GARIS AIR |             |             |             |            |
|---------|----------------------|-------------|-------------|-------------|------------|
|         | 0 - 1,356 m          | 0 - 2,712 m | 0 - 4,068 m | 0 - 5,424 m | 0 - 6,78 m |
| AP      | 0.000                | 0.000       | 0.000       | 3.553       | 16.370     |
| 1       | 2.625                | 7.753       | 15.154      | 27.582      | 46.460     |
| 2       | 6.044                | 16.214      | 30.099      | 48.909      | 71.806     |
| 3       | 10.654               | 26.325      | 45.822      | 69.219      | 95.172     |
| 4       | 16.225               | 37.483      | 61.708      | 88.506      | 116.776    |
| 5       | 21.873               | 48.341      | 76.573      | 106.010     | 136.122    |
| 6       | 25.695               | 55.579      | 86.443      | 117.603     | 148.902    |
| 7       | 27.575               | 58.771      | 90.500      | 122.261     | 154.021    |
| 8       | 28.185               | 59.730      | 91.564      | 123.404     | 155.243    |
| 9       | 28.496               | 60.191      | 92.029      | 123.869     | 155.708    |
| 10      | 28.631               | 60.389      | 92.229      | 124.068     | 155.908    |
| 11      | 28.656               | 60.424      | 92.264      | 124.104     | 155.944    |
| 12      | 28.845               | 60.614      | 92.454      | 124.293     | 156.133    |
| 13      | 28.817               | 60.585      | 92.425      | 124.265     | 156.104    |
| 14      | 28.680               | 60.342      | 92.118      | 123.920     | 155.737    |
| 15      | 25.333               | 54.751      | 85.204      | 116.225     | 147.544    |
| 16      | 19.755               | 44.727      | 71.740      | 99.880      | 128.636    |
| 17      | 13.219               | 32.044      | 53.388      | 76.053      | 99.505     |
| 18      | 6.532                | 18.524      | 33.124      | 49.035      | 65.799     |
| 19      | 1.597                | 6.553       | 13.482      | 21.529      | 30.381     |
| FP      | 0.000                | 0.000       | 0.000       | 0.000       | 0.000      |





Gambar 15. Bonjean curve

## V.4 Hambatan, propulsi, dan daya mesin

### V.4.1 Perhitungan hambatan

Perhitungan hambatan dan tahanan menggunakan metode *Guldhammer* dan *Harvald*.

Ketentuan metode *Harvald* adalah diagram  $C_R$  yang disajikan adalah untuk kapal standar dengan harga beam draft  $B/T = 2,5$  dan dengan batasan sebagai berikut:

- Rentang kecepatan pada harga  $Fr(=Fn) = 0,15 \sim 0,45$
- Harga *length displacement*  $L/\nabla^{1/3} = 4,0 \sim 8,0$
- Harga I prismatic coefficient  $C_p(= \varphi) = 0,50 \sim 0,80$

**Tabel 55. Tabel Fn dan Rn**

| Froude Number (Fn)                |   |        |      | Reynold Number (Rn)        |   |                        |     |
|-----------------------------------|---|--------|------|----------------------------|---|------------------------|-----|
| $Fn = Vs / \sqrt{(g \times Lwl)}$ |   |        |      | $Rn = (Vs \times Lwl) / v$ |   |                        |     |
| dimana :                          |   |        |      | dimana :                   |   |                        |     |
| vs                                | = | 14,00  | Knot | Vs                         | = | 7,20                   | m/s |
|                                   | = | 7,2016 | m/s  | Lwl                        | = | 129,71                 | m   |
| g                                 | = | 9,81   | Knot | v                          | = | viskositas air laut    |     |
| Lwl                               | = | 129,71 | m    |                            | = | $1,188 \times 10^{-6}$ |     |
| maka :                            |   |        |      | maka :                     |   |                        |     |
| Fn                                | = | 0,20   |      | Rn                         | = | 786295905,72           |     |

Dimana semua ketentuan kapal rancangan sesuai dengan ketentuan metode *Harvald* :

|                  |         |            |
|------------------|---------|------------|
| Fn               | : 0,20  | (memenuhi) |
| $L/\nabla^{1/3}$ | : 5,180 | (memenuhi) |
| $C_p$            | : 0,77  | (memenuhi) |

Koreksi CR, diagram *Guldhammer* dan *Harvald*

**Tabel 56. Koreksi CR 5**

| Berdasarkan diagram CR 5 |      |           |
|--------------------------|------|-----------|
| $L/\nabla^{1/3}_{(2)}$   | 5    | $10^3 CR$ |
| Fn                       | 0,20 | 1,1       |
| CP                       | 0,77 |           |

$$CR = 10^3 CR/1210$$

$$CR = 0,0011$$

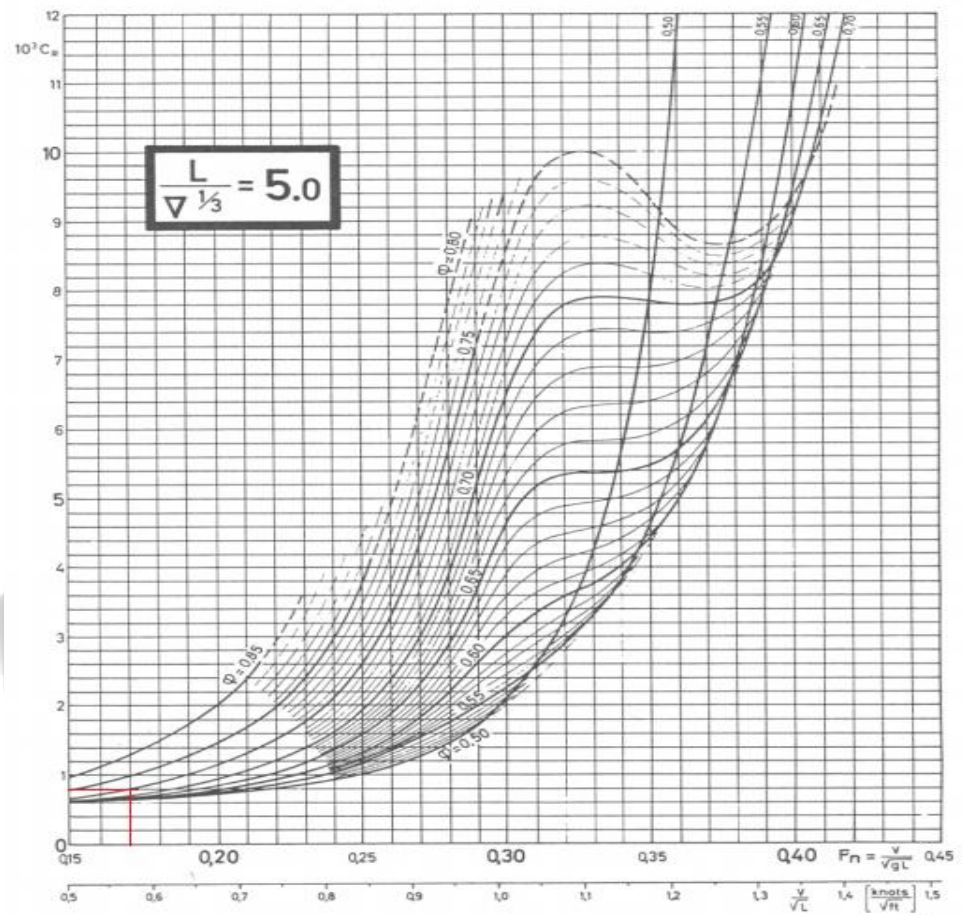


Figure 5.5.7. Residuary resistance coefficient versus speed-length ratio for different values of longitudinal prismatic coefficient.  $L/V^{1/3} = 5.0$ .

Gambar 16. Grafik CR

Koreksi CR, Ratio B/T

**Ratio B/T kapal Rancangan**

|     |   |       |   |
|-----|---|-------|---|
| B   | = | 18,49 | m |
| T   | = | 8,61  | m |
| B/T | = | 2,15  |   |

**Ratio B/T kapal Standar**

|     |   |      |   |
|-----|---|------|---|
| B/T | = | 2,50 | m |
|-----|---|------|---|

**Koreksi Ratio B/T**

$$\text{Koreksi B/T} = 0.16(B/T - 2.5)$$

|                    |   |              |
|--------------------|---|--------------|
| $10^3$ Koreksi B/T | = | -0,056399535 |
| Koreksi B/T        | = | -5,64E-05    |

Koreksi CR, letak LVB

**Tabel 57. Koreksi CR, Letak LVB**

| Letak LCB   |      |           |      |
|---|------|-----------|------|
| Fn  | 0,20 | CP        | 0,77 |
| LCB   |      | 2,03      | %    |
| LCB <sub>standard</sub>   |      | 1,8       | %    |
| $\Delta\text{LCB} = \text{LCB} - \text{LCB}_{\text{standard}}$                                |      |           | 0,23 |
| Factor ( $\delta 10^3 \text{CR} / \sum \text{LCB}$ )  |      | 0,01      |      |
| $\text{CR} = (\delta 10^3 \text{CR} / \sum \text{LCB}) \times (\Delta\text{LCB}) \times 10^3$ |      |           |      |
| CR  | =    | 0,0000023 |      |

Koreksi CR, bentuk penampang badan kapal

**Tabel 58. Penampang Badan Kapal**

| Bentuk Penampang Badan Kapal |            |            |                  |
|------------------------------|------------|------------|------------------|
| Haluan                       | extrim 'U' | extrim 'V' | $\times 10^{-3}$ |
|                              | -0,1       | 0,1        |                  |
| Buritan                      | extrim 'U' | extrim 'V' |                  |
|                              | -0,1       | 0,1        |                  |

Koreksi tersebut diatas berlaku untuk rentang  $Fn = 0,20 \sim 0,25$

Sedangkan  $f_n$  kapal rancangan adalah 0,17 jadi berdasarkan rentang  $f_n$  di atas tidak diperlukan

Koreksi CR, bulbous bow

**Tabel 59. Koreksi CR, bulbous bow**

|        |      |
|--------|------|
| $F_n'$ | 0,20 |
| CP     | 0,77 |

Tabel-9.1 Koreksi terhadap  $10^3 C_R$  karena adanya *bulbous bow* <sup>(8)</sup>

| $\phi$ \ Fr | 0,15 | 0,18 | 0,21 | 0,24 | 0,27 | 0,30 | 0,33 | 0,36 |
|-------------|------|------|------|------|------|------|------|------|
| 0,50        | -    | -    | +0,2 | 0    | -0,2 | -0,4 | -0,4 | -0,4 |
| 0,60        | -    | -    | +0,2 | 0    | -0,2 | -0,3 | -0,3 | -    |
| 0,70        | -    | +0,2 | 0    | -0,2 | -0,3 | -0,3 | -    | -    |
| 0,80        | +0,1 | 0    | -0,2 | -    | -    | -    | -    | -    |

$$10^3 CR = 0$$

$$CR = 0$$

$$10^3 CR = 0$$

$$CR = 0$$

Koreksi CR, *appendages*

**Tabel 60. Koreksi CR, *Appendages***

| Appendages    |  |
|---------------|--|
| Bossing       | 3% ~ 5%  |
|               | bagi Kapal 'gendut'                            |
| Shaft Bracket | 5% ~ 8%  |
|               | bagi Kapal 'lansing'                           |
| Daun Kemudi   | tidak ada koreksi, karena kapal standard telah |
| Bilge Keel    | tidak ada koreksi, karena kapal standard telah |

$$10^3 CR = 3\%$$

$$CR = 0,00003$$

CR total dari koreksi yang di atas

$$CR = 0,0010759$$

Menghitung Coefisien Tahanan Gesek ( $C_f$ ) dengan rumus ITTC 1957

Menghitung CA metode *Guldhammer & Harvald*

$$L_{wl} = 129,71 \text{ m}$$

|  |   |
|--|---|
| Kapal dengan panjang $L_{wl} \leq 100 \text{ m}$ | $\rightarrow C_A = 0,40 \cdot 10^{-3}$  |
| $L_{wl} = 150 \text{ m}$                         | $\rightarrow C_A = 0,20 \cdot 10^{-3}$  |
| $L_{wl} = 200 \text{ m}$                         | $\rightarrow C_A = 0$                   |
| $L_{wl} = 250 \text{ m}$                         | $\rightarrow C_A = -0,20 \cdot 10^{-3}$ |
| $L_{wl} = 300 \text{ m}$                         | $\rightarrow C_A = -0,30 \cdot 10^{-3}$ |

**Gambar 17. Menentukan CA Metode *Guldhammer & Harvald***

$$C_A = 0,0002$$

Menghitung CAA (tahanan udara) metode *Guldhammer & Harvald*

$$C_{AA} = 0,07x[10]^{(-3)}$$

$$C_{AA} = 0,00007$$

Menghitung CAS (tahanan kemudi) metode *Guldhammer & Harvald*

$$C_{AS} = 0,04x[10]^{(-3)}$$

$$C_{AS} = 0,00004$$

Menghitung koefisien tahanan Total CT

$$C_T = C_r + C_f + C_A + C_{AA} + C_{AS}$$

$$C_T = 0,002963217$$

Menghitung RT metode *Guldhammer & Harvald*

$$R_T = C_T \cdot \frac{1}{2} \cdot \gamma \cdot S \cdot V^2$$

$$R_T = 291,6687342 \text{ kN}$$

Menghitung RT dinas metode *Guldhammer & Harvald*

$$R_T \text{ dinas} = R_T + 15\% R_T$$

$$= 335,4190443 \text{ Kn}$$

#### IV.4.1 Perhitungan daya mesin

Perhitungan *Effective Horse Power* (EHP)

$$\text{EHP} = R_{tdinas} \times V_s$$

$$R_{tdinas} = 335,41904432 \text{ Kn}$$

$$V_s = 7,2016 \text{ m/s}$$

Maka

$$\text{EHP} = 2415,55379 \text{ KW}$$

$$= 3284,232828 \text{ HP}$$

Perhitungan *Wake Friction* (w)

$$W = 0.5 C_b - 0.05$$

$$W = 0,33$$

Perhitungan *Thrust Deduction Factor* (t)

$$t = k - w$$

dimana nilai k adalah antara 0.7-0.9 , diambil harga K: 0,8

$$t = 0,8 - 0,33$$

$$t = 0,264$$

Perhitungan *Speed of Advance* (Va)

$$V_a = (1 - W) V_s$$

$$V_a = 9,38 \text{ knot}$$

Perhitungan Efisiensi Propulsif

- Efisiensi Relatif Rotatif ( $\eta_{rr}$ ) Nilai dari  $\eta_{rr}$  untuk single screw ship antara 1,02 – 1,05. Diambil : 1,05
- Efisiensi Propulsi ( $\eta_o$ ) efficiency dari propeller pada saat dilakukan open water test. nilainya antara 40-70%,diambil : 50%  $\eta_o = 0,5$
- Efisiensi Lambung ( $\eta_H$ )
 
$$\eta_H = (1 - t) / (1 - w)$$

$$\eta_H = (1 - 0,264) / (1 - 0,33)$$

$$\eta_H = 1,098$$
- Perhitungan Koefisien Propulsi ( $P_c$ )
 
$$P_c = \eta_{rr} \times \eta_o \times \eta_H$$

$$P_c = 1,05 \times 0,5 \times 1,098$$

$$P_c = 0,576$$

Perhitungan *Delivered Horse Power* (DHP)

$$DHP = EHP / P_c$$

$$DHP = 3284,23 / 0,576 \text{ Hp}$$

$$DHP = 2589,867971 \text{ Hp}$$

Perhitungan *Thrust Horse Power* (THP)

$$THP = EHP / \eta_H$$

$$THP = 3284,23 / 1,098$$

$$THP = 2989,722$$

Perhitungan *Shaft Horse Power* (SHP)

Untuk kapal yang kamar mesinnya terletak di bagian belakang akan mengalami *losses* sebesar 2%, sedangkan pada kapal yang kamar mesinnya pada daerah midship kapal mengalami *losses* sebesar 3%. Pada perencanaan ini kamar mesin di bagian belakang sehingga mengalami *losses* atau efisiensi transmisi porosnya ( $\eta_{\eta b}$ ) sebesar = 98%

$$SHP = DHP / \eta_{\eta b}$$

$$SHP = 5694,71 / 0,98$$

$$SHP = 2642,72242 \text{ Hp}$$

Perhitungan Power Main Engine

- BHP Scr

Adanya pengaruh efisiensi roda sistem gigi transmisi ( $\eta_G$ ), pada tugas ini memakai sistem roda gigi reduksi tunggal atau *single reduction gears* dengan loss 2% untuk arah maju sehingga  $\eta_G = 98\%$

$$BHP \text{ Scr} = SHP / \eta_G$$

$$BHP \text{ Scr} = 5810,928 / 0,98$$

$$BHP \text{ Scr} = 5929,519 \text{ HP}$$



- BHP mcr

HP mcr adalah daya *output* dari motor penggerak keluaran pabrik (*Maximum Continuous Rating = 100%*) . Dimana besarnya 80% - 85%, maka daya yang diambil sebesar 85%. Sehingga cukup dengan daya 85% dari MCR kapal dapat bergerak dengan kecepatan (vs). Daya BHP SCR diambil 85%

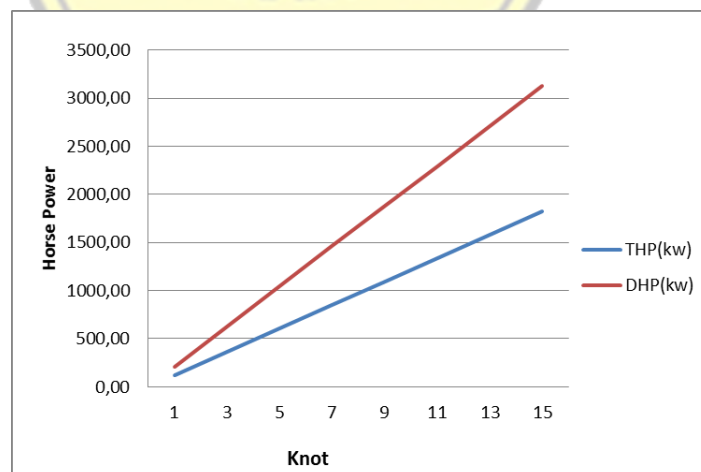
$$\text{BHP Mcr} = \text{BHP scr} / 85\%$$

$$\text{BHP Mcr} = 5929,519 / 85\%$$

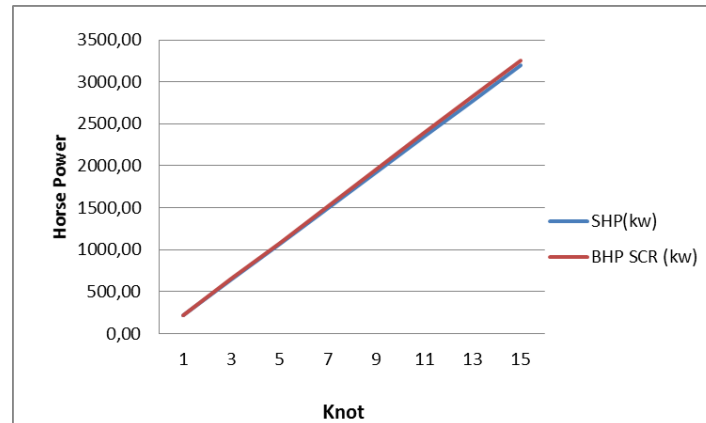
$$\begin{aligned} \text{BHP Mcr} &= 6975,904 \text{ HP} \\ &= 5130,77 \text{ KW} \end{aligned}$$



**Gambar 18. Grafik EHP dan BHP**



**Gambar 19. Grafik THP dan DHP**



**Gambar 20. Grafik SHP dan BHP SCR**

### *Main Engine & Reduction Gear*

Dari perhitungan diatas didapatkan data mesin dibawah ini

**MaK 7 M 43 C7000HP @500**  
**Model: MaK 7 M 43 C**  
**Brand: MaK**  
**Power 7000 HP**  
**Rated Speed 500 r/min**

**Product Specifications**  
**Stroke 610 mm (24.02in)**  
**Bore 430 mm (16.93in)**  
**Height 6145 mm (241.93in)**  
**Width 2905 mm (114.37in)**  
**Length 9068 mm (357.01in)**  
**Power 7000 HP (5219.20kw)**  
**Weight 235895 kg (520059.45lbs)**  
**Displacement 620000 cm<sup>3</sup> (620.00L, 37834.72in<sup>3</sup>)**  
**Rated Speed 500 r/min**

**Gambar 21. Data Main Engine**

**Tabel 61. Pemilihan Main Engine**

| Pemilihan Main Engine         |                         |                 |
|-------------------------------|-------------------------|-----------------|
| Name                          | Mak 8 M 43 C8000HP @500 |                 |
| Merk                          | Mak                     |                 |
| Type                          | Mak 8 M 43 C            |                 |
| Stroke                        | 610                     | mm              |
| Bore                          | 430                     | mm              |
| Height                        | 6145                    | mm              |
| Width                         | 2905                    | mm              |
| Length                        | 9798                    | mm              |
| Power                         | 8179,9591               | HP              |
|                               | 6000                    | KW              |
| Cylinders Arrangement /Number | -                       |                 |
| Weight                        | 251327                  | Kg              |
| Displacement                  | 7090000                 | cm <sup>3</sup> |
| Rated Speed                   | 500                     | r/min           |

**Tabel 62. Reduction Gearbox**

| Pemilihan Reduction Gearbox |             |     |
|-----------------------------|-------------|-----|
| Name                        | ZF W11250NC |     |
| Merk                        | ZF          |     |
| Type                        | W63000 NC   |     |
| Ratio                       | 5.960       |     |
| Max. Input Power            | 2193        | HP  |
|                             | 1635        | KW  |
| Max. Input RPM              | 1900        | RPM |

## V.5 Rencana Umum, *Tonnage*, lambung timbul dan *Capacity plan*

### V.5.1 Definisi Rencana Umum

Rencana umum dari sebuah kapal dapat didefinisikan sebagai perancangan di dalam penentuan atau penandaan dari semua ruangan yang dibutuhkan, ruangan yang dimaksud seperti ruang muat dan ruang kamar mesin dan akomodasi, dalam hal ini disebut *superstructure* (bangunan atas). Di samping itu juga direncanakan penempatan peralatan-peralatan dan letak jalan-jalan dan beberapa sistem dan perlengkapan lainnya.

Ada 4 bagian/ karakteristik rencana umum menurut *Ship Design and Construction* :

1. Penentuan lokasi ruang muat
2. Penentuan batas-batas ruang termasuk kamar pribadi
3. Penentuan dan pemilihan perlengkapan kamar mandi
4. Penentuan jalan atau lintasan yang cukup

Langkah pertama yang dihadapi dalam membuat rencana umum adalah penentuan lokasi ruangan dan batas dari lambung kapal dan bangunan atas, ruangan yang di maksud :

1. Ruang kamar mesin
2. Ruang muat
3. Crew, penumpang, ruangan pada crew yang utama
4. Tangki-tangki
5. Beberapa ruangan lainnya

Pada saat yang bersamaan juga ditentukan kebutuhan lain seperti :

1. Sekat kedap masing-masing ruangan
2. Stabilitas yang cukup
3. Struktur konstruksi
4. Penyediaan jalan yang cukup

Rencana umum adalah suatu proses yang berangsur-angsur di susun dan ini dari percobaan, penelitian, dan masukan dari data-data kapal yang sudah ada (pembanding). Informasi yang mendukung rencana umum :

1. Penentuan besarnya volume ruang muat, tipe dan jenis muatan yang akan di muat
2. Metode dan sistem bongkar muat
3. Volume ruangan untuk ruangan kamar mesin yang ditentukan dari tipe mesin dan dimensi mesin
4. Penentuan tangki-tangki terutama perhitungan volume seperti tangki untuk minyak, *ballast*, maupun pelumas mesin

5. Penentuan volume ruangan akomodasi jumlah crew, penumpang, dan standard akomodasi
6. Pembagian sekat melintang
7. Penentuan dimensi kapal
8. Lines Plan

Rencana umum dari sebuah kapal merupakan gambaran penyusunan ruangan-ruangan, peralatan-peralatan serta pintu-pintu yang tepat. Langkah-langkah dalam penyusunan rencana umum dari sebuah kapal antara lain pembagian ruangan-ruangan utama, pengaturan batas-batas tiap ruangan, penempatan perlengkapan-perengkapan di dalam ruangan serta penyusunan pintu-pintu pada tiap ruangan.

Dalam merancang sebuah kapal tidak dapat dihindari adanya berbagai macam kepentingan yang akan saling bertentangan dan itu akan didapatkan pada penyusunan rencana umum ini.

Efisiensi dari suatu kapal salah satunya ditentukan oleh penyusunan ruangan-ruangan yang tepat serta penempatan pintu-pintu yang efektif di antara ruangan-ruangan tersebut. Dapat dikatakan bahwa penyusunan ruangan-ruangan yang baik akan dapat meningkatkan nilai guna dan nilai ekonomis dari sebuah kapal. Hal ini mempengaruhi pada konstruksi dan biaya operasional kapal tersebut.

Langkah pertama untuk pembuatan rencana umum adalah pembagian ruangan-ruangan utama dalam kapal, misalnya pembagian ruangan pada lambung kapal untuk ruang muat, kamar mesin dan tangki-tangki serta pembagian ruangan-ruangan pada bangunan atas untuk ruangan akomodasi dan lain-lain

Selain itu terdapat beberapa hal yang perlu diperhatikan dalam menyusun rencana umum, antara lain :

1. Besarnya volume ruang muat didasarkan pada jenis dan jumlah muatan

2. Cara penyimpanan muatan dalam ruang palka dan sistem penanganan muatan (Cargo Handling)
3. Besarnya volume ruang akomodasi didasarkan pada jumlah anak buah kapal dan penumpang serta standard ruang akomodasi
4. Besarnya volume tangki terutama tangki *ballast* dan tangki bahan bakar didasarkan pada tipe mesin yang digunakan dan jalur pelayarannya
5. Standar pembagian sekat baik sekat melintang maupun sekat memanjang
6. Ukuran utama kapal
7. Gambar Rencana Garis

Permasalahan dalam penyusunan rencana umum biasanya tergantung dari tipe kapal yang direncanakan. Namun pada dasarnya pembuatan rencana umum untuk semua tipe memiliki kesamaan dalam hal-hal tertentu seperti dalam penyusunan ruangan akomodasi dan daya mesin meskipun untuk kapal yang berbeda akan menyebabkan terjadinya perbedaan kapasitas.

### V.5.2 Perhitungan Jumlah Crew

Dengan komposisi sebagai berikut (dari *Ship Resistance and Propulsion*, hal 168) Dalam penentuan jumlah crew maka dapat di hitung dengan rumus :

$$Z = C_{st} \cdot \{ C_{dk} (LBH \cdot 35/10^5)^{1/6} + C_{eng} (BHP/10^3)^{1/5} \} + \text{Cadets}$$

$$C_{st} = \text{Coefisien Steward Dept} \quad 1,2 - 1,33$$

$$C_{dk} = \text{Coefisien Deck Dept} \quad 11,5 - 14,5$$

$$C_{eng} = \text{Coefisien Engine Dept} \quad 8,5 - 11,0 \quad \text{Diesel}$$

$$11,0 - 15 \quad \text{Turbine Single}$$

$$13,73 - 16,5 \quad \text{Turbine Double}$$

$$C_{det} = \text{Cadangan} = 1,00$$

Dari rumus di atas didapatkan

$$Z = C_{st} \cdot \{ C_{dk} (LBH \cdot 35/10^5)^{1/6} + C_{eng} (BHP/10^3)^{1/5} \} + \text{Cadets}$$

$$Z = 1,2 \cdot \{ 11,5 (27079,82 \times 35/10^5)^{1/6} + 8,5 (7000/10^3)^{1/5} \} + 1$$

$$Z = 36,32 = 36 \text{ orang}$$

Pembagian/ susunan *Crew* Kapal

Susunan *Crew* Kapal

Secara garis besar tugas-tugas dari *crew* kapal dapat dikelompokkan pada:

1. *Deck Department*, dipimpin oleh Mualim I, bertanggung jawab terhadap navigasi, peralatan geladak, bongkar muat di atas kapal.
2. *Engine Department*, dipimpin oleh Kepala Kamar Mesin (KKM), bertanggung jawab terhadap jalannya mesin induk, mesin bantu, ketel dan seluruh instalasi mesin di atas kapal.
3. *Catering Department*, dipimpin oleh *Chief Steward*, bertanggung jawab pada kelancaran pelayanan makanan, pelayanan kamar, dan pekerjaan lain di atas kapal.

Susunan Anak Buah Kapal

- |    |                          |   |                |
|----|--------------------------|---|----------------|
| a. | Nahkoda / Captain        | = |                |
|    | 1 Orang                  |   |                |
| b. | Deck Departement         |   |                |
| 1. | Mualim                   | = | 2 Orang        |
| 2. | Juru Mudi                | = | 4 Orang        |
| 3. | Kelasi                   | = | 4 Orang        |
| 4. | Radio Officer            | = | <u>2 Orang</u> |
|    | Jumlah                   | = | 13 Orang       |
| c. | Engine Departement       |   |                |
| 1. | Kepala Kamar Mesin (KKM) | = | 1 Orang        |
| 2. | Masinis                  | = | 2 Orang        |
| 3. | Electriciant             | = | 2 Orang        |
| 4. | Pump Man                 | = | 2 Orang        |
| 5. | Oil Man                  | = | 2 Orang        |
| 6. | Engine Crews             | = | 3 Orang        |
| 7. | Filler                   | = | <u>1 Orang</u> |
|    | Jumlah                   | = | 13 Orang       |
| d. | Catering Departement     |   |                |

|                                     |         |                |
|-------------------------------------|---------|----------------|
| 1. Koki                             | =       | 4 Orang        |
| 2. Pembantu Koki                    | =       | 2 Orang        |
| 3. Pelayan                          | =       | <u>4 Orang</u> |
|                                     | Jumlah= | 10 Orang       |
| Maka jumlah seluruh anak buah kapal | =       | 36 Orang       |

### V.5.3 Perhitungan LWT, DWT, Payload dan TEU's

Berat baja kapal (Wst)

$$\begin{aligned}
 Wst &= K \times E1,36 \\
 K &= 0,029 \sim 0,037 \text{ di ambil harga } K = 0,035 \\
 E &= Lpp (B + T) + 0,85 Lpp (H - T) + 0,85 \Sigma lh \\
 \Sigma lh &= (l1 \times h1) + (l2 \times h2) \\
 h1 &= \text{tinggi forecastle} = 2,4 \text{ m} \\
 l1 &= \text{panjang forecastle} = 10,26 \text{ m} \\
 h2 &= \text{tinggi poop} = 2,4 \text{ m} \\
 l2 &= \text{panjang poop} = 25,7 \text{ m} \\
 \Sigma lh &= 86,16 \\
 E &= 2529,54 \text{ ton}
 \end{aligned}$$

Berat outfit dan akomodasi (Woa)

Rumus Katsoulis (*Lectures on ship design and ship theory*)

$$Woa = K \times L1,3 \times B0,8 \times H0,3$$

$$K = 0,045 \text{ untuk Tanker/Bulker}$$

$$K = 0,065 \text{ untuk General Cargo/Container}$$

$$Woa = 463,7291$$

atau memakai rumus ini

$$Woa = 0,4 \times Lpp \times B$$

$$Woa = 460,0477$$

Berat instalasi permesinan (Wep)

Rumus Watson RINA 1977



$$\begin{aligned}
 W_m &= W_{me} + W_{pe} \\
 W_m &= \text{berat total permesinan} \\
 W_{pe} &= \text{berat main engine} \\
 e &= \text{berat remainder} = 0,56 \times \text{BHP}_{0,7} \\
 W_m &= (0,56 \times \text{BHP}_{0,7}) + W_{me} \\
 W_m &= 193,066 \quad \text{ton}
 \end{aligned}$$

Berat cadangan (Wres)

Wres diperlukan untuk menghindari kesalahan perhitungan, dll

$$\begin{aligned}
 W_{res} &= (2 \sim 3) \% \text{ LWT} \\
 \text{LWT} &= W_{st} + W_{oa} + W_m \\
 \text{LWT} &= 2338,657 \quad \text{ton} \\
 W_{res} &= 58,46643 \quad \text{ton}
 \end{aligned}$$

Maka

$$\begin{aligned}
 \text{LWT total} &= W_{st} + W_{oa} + W_{pe} + W_{res} \\
 \text{LWT total} &= 2397,124 \quad \text{ton}
 \end{aligned}$$

Dari perhitungan di atas maka kita dapat menentukan DWT kapal, yaitu :

$$\begin{aligned}
 \text{DWT} &= D - \text{LWT} \\
 \text{DWT} &= 10500 \quad \text{ton}
 \end{aligned}$$

Komponen-komponen DWT

Berat Fuel Oil

$$W_{fo} = (P_{me} \times b_{me}) \times \frac{S}{V_s} \times 10^{-6} \times (1,1 - 1,3)$$

$$\begin{aligned}
 P_{me} &= \text{BHP motor induk} &= & 7000 \quad \text{hp} \\
 b_{me} &= \text{SFOC motor induk} &= & 197 \\
 R &= \text{Radius pelayaran} &= & 1064 \quad \text{mil} \\
 x &= \text{harga tambahan terdiri dari} \\
 &\cdot \text{Sisa tangki yang tidak bisa di sedot} \\
 &\text{Cadangan kecepatan percobaan} \\
 &\text{Waktu tunggu} \\
 x &= 1,1 \sim 1,3 \text{ di ambil} & & 1,2 \\
 W_{fo} &= 164,5521 \quad \text{ton}
 \end{aligned}$$

## Berat Fuel Oil Auxillary Engine (Wae)

$$\begin{aligned} W_{ae} &= (0,1 \sim 0,2) W_{fo} \\ W_{ae} &= 0,16 \times W_{fo} \\ W_{ae} &= 26,32833 \quad \text{ton} \end{aligned}$$

## Berat Lubrication Oil (Wlo)

$$\begin{aligned} W_{ae} &= (0,1 \sim 0,2) W_{fo} \\ W_{ae} &= 0,16 \times W_{fo} \\ W_{ae} &= 24,79873 \quad \text{ton} \end{aligned}$$

## Berat Lubrication Oil (Wlo)

$$\begin{aligned} W_{lo} &= (0,02 \sim 0,04) W_{ae} \\ W_{lo} &= 0,03 \times W_{ae} \\ W_{lo} &= 0,78985 \quad \text{ton} \end{aligned}$$

## Air tawar (Wfw)

$$\begin{aligned} W_{fw} &= W_{at} + W_{we} \\ W_{at} &= Z \times C_a \times S/V_s \times 1,4 \times 1/24 \times 10^{-3} \text{ ton} \\ W_{we} &= C_{we} \times S/V_s \times 1,4 \times \text{BHP} \times 10^{-3} \text{ ton} \end{aligned}$$

Di mana

$$\begin{aligned} W_{at} &= \text{berat air tawar untuk keperluan crew} \\ W_{we} &= \text{berat air tawar untuk pendingin mesin} \\ Z &= \text{jumlah crew} = 36 \quad \text{orang} \quad 7200 \\ C_a &= \text{pemakaian untuk crew} \quad 200 \quad \text{kg/orang} \\ C_{we} &= \text{pemakaian untuk pendingin mesin} \quad 0,103 \quad \text{kg/hp} \\ R &= \text{jarak pelayaran} \quad 1064 \quad \text{mil} \\ V_s &= 14,0 \text{ knot} \\ W_{at} &= 1149,12 \\ W_{we} &= 100,374 \end{aligned}$$

Maka berat air tawar total adalah :

$$W_{fw} = 1249,494 \text{ ton}$$

## Provision/Person/ Luggage (Wc)

1. Berat provision = 3 ~ 5 kg/orang hari  
 Berat provision =  $37 \times 3 \times (2000 / (12,5 \times 24)) \times 10^{-3}$   
 Berat provision = 0,264906
  2. Person = 75 kg/orang  
 Person =  $37 \times 75 \times 10^{-3}$   
 Person = 2,775
  3. Luggage = 60 kg/orang  
 Luggage =  $37 \times 60 \times 10^{-3} = 2,04$
- Maka :
- Wc = 5,259906 ton

## Berat cadangan

Untuk mengatasi adanya kesalahan-kesalahan dalam perencanaan maka perlu disediakan berat cadangan :

$$\begin{aligned} W_r &= 1\% \text{ displacement kapal} \\ W_r &= 0,01 \times 10.417,11 \\ W_r &= 104,17 \text{ ton} \end{aligned}$$

Maka berat komponen DWT keseluruhannya adalah :

$$\begin{aligned} W_{\text{total}} &= W_{fo} + W_{ae} + W_{lo} + W_{fw} + W_c + W_r \\ &= 1550,594 \text{ ton} \end{aligned}$$

Maka besarnya payload adalah :

$$\begin{aligned} \text{Payload} &= \text{DWT} - W_{\text{total}} \\ \text{Payload} &= 8949,406 \text{ ton} \\ \text{TEU's} &= \text{Payload} / \text{Berat Kontainer 40 Feet} \\ &= 8949,406 / 31,57 \text{ ton} \\ &= 283,47 \sim 283 \text{ TEU's} \end{aligned}$$

#### V.5.4 Ruang Akomodasi

##### a. Ruang Akomodasi

Ruang akomodasi meliputi: *sleeping room, mess room, sanitary accomodation, hospital* direncanakan sesuai dengan *Crew Accomodation Convention* dari *International Labour Organization*.

b. *Sleeping Room*

Luas lantai didasarkan pada BRT (*Bruto Register Tonnage*) atau *gross tonnage* kapal adalah 1721 Ton Persyaratan :

- 1) Tidak boleh ada hubungan langsung di dalam ruang tidur dan ruang untuk palka, ruang mesin, dapur, ruang cuci untuk umum, WC, lamp room, paint room, dan *drying room*( ruang pengering)
- 2) Ruang tidur harus diletakan diatas garis air muat di tengah atau di belakang kapal. Bila keadaan tak memungkinkan, ruang tidur boleh di letakkan di bagian depan kapal, tetapi tidak di depan sekat tubrukan.
- 3) Luas lantai untuk ruang tidur per orang : untuk kapal > 3000 BRT yaitu 2,78 m
- 4) Tinggi ruangan dalam keadaan bebas adalah 1900 mm.
- 5) Ruang tidur perwira diusahakan satu kamar untuk satu orang (*master, chief officer, chief engineer, chief steward, radio officer*).
- 6) Bintara (*petty officer*) untuk satu kamar bisa untuk dua orang max.
- 7) Kelasi dapat satu kamar bisa untuk 3 orang untuk kapal-kapal biasa
- 8) Ukuran tempat tidur :
  - Ukuran minimal : (1900 x 680) mm<sup>2</sup>
  - Jarak tempat tidur tidak boleh diletakan berjajar, sehingga tak ada jarak cukup diantaranya
  - Tempat tidur tidak boleh lebih dari dua susun, dengan tempat tidur bawah jaraknya minimal 300 mm dari lantai, untuk tempat tidur atas terletak di tengah tempat tidur bawah dan langit-langit
  - Tempat tidur tidak boleh di letakan memanjang kapal, apabila tersusun dua di mana side lighth terpasang di situ, jadi hanya boleh satu tempat tidur saja.
- 9) *Sleeping room* tidak boleh diletakan memanjang kapal, *sleeping room* untuk *radio officer/ operator*, harus mempunyai ruang tidur yang letak dan keadaanya sesuai dengan tugasnya di kapal. Bila ada *auto alarm, sleeping room* untuk *radio officer* harus cukup dekat dengan *radio room* dan dapat dicapai dalam waktu 30 detik. Jarak horizontal 50 yard

~ 30 detik, bila ada tangga, Jarak vertikal di kalikan 3 (Jarak datar x 3).

c. *Mess Room*

Persyaratan :

- 1) Setiap kapal harus punya *mess room accommodation* yang cukup
- 2) Kapal berukuran > 1000 BRT harus dilengkapi dengan *mess room* yang terpisah antara lain :
  - *Master officer* (Perwira)
  - *Petty officer* (bintara) *deck department* dan *engine department*
  - Tingkatan lain *department* dan *engine department*

Untuk *catering department* bisa menggunakan fasilitas *mess room* tersebut, tetapi untuk kapal > 500 BRT dengan crew *Catering department* lebih 5 orang harus dipertimbangkan adanya *mess room* terpisah

- 3) *Mess room* harus dilengkapi dengan meja, kursi dan perlengkapan lain yang bisa menampung keseluruhan crew kapal pada saat yang bersamaan (jumlah crew = jumlah kursi)

d. *Sanitary Accomodation*

Ketentuan untuk sanitary accomodation :

- 1) Setiap kapal harus diperlengkapi dengan sanitary accomodation, minimal 1 toilet, 1 wash basin dan 1 bath tub/shower untuk 8 orang ABK.
- 2) Untuk kapal  $\geq$  1000 BRT, harus dilengkapi minimal 4 WC.
- 3) Pada radio room harus terdapat sanitary accomodation.

e. *Hospital Accomodation*

Ketentuan dalam merencanakan hospital accomodation :

- 1) Kapal dengan ABK lebih dari 15 orang dan berlayar lebih dari 3 hari maka harus dilengkapi dengan hospital accomodation.
- 2) Fasilitas sanitair untuk ruang ini harus disediakan tersendiri.

f. Tempat Ibadah ( Musholla )

Pada kapal ini disediakan satu ruangan Musholla untuk sholat berjama'ah yang dapat menampung 4 orang.

g. Ruang Navigasi

Terdiri dari chart room, wheel house dan radio room yang terletak pada tempat yang tertinggi pada bangunan atas kapal

1) Wheel House

Pandangan wheel house ke arah depan dan samping tidak boleh terganggu dan garis pandang ke arah haluan harus memotong garis air tidak boleh  $>1,25$  panjang kapal.

2) Chart Room

- Diletakan di belakang wheel house
- Ukurannya tidak boleh  $< 8 \times 8$  ft ( 2,4 x 2,4 m)
- Antara chart dengan wheel house dihubungkan sliding door.

3) Radio Room

- Luasnya tidak boleh  $< 120$  sqft = 11,15 m<sup>2</sup>
- Ditempatkan setinggi mungkin di atas kapal, terlindung dari air, tidak ada gangguan suara dan terpisah dari kegiatan lain.
- Radio room harus dihubungkan dengan wheel house.

h. Ruangan lain yang direncanakan

1) Cargo control room

2) Steering gear compartment

3) ESEP ( Emergency Source Electric Power) pada bridge deck

4) Store (rope store, boatswain store, lamp store, electrical store, paint store) diletakan pada main deck.

5) Dry provision store room, harus diletakkan dekat dengan dapur atau pantry.

6) Cold provosion store room yang terdiri dari :

- Meat room ( max 180F)
- Vegetable room ( max 350F )

Luas provision store room  $\pm 0,8 - 1$  m<sup>2</sup> / orang dan untuk cold store room adalah  $1/3 - 1/2$  darinya.

7) Ship Officer

Pada kapal berukuran  $> 3000$  BRT harus dilengkapi dengan satu ruangan untuk deck departement dan engine departement.

## 8) Galley

Dengan ketentuan :

- Diletakkan berdekatan dengan mess room, bila jauh harus ada pantry untuk tempat penyimpanan dan memanaskan masakan.
- Harus terhindar dari asap dan debu.
- Harus ada penerangan, sirkulasi udara, perawatan dan perbaikan.
- Tidak boleh ada bukaan ke sleeping room. Luas galley adalah 0,5 m<sup>2</sup> / orang, sehingga luasnya = 11m<sup>2</sup>

## 9) Pantry, Laundry, CO2 room, Foam Tank room, Library

**V.5.5 Perencanaan tangki**

## a. Tangki Fuel Oil

Tangki bahan bakar (Fuel oil tank) diletakkan di double bottom panjang Fuel Oil Tank 16 jarak gading ( $a_0 = 0,6$  m) [66 m], di antara gading no.38 s/d 62.

## b. Tangki Fuel Oil Mesin Bantu

Tangki bahan bakar mesin bantu (Fuel oil AE tank) diletakkan di double bottom panjang Fuel Oil AE Tank 2 jarak gading ( $a_0 = 0,6$  m) [12 m], di antara gading no.28 s/d 30.

## c. Tangki Minyak Pelumas (Lubricant Oil)

Tangki minyak lumas diletakkan di dasar ganda kamar mesin sepanjang 1 jarak gading normal ( $a_0$ ) diantara gading no.27 s/d 28.

## d. Tangki Air Tawar

Tangki air tawar diletakkan di dasar ganda kamar mesin sepanjang 18 jarak gading normal ( $a_0$ ) diantara gading no.47 s/d 65.

## e. Tangki Ballast IV

Tangki ballast IV diletakkan di dasar ganda sepanjang 20 jarak gading normal ( $a_0$ ) di antara gading no. 65 s/d 85.

## f. Tangki Ballast III

Tangki ballast III diletakkan di dasar ganda sepanjang 19 jarak gading normal ( $a_0$ ) di antara gading no. 85 s/d 104.

g. Tangki Ballast II

Tangki ballast II diletakkan di dasar ganda sepanjang 20 jarak gading normal ( $a_0$ ) di antara gading no. 104 s/d 124.

h. Tangki Ballast I

Tangki ballast I diletakkan di dasar ganda sepanjang 19 jarak gading normal ( $a_0$ ) di antara gading no. 124 s/d 143

### V.5.6 Perlengkapan Navigasi dan Komunikasi

a. Perlengkapan navigasi

1) Lampu navigasi

a) Mast Head Light/lampu tiang

- Warna putih
- Sudut penerangan 2250
- Diletakkan disisi depan tiang dan harus dapat dilihat jarak 5 mil
- LetakNya  $0.5 \text{ Loa} < 12 < 100 \text{ m}$
- Tinggi 15 sampai 40 feet
- Mast head light ini ada 2 lampu yaitu fore mast light dan after mast head light
- Sudut sinar 2250
- Berfungsi agar tidak terjadi tubrukan pada saat kapal berlayar (untuk mengetahui arah gerakan kapal)

b) Anchor Light/lampu jangkar

- Warna putih
- Sudut penerangan 3600
- Dipasang pada saat lego jangkar (kalau siang dipasang bohlam hitam)
- LetakNya  $L \leq 0.25 \text{ Loa}$  atau  $\leq 20.337 \text{ m}$
- Tinggi dari main deck 23 feet = 7 m

c) Side Light/lampu samping

- Sudut penerangan 112.50



- Pada sisi kanan kapal (Port side) berwarna merah
  - Pada sisi kiri kapal (starboard) berwarna hijau
  - Diletakkan pada bagian atas geladak wheel house
  - Sudut sinar 112,50
  - Tinggi lampu dari geladak utama (h3)
- d) Stern Light/lampu buritan
- Warna putih
  - Sudut penerangan 1350
  - Diletakkan pada buritan kapal
  - Tingginya kurang dari anchor light
- e) Morse signal lamp/Lampu morse
- Lampu yang digunakan untuk mengirim isyarat morse
  - Harus bisa digunakan pada siang atau malam hari.
- f) Flood light/Lampu pancar
- Lampu yang terletak pada ujung kapal
  - Arah sinarnya dapat diatur
- g) Search lamp/Lampu sorot
- Lampu dengan reflektor yang dipasang pada anjungan kapal yang dipergunakan untuk menerangi suatu objek pada jarak yang jauh pada kapal.
- h) Boat deck light/Lampu geladak sekoci
- Lampu yang dipergunakan untuk pada malam hari apabila kapal dalam keadaan darurat.
- i) Daylight signal lamp/Lampu isyarat siang hari
- Lampu dikapal yang berfungsi untuk mengirim isyarat pada siang hari.
- 2) Peralatan navigasi lainnya

- a) Bell  
Digunakan sebagai tanda untuk menyatakan waktu pergantian jaga pada crew, kadang-kadang dipakai sebagai peringatan keadaan berbahaya.
- b) Fog horn/terompet kabut,  
Biasanya dibunyikan dengan memakai uap, udara atau ditiup.
- c) Black ball/bola jangkar,  
Sebagai tanda bahwa kapal sedang turun jangkar yang terlihat pada siang hari dengan menggunakan plat bulat berdiameter 2 feet yang dibuat tegak lurus satu sama lain.
- d) Bendera isyarat/ signal flag, Bendera nasional/national flag
- e) Rocket or socket signal 12 bh, Signal code book, Daftar dari kapal-kapal niaga
- f) Termometer (for sea water), barometer, binocular/teropong,
- g) Hand lead tidak kurang dari 3,2 kg (berikut tali-talinya tidak boleh kurang dari 46 m), dan deep sea lead tidak kurang dari 12,7 kg ( dan tali-talinya tidak kurang dari 230 m.
- h) Deep sea sounding machine.
- i) Sextant/sektan, alat astronomi jinjing yang dipergunakan untuk mengukur sudut dengan bantuan cermin.
- j) Magnetic kompas, yang diletakkan di geladag navigasi dan posisinya kesemua arah.

#### b. Peralatan Komunikasi

- 1) Telegraph, Berupa Telegraph kamar mesin, Telegraph rumang kemudi, geladag dan Telegraph jangkar.
- 2) Voice tube, peralatan ini biasanya terbuat dari pipa yang digalvanis, pipa suara digunakan untuk jarak pendek dengan diameter 38 m/m, sedangkan jarak panjang 50 atau 64 m/m.

- 3) Telephon dan bel pemanggil (Calling bell) Telephon yang dipakai umumnya sama dengan telephon yang dipakai di darat. Biasanya digunakan pada kapal barang modern.

Calling bell umumnya dipasang pada catering service, dimana bell dipencet pada kamar-kamar penumpang, public room, kamar mandi, kamar perwira, dsb.

### V.5.7 Perancangan *Propeller* dan Kemudi

#### a. *Propeller*

diameter *propeller* (DP)

$$\begin{aligned} DP &= 0,6 \times T \\ &= 5,166 \text{ m} \end{aligned}$$

diameter bos poros (Db)

$$\begin{aligned} Db &= 1/6 \times Dp \\ &= 0,861 \text{ m} \end{aligned}$$

jarak dasar sampai bos poros *propeller*

$$\begin{aligned} &= (0,045 \times T + 0,5 \times Dp) \\ &= 2,97045 \text{ m} \end{aligned}$$

jarak Ap sampai bos poros *propeller*

$$\begin{aligned} &= 0,0266 \times lpp \\ &= 3,349738 \text{ m} \end{aligned}$$

luas *propeller*

$$\begin{aligned} &= 0,6 \times Dp \\ &= 3,0996 \text{ m}^2 \end{aligned}$$

rongga *propeler*

$$\begin{aligned} a &= 0,1 \times Dp \\ &= 0,5166 \text{ m} \end{aligned}$$

#### b. Sepatu kemudi

tinggi sepatu kemudi

$$\begin{aligned} &= 0,09 \times T \\ &= 0,7749 \text{ m} \end{aligned}$$

panjang sepatu kemudi

$$= 0,07 \times T$$

$$= 0,6027 \text{ m}$$

c. Daun kemudi

luas daun kemudi

dari " *Det Norske Veritas*" didapat rumus untuk menghitung luas daun kemudi sebagai berikut:

$$A = C1 \times C2 \times C3 \times C4 \times 1,75 \times L \times T/100$$

$$C1 = 1(\text{in general})$$

$$C2 = 1(\text{in general})$$

$$C3 = 1(\text{for NACA- profils and plate rudder})$$

$$C4 = 1,5(\text{for rudder outside the propeller jet})$$

$$A = 17,91292739 \text{ m}^2 \sim 28\text{m}^2 \quad (\text{dibulatkan})$$

luas bagian balansir kemudi (A')

$$= 23\% \times 18$$

$$= 6,44 \text{ m}$$

tinggi kemudi (h)

$$h = 0,7 \times T$$

$$= 6,027 \text{ m}$$

lebar kemudi (b)

$$b = A/h$$

$$= 4,645761 \text{ m}$$

lebar bagian balansir(b')

$$b' = A'/h$$

$$= 1,068525 \text{ m}$$

tinggi poros(t)

$$t = 0,4 \times T$$

$$= 3,444$$

Sudut kecondongan propeller (120 – 150).

• Gaya Kemudi

Dari BKI vol II 2006 diperoleh rumus sebagai berikut:

$$CR = 132 \times A \times v^2 \times K1s \times K2 \times K3 \times Kt \quad (N)$$

$$K1 = \text{Koefisien, diperoleh dari rumus}$$

$$= (\Delta + 2)/3$$

$$\Delta = b^2/At$$

$$= 0,770825$$

$$K1 = 0,923608$$

$$K2 = \text{Koefisien berdasarkan tipe kemudi}$$

untuk tipe kemudi NACA maka:

$$K2 = 1,1$$

$$K3 = \text{koefisien berdasarkan letak kemudi}$$

untuk kemudi tepat dibelakang propeller

$$= 1$$

$$Kt = 1 \quad (\text{normal})$$

maka

$$CR = 735984,3$$

$$= 735,9843 \quad KN$$

Momen Torsi Kemudi

$$QR = CR \times r \quad (Nm)$$

dimana

$$r = c (\mu - kb) \quad (m)$$

$$c = \text{lebar kemudi} = 3,629 \quad m$$

$$\mu = 0,33$$

$$kb = \text{faktor balance}$$

$$0,073$$

$$r = 0,929283 \quad m$$

$$QR = 683,9378 \quad KNm$$

Diameter Tongkat Kemudi

$$D_t = 4,2\sqrt[3]{Q_R/k_r} \text{ (mm)}$$

$$k_r = \left(\frac{ReH}{235}\right)^{0,75} = \left(\frac{235}{235}\right)^{0,75} = 1$$

$$\begin{aligned} ReH &= \text{tegangan yield material} \\ &= 235 \text{ N/mm}^2 \\ &= 37,00452 \end{aligned}$$

Steering gear

$$\begin{aligned} Nm &= 1,4.Qr.Nrs/103.Nq \\ Nrs &= t/3T ; t = 350 ; T = 25 \text{ detik} \\ Nq &= 0,1 \sim 0,35 \text{ diambil harga } 0,1 \\ Nm &= 346,313 \text{ HP} = 350 \text{ HP} \end{aligned}$$

### V.5.8 Pintu, Jendela dan Tangga

Reff: Practical Shipbuilding III B

a. Pintu

- 1) Untuk ke luar lebarnya: 600 ~ 750 mm, direncanakan 700 mm.
- 2) Untuk kabin lebarnya: 640 ~ 660 mm., direncanakan 650 mm
- 3) Tinggi dari deck: 1850 ~ 1950 mm, direncanakan 1900 mm.
- 4) Tinggi ambang untuk kabin: 120 ~ 200 mm, direncanakan 150 mm.
- 5) Tinggi ambang untuk keluar: 300 ~ 450 mm, direncanakan 300 mm

b. Jendela

- 1) Jendela boat deck dan navigation deck berbentuk segiempat dengan ukuran 350 x 500 mm.
- 2) Jendela untuk wheel house

Berdasarkan simposium on the design of ship bridges;

- Bagian depan harus membentuk sudut  $15^0$  keluar.
- Sisi bawah jendela harus 1,2 ~ 2 m di atas deck.
- Jarak antara sesama jendela tidak boleh lebih dari 100 mm

- 3) Jendela pada main deck dan poop deck berbentuk lingkaran dengan diameter 400 mm.

c. Tangga

- 1) Lebar tangga di luar bangunan minimal: 750 ~ 900 mm, direncanakan 800 mm.
  - 2) Lebar tangga di dalam bangunan minimal 520 mm, direncanakan 700 mm.
  - 3) Pegangan di luar bangunan minimal: 950 ~ 1600 mm, direncanakan 1000 mm.
  - 4) Tinggi pegangan di dalam bangunan minimal 830 mm, direncanakan 1000 mm.
  - 5) Jarak anak tangga 200 mm.
  - 6) Ukuran standar tangga menurut Japan Ship Design Standard:
    - Tangga eksterior dan interior  
Lebar tangga: 500 ~ 700 mm.  
Kemiringan:  $50^{\circ} \sim 60^{\circ}$
    - Anak tangga:  $180 \times 10 \text{ mm}^2$  ;  $180 \times 9,5 \text{ mm}^2$
    - Vertikal Ladder
      - Lebar : 250 ~ 300 mm.
      - Jarak antar anak tangga : 250 x 350 mm.
      - Anak tangga:  $65 \times 9 \text{ mm}^2$
    - Port Gang Way (Accommodation Ladder)
      - Lebar minimum: 600 mm
      - Sudut kemiringan  $45^{\circ}$ , diukur pada keadaan ballast waterline.
      - Sarat kapal kosong ( $T_0$ ) = 7,48 m
      - Panjang port gangway (l)
 
$$l = H - T_0 / \sin 55^{\circ}$$

$$H = \text{Tinggi kapal} + \text{tinggi poop} = 15,4 \text{ m}$$

$$l = 15,4 - 7,48 / \sin 55^{\circ}$$

$$= 6,27 \text{ m}$$
- Dipasang pada sisi kanan lambung kapal menggantung pada poop deck.

### V.5.9 Perencanaan Bulwark dan Rail

#### a. Bulwark

Berdasarkan peraturan BKI 2006.

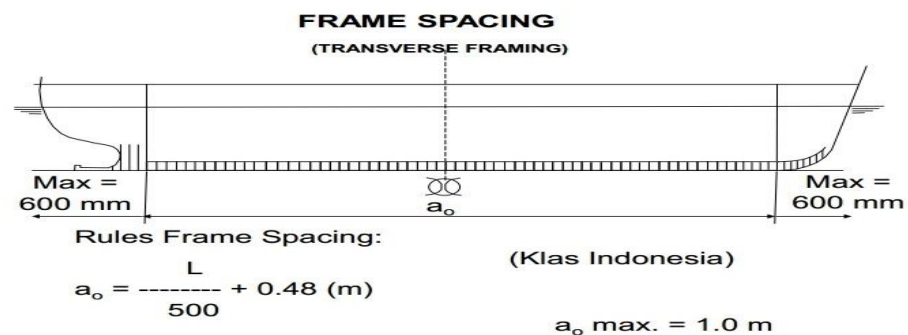
- 1) Tinggi bulwark min 1 m. Direncanakan tinggi bulwark 1 m.
- 2) Dipasang di tepi geladak dengan fungsi:
  - Menjamin keselamatan penumpang dan ABK.
  - Mencegah basahnya benda-benda di atas geladak akibat gerakan oleng kapal.

#### b. Rail

- 1) Railing dipasang ditempat dimana pemasangan bulwark tidak begitu penting.
- 2) Berjarak 2 kali jarak gading normal ( $a_0$ ).
- 3) Pada pelat bilah jarak pipa datar 300 mm.
- 4) Ketinggian railing dari atas geladak sebesar 1,07 m.
- 5) Pipa railing teratas lebih besar daripada pipa yang lainnya.

### V.5.10 Penentuan ruang sekat dan ruang muat

Penentuan sekat-sekat melintang kapal (*transverse bulkhead*)



**Gambar 22. Frame Spacing**

Jarak gading *Frame spacing*

$$a = (l_{pp}/500) + 0,48$$

$$a = 0,73 \text{ m}$$

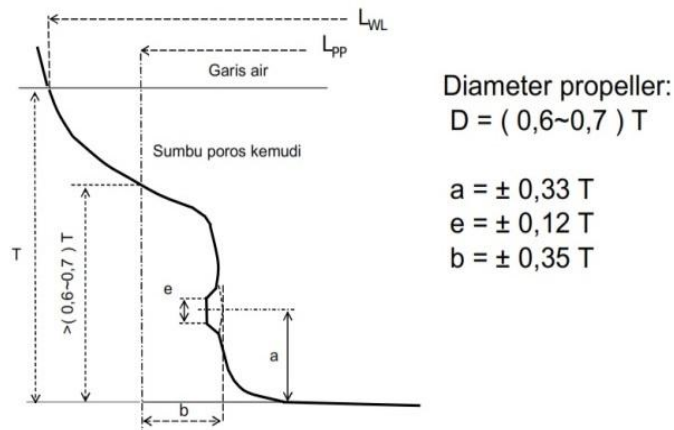


Menentukan Bulkhead menurut BKI 2009 , Volume II . Maka:

**Tabel 63. Penentuan, Diameter, Poros, dan Jarak Propeller**

Linggih Buritan

| Dimensi | Rumus           | Hasil  |
|---------|-----------------|--------|
| D       | $0,7 \times T$  | 6,03 m |
| a       | $0,34 \times T$ | 2,84 m |
| e       | $0,13 \times T$ | 1,12 m |
| b       | $0,34 \times T$ | 2,93 m |



**Gambar 23. Linggih Buritan**

stern post dari AP = 2,93 m

=  $2,93 / \text{jarak gading}(0,6)$

= 4,878 ~ 5 jarak gading

SB =  $(5 + 5) Jg \times 0,6$

= 6 m (dari AP; 9jg)

Sekat Haluan / Sekat Tubrukan ( Forepeak Bulkhead/Collision Bulkhead)

$0,05 LPP \leq \text{Jarak Sekat Haluan} \leq 0,08 LPP$  , dari FP

SH =  $0,93 \times LPP$

= 10,0743

$$= 10,0743/\text{jarak gading}(0.6)$$

$$= 16,7905 \sim 17\text{jarak gading}$$

$$\text{Afp} = 0,6 \text{ m}$$

$$\text{SH} = \text{Jum. Gd} \times \text{afp}$$

$$= 10,2 \text{ m (diukur dari FP)}$$

Sekat Kamar Mesin ( Engine Room Bulkhead)  $17\% \text{ LPP} \leq \text{Jarak}$

Sekat Kamar Mesin  $\leq 20\% \text{ LPP}$  , dari AP

$$\text{SKM} = 20\% \times \text{LPP}$$

$$= 25,185$$

$$= 25,185 - (\text{SB})$$

$$= 19,185$$

$$= 19,185/\text{jarak gading}(0.7)$$

$$= 27,4082 \sim 27 \text{ jarak gading}$$

$$\text{SKM} = 27 (\text{JG}) \times 0,8$$

$$= 19,71 \text{ m (dari SB ; 21jg)}$$

Sekat Ruang Muat

Menurut LR jumlah sekat untuk kapal :

- $86,9 \text{ m} \leq L \leq 102,1 \text{ m} \rightarrow 5 \text{ sekat}$
- $102,1 \text{ m} \leq L \leq 123,4 \text{ m} \rightarrow 6 \text{ sekat}$
- $123,4 \text{ m} \leq L \leq 143,3 \text{ m} \rightarrow 7 \text{ sekat}$
- $143,3 \text{ m} \leq L \leq 164,6 \text{ m} \rightarrow 8 \text{ sekat}$
- $164,6 \text{ m} \leq L \leq 185,9 \text{ m} \rightarrow 9 \text{ sekat}$

#### Gambar 24. Penentuan Jumlah Sekat

Maka Jumlah Sekat Ruang Muat Yang Didapat:

$$\begin{aligned}\Sigma \text{SRM} &= 7 \text{ Sekat} - (\text{Sh} + \text{SB} + \text{SRM}) \\ &= 4 \text{ sekat ruang muat} \\ &= 5 \text{ ruang muat}\end{aligned}$$

$$\begin{aligned}\text{Panjang Ruang Muat} &= \text{LPP} - (\text{p.SB} + \text{p.SRM} + \text{p.SH}) \\ &= 90,02 \text{ m} / (\text{dibagi } 5 \text{ RM}) \\ &= 18,00381 / \text{jarak gading}(0.7) \\ &= 25,71972 \sim 26 \text{ jarak gading}\end{aligned}$$

Maka :

$$\begin{aligned}\text{Ruang Muat 1,2} &= 35 (\text{JG}) \times 0,7 \\ &= 24,5 \text{ m} (35 \text{ jg})\end{aligned}$$

$$\begin{aligned}\text{Sisa Ruang Muat} &= \text{P} - 2(\text{RM}) \\ &= 24,42 / \text{jarak gading}(0.7) \\ &= 34,88571 \sim 34 \text{ jarak gading}\end{aligned}$$

$$\begin{aligned}\text{Ruang Muat 3} &= 19 (\text{JG}) \times 0,7 \\ &= 13,87 \text{ m} (19 \text{ jg})\end{aligned}$$

Menentukan bangunan atas kapal (*Forecastle Deck & Poop Deck*)

$$\begin{aligned}\text{Panjang Forecastle Deck} &= \text{Jarak Sekat Haluan} \\ &= 10,2 \text{ m}\end{aligned}$$

$$\begin{aligned}\text{Tinggi ForecastleDeck} &= \pm 2,4 \sim 2,5 \text{ meter} \\ &= 2,4 \text{ m}\end{aligned}$$

$$\text{Panjang PoopDeck} = \text{Jarak SKM} + \text{Jarak SB}$$

$$= 25,71 \text{ m}$$

$$\text{Tinggi PoopDeck} = \pm 2,4 \sim 2,5 \text{ meter}$$

$$= 2,4 \text{ m}$$

### V.5.11 Peralatan tambat

#### a. Jangkar dan rantai jangkar

Pemilihan perlengkapan kapal seperti jangkar, rantai jangkar dan alat-alat tambat lainnya tergantung dari angka penunjuk (equipment number). Menurut BKI volume II 2014 section 18.B. angka penunjuk dapat dihitung dengan rumus sebagai berikut:

$$Z = D^{2/3} + 2hB + \frac{A}{10}$$

**dimana:** D = Displacement (ton) = 7963,00 ton

h = free board + tinggi bangunan atas = (8,36 – 6,45) + (2,4 x 6) = 16,31 m

A = Luas bidang lateral dari badan dan bangunan atas yang berada di atas garis air

|                         |                       |                           |
|-------------------------|-----------------------|---------------------------|
| - Lambung Kapal         | = (H – T) x Lwl       |                           |
|                         | = (8,36-6,45)x 113,61 | = 153,3724 m <sup>2</sup> |
| - Bangunan Atas (F'Cle) | = 10,66 x 2,4         | = 25,584 m <sup>2</sup>   |
| - Bangunan Atas (Poop)  | = 20,99 x 2,4         | = 50,376 m <sup>2</sup>   |
| - Geladak Boat          | = 21 x 2,4            | = 50,4 m <sup>2</sup>     |
| - Geladak Compass       | = 10,46 x 2,4         | = 25,104 m <sup>2</sup>   |
| - Geladak Navigasi      | = 9,08 x 2,4          | = 21,792 m <sup>3</sup>   |
|                         |                       | = 390,251 m <sup>2</sup>  |

$$\text{Maka: } Z = 7963^{2/3} + (2/3) \times (2 \times 16,31 \times 14,18) + (420,8494/10)$$

$$Z = 903,402254$$

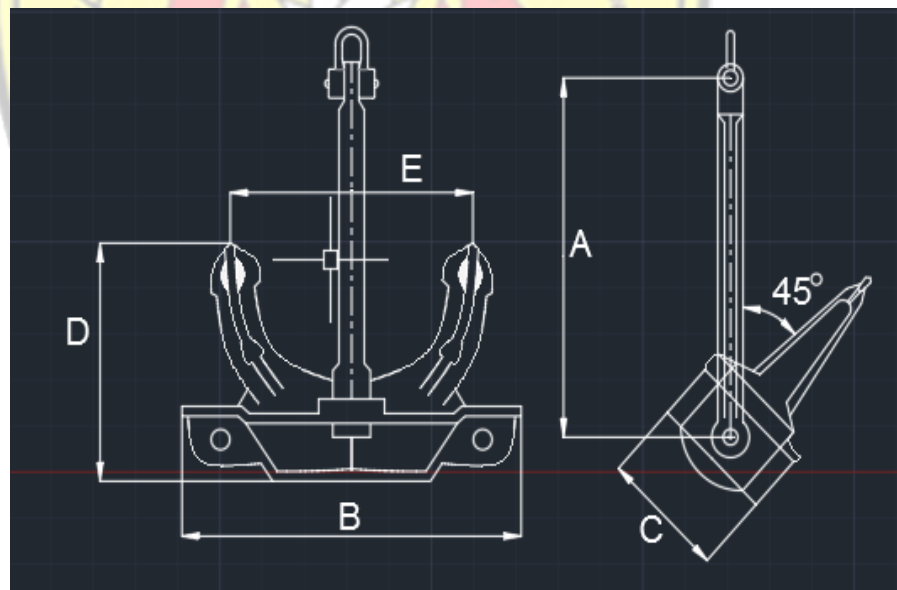
Dari BKI volume II 2014 section 18 tabel 18.2 untuk angka penunjuk Z seperti dibawah ini

Tabel 64. Penentuan, jangkar dan peralatan tambat

| No. for Reg. | Equipment numeral $Z_1$ or $Z_2$ | Stockless anchor     |                 |               | Stud link chain cables |       |       |  |                        |         | Recommended ropes      |               |        |                        |     |
|--------------|----------------------------------|----------------------|-----------------|---------------|------------------------|-------|-------|--|------------------------|---------|------------------------|---------------|--------|------------------------|-----|
|              |                                  | Bower anchor         |                 | Stream anchor | Bower anchors          |       |       | Stream wire or chain for stream anchor |                        | Towline |                        | Mooring ropes |        |                        |     |
|              |                                  | Number <sup>1)</sup> | Mass per anchor | Total length  | Diameter               |       |       | Length                                 | Br. load <sup>2)</sup> | Length  | Br. load <sup>2)</sup> | Number        | Length | Br. load <sup>2)</sup> |     |
|              |                                  |                      |                 |               | $d_1$                  | $d_2$ | $d_3$ |  |                        |         |                        |               |        |                        |     |
|              |                                  | [kg]                 | [m]             | [mm]          | [mm]                   | [mm]  | [m]   | [kN]                                   | [m]                    | [kN]    |                        | [m]           | [kN]   |                        |     |
| 1            | 2                                | 3                    | 4               | 5             | 6                      | 7     | 8     | 9                                      | 10                     | 11      | 12                     | 13            | 14     | 15                     | 16  |
| 101          | up to 50                         | 2                    | 120             | 40            | 165                    | 12,5  | 12,5  | 12,5                                   | 80                     | 65      | 180                    | 100           | 3      | 80                     | 35  |
| 102          | 50 - 70                          | 2                    | 180             | 60            | 220                    | 14    | 12,5  | 12,5                                   | 80                     | 65      | 180                    | 100           | 3      | 80                     | 35  |
| 103          | 70 - 90                          | 2                    | 240             | 80            | 220                    | 16    | 14    | 14                                     | 85                     | 75      | 180                    | 100           | 3      | 100                    | 40  |
| 104          | 90 - 110                         | 2                    | 300             | 100           | 247,5                  | 17,5  | 16    | 16                                     | 85                     | 80      | 180                    | 100           | 3      | 110                    | 40  |
| 105          | 110 - 130                        | 2                    | 360             | 120           | 247,5                  | 19    | 17,5  | 17,5                                   | 90                     | 90      | 180                    | 100           | 3      | 110                    | 45  |
| 106          | 130 - 150                        | 2                    | 420             | 140           | 275                    | 20,5  | 17,5  | 17,5                                   | 90                     | 100     | 180                    | 100           | 3      | 120                    | 50  |
| 107          | 150 - 175                        | 2                    | 480             | 165           | 275                    | 22    | 19    | 19                                     | 90                     | 110     | 180                    | 100           | 3      | 120                    | 55  |
| 108          | 175 - 205                        | 2                    | 570             | 190           | 302,5                  | 24    | 20,5  | 20,5                                   | 90                     | 120     | 180                    | 110           | 3      | 120                    | 60  |
| 109          | 205 - 240                        | 2                    | 660             |               | 302,5                  | 26    | 22    | 20,5                                   |                        |         | 180                    | 130           | 4      | 120                    | 65  |
| 110          | 240 - 280                        | 2                    | 780             |               | 330                    | 28    | 24    | 22                                     |                        |         | 180                    | 150           | 4      | 120                    | 70  |
| 111          | 280 - 320                        | 2                    | 900             |               | 357,5                  | 30    | 26    | 24                                     |                        |         | 180                    | 175           | 4      | 140                    | 80  |
| 112          | 320 - 360                        | 2                    | 1020            |               | 357,5                  | 32    | 28    | 24                                     |                        |         | 180                    | 200           | 4      | 140                    | 85  |
| 113          | 360 - 400                        | 2                    | 1140            |               | 385                    | 34    | 30    | 26                                     |                        |         | 180                    | 225           | 4      | 140                    | 95  |
| 114          | 400 - 450                        | 2                    | 1290            |               | 385                    | 36    | 32    | 28                                     |                        |         | 180                    | 250           | 4      | 140                    | 100 |
| 115          | 450 - 500                        | 2                    | 1440            |               | 412,5                  | 38    | 34    | 30                                     |                        |         | 180                    | 275           | 4      | 140                    | 110 |
| 116          | 500 - 550                        | 2                    | 1590            |               | 412,5                  | 40    | 34    | 30                                     |                        |         | 190                    | 305           | 4      | 160                    | 120 |
| 117          | 550 - 600                        | 2                    | 1740            |               | 440                    | 42    | 36    | 32                                     |                        |         | 190                    | 340           | 4      | 160                    | 130 |
| 118          | 600 - 660                        | 2                    | 1920            |               | 440                    | 44    | 38    | 34                                     |                        |         | 190                    | 370           | 4      | 160                    | 145 |
| 119          | 660 - 720                        | 2                    | 2100            |               | 440                    | 46    | 40    | 36                                     |                        |         | 190                    | 405           | 4      | 160                    | 160 |
| 120          | 720 - 780                        | 2                    | 2280            |               | 440                    | 48    | 42    | 38                                     |                        |         | 190                    | 440           | 4      | 160                    | 170 |
| 121          | 780 - 840                        | 2                    | 2460            |               | 467,5                  | 50    | 44    | 38                                     |                        |         | 190                    | 480           | 4      | 170                    | 185 |
| 122          | 840 - 910                        | 2                    | 2640            |               | 467,5                  | 52    | 46    | 40                                     |                        |         | 190                    | 520           | 4      | 170                    | 200 |
| 123          | 910 - 980                        | 2                    | 2850            |               | 495                    | 54    | 48    | 42                                     |                        |         | 190                    | 560           | 4      | 170                    | 215 |
| 124          | 980 - 1060                       | 2                    | 3060            |               | 495                    | 56    | 50    | 44                                     |                        |         | 200                    | 600           | 4      | 180                    | 230 |
| 125          | 1060 - 1140                      | 2                    | 3300            |               | 495                    | 58    | 50    | 46                                     |                        |         | 200                    | 645           | 4      | 180                    | 250 |
| 126          | 1140 - 1220                      | 2                    | 3540            |               | 522,5                  | 60    | 52    | 46                                     |                        |         | 200                    | 690           | 4      | 180                    | 270 |
| 127          | 1220 - 1300                      | 2                    | 3780            |               | 522,5                  | 62    | 54    | 48                                     |                        |         | 200                    | 740           | 4      | 180                    | 285 |
| 128          | 1300 - 1390                      | 2                    | 4050            |               | 522,5                  | 64    | 56    | 50                                     |                        |         | 200                    | 785           | 4      | 180                    | 305 |
| 129          | 1390 - 1480                      | 2                    | 4320            |               | 550                    | 66    | 58    | 50                                     |                        |         | 200                    | 835           | 4      | 180                    | 325 |

Berdasarkan berat jangkar maka dipilih jangkar berengsel dan tanpa tongkat dari tipe Hall Anchor dan gambar dengan ukuran sebagai berikut :

|       |   |                       |
|-------|---|-----------------------|
| Merk  | = | MORDEC                |
| Type  | = | Hall Stockless Anchor |
| Berat | = | 3000 kg               |
| A     | = | 2374 mm               |
| B     | = | 1832 mm               |
| C     | = | 841 mm                |
| D     | = | 282 mm                |
| E     | = | 1283 mm               |
| F     | = | 1283 mm               |
| G     | = | 284 mm                |
| H     | = | 360 mm                |
| ∅     | = | 82 mm                 |



**Gambar 25. Jangkar**

Rantai jangkar

Panjang total : 467,5 m

D1 = 52 mm

D2 = 46 mm

D3 = 40 mm

Dipilih rantai jangkar dengan diameter 40 mm dengan ukuran sebagai berikut

b. Mesin jangkar

Windlass digunakan untuk mengencangkan (*heave up*) dan mengarea (*slack away*) daripada tali-tali tambat kapal, sedangkan Fairlead digunakan untuk mengatur arah dan mengurangi gesekan tali-tali tambat. Sedangkan bollard digunakan untuk mengikatkan, mematikan, mengatur arah tali-tali tambat. Pada gambar dibawah ini dijelaskan berbagai macam Fairlead dan Bollard serta susunan Mooring Arrangement pada bagian Forecastle.

Menurut BKI volume III 2006 bab 14.B.4.11 derek jangkar harus mampu menghasilkan tenaga angkat atau tarik nominal sebesar:

$$Z = 42,5 d^2$$

Dimana: Z = gaya angkat/tarik nominal (kg).

d = diameter rantai jangkar = 40 mm

maka:

$$\begin{aligned} Z &= 42,5 \times 40^2 \\ &= 68.000 \text{ kg} \end{aligned}$$

Tenaga penggerak yang dibutuhkan pada kecepatan rata-rata 9 m/menit adalah:

$$E = \frac{Z \times v}{75 \times 60 \times \eta}$$

dimana: E = tenaga penggerak yang dibutuhkan (HP)

Z = Gaya angkat/tarik nominal (kg)

V = Kecepatan rata-rata 9 m/menit.

$\eta$  = efisiensi = 0,7

maka:

$$\begin{aligned} E &= \frac{68000 \times 9}{75 \times 60 \times 0,7} \\ &= 194,28 \text{ HP} \end{aligned}$$

Dari “Practical Shipbuilding III B” untuk diameter rantai jangkar 50 mm diperoleh spesifikasi mesin jangkar sebagai berikut:

- Type : Electric Windlass type EAH-3
- Pulling force : 9025 kg
- Kecepatan : 7,5 m/menit
- Motor : 303,57 HP

Windlass dibuat sedemikian rupa sehingga memenuhi persyaratan sebagai berikut:

- Mampu menarik jangkar beserta rantainya meskipun jangkarnya tertancap dalam didasar laut.
- Dapat menarik setiap rantai, maupun kedua-duanya dalam waktu yang bersamaan.
- Dapat melepaskan setiap rantai maupun kedua-duanya dalam waktu yang bersamaan.
- Kecepatan pada waktu melepaskan harus dapat diatur pada setiap sisi rantai (kiri atau kanan).
- Dapat menarik rantai dan bersamaan dengan itu melepaskan yang lainnya.

Pemilihan **windlass** dilihat dari segi ukurannya tergantung dari beberapa hal antara lain:

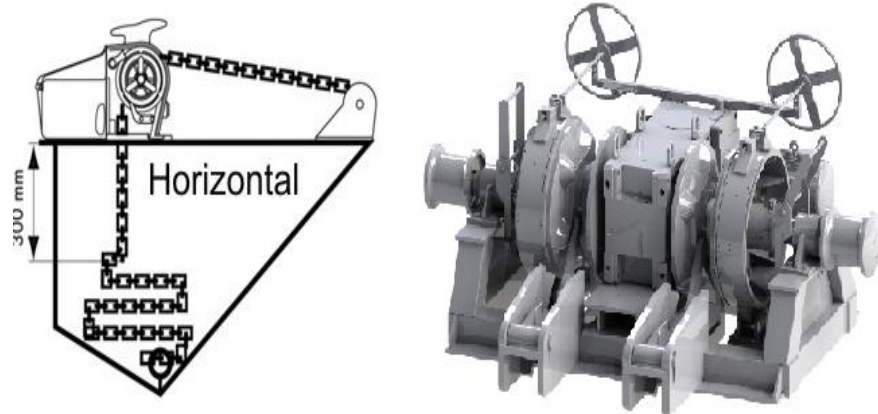
1. Ukuran kapal
2. Service dari kapal
3. Berat jangkar dan rantai jangkar
4. Losses akibat gelombang air
5. Losses akibat gesekan dari hawspipe (30%-40%)

Type windlass yang mempunyai poros (poros dari wildcat, gearbox utama, dan gypsy head) yang horizontal dengan deck kapal.

Windlass horizontal digerakan oleh motor hidrolis dan motor listrik ataupun oleh mesin uap. Windlass jenis ini lebih murah dalam pemasangannya tapi dibutuhkan perawatan yang lebih sulit karena



permesinannya yang berada diatas deck dan terkena langsung dengan udara luar dan gelombang seperti pada gambar di bawah ini.



**Gambar 26. Mesin Jangkar**

c. Chain Locker (kotak rantai)

Ketentuan-ketentuan dari Chain Locker:

- umumnya didalamnya dilapisi dengan kayu untuk mencegah suara berisik pada saat lego/hibobo jangkar.
- Dasar dari chain locker dibuat berlubang untuk mengeluarkan kotoran yang dibawa jangkar dari dasar laut. Dibawah dasar chain locker dilengkapi dengan bak dasar dari semen dibuat miring supaya kotoran mudah mengalir.
- Disediakan alat pengikat ujung rantai jangkar agar tidak hilang pada waktu lego jangkar.
- Harus ada dinding pemisah antara kotak rantai sebelah kiri dan kanan.

Volume kotak rantai ditentukan oleh volume dari rantai jangkar

$$\text{Volume Chain locker (V)} = 1,1 \times d^2 \times L/10^5$$

Dimana :

$$L = \text{Panjang Rantai Jangkar} = 467,5 \text{ m}$$

$$\text{Diameter rantai jangkar (d)} = 40 \text{ mm}$$

$$\begin{aligned} \text{Maka, } V &= 8,23 \text{ m}^3 \\ \text{Ditambah 20\% untuk Volume Bak Lumpur} \\ \text{Ditambah 5\% untuk konstruksi kayu} \\ \text{Jadi, } V &= 1,1 \times 40 \times 467,5 / 10^5 = 9,89 \text{ m}^3 \\ \text{Chain locker direncanakan: } P \times l \times t &= 3 \times 2 \times 2 \end{aligned}$$

### V.5.12 Perlengkapan bongkar muat

#### a. Palka

Palka merupakan tempat laluan untuk memasukkan dan mengeluarkan muatan dari ruang muat (Cargo Hold) menuju ke pelabuhan atau sebaliknya, menurut Ing, J.P. De Haan, dalam PRACTICAL SHIPBUILDING, handbook, bahwa panjang lubang palka (L) 63% dari panjang kompartemen ruang muat dan lebarnya(w) 60% lebar kapal.

Untuk ruang muat dimensi lubang palkahnya adalah :

$$L = 63\% L \text{ kompartement}$$

$$W = 60\% B$$

Panjang ruang muat

$$\text{Ruang muat 1-2} = 24,5 \text{ m}$$

$$\text{Ruang muat 3} = 24,4 \text{ m}$$

$$L = 15,435$$

$$W = 9,822$$

### V.5.13 Tonnage

Kapal dalam fungsinya sebagai alat angkut yang dipergunakan dalam kegiatan ekonomi, maka kapal tersebut tentulah dikenakan pajak-pajak serta memerlukan biaya sehubungan dengan kegiannya. Sebagaimana diketahui, pertambahan besar kapal itu sangat bervariasi baik terhadap panjang, lebar maupun tingginya.

Besarnya panjang kapal atau bahkan panjang dan lebar sekalipun, blum dapat dipakai sebagai pedoman untuk menunjukkan besarnya kapal. Sebab ukuran besarnya kapal adalah persoalan kapasitas muatan (*carrying capacity*). Oleh karna itu dalam menentukan pajak, berlaku

pedoman bahwa besarnya pajak yang dikenakan pada sebuah kapal haruslah sebanding dengan kemampuan kapal tersebut untuk memberikan penghasilan (*potensial earning capacity*). Atas dasar pemikiran ini karena tonnage kapal dianggap dapat menggambarkan *potensial earning capacity* sebuah kapal, maka besar pajak-pajak yang dikenakan pada suatu kapal dapat didasarkan atas besarnya *tonnage* nya.

dapat di simpulkan guna *tonnage* adalah:

- a. Untuk menunjukkan ukuran besarnya kapal, yaitu kapasitas muatan
- b. Bagi pemerintah adalah untuk dasar pegangan dalam memungut pajak diantaranya adalah untuk dasar pegangan dalam memungut pajak diantaranya adalah pajak pelabuhan sebagai imbalan atas pelayanan yang telah diterima oleh kapal itu.
- c. Bagi pemilik untuk memperkirakan pendapatan maupun pengeluaran pajak dan ongkos yang harus dikeluarkan pada waktu tertentu.
- d. *Tonnage* digunakan pula sebagai batasan-batasan terhadap berlakunya syarat-syarat keselamatan kapal ataupun beberapa syarat lainnya.

Ada 2 macam pengukuran register *tonnage* yang dikenal, yaitu:

1. GRT (*Gross Register Tonnage*) atau BRT (*Bruto Register Tonnage*)
2. NRT (*Netto Register Tonnage*)

Gross register tonnage (GRT) adalah perhitungan volume semua ruangan terletak dibawah geladak kapal ditambah dengan volume ruangan tertutup yang terletak diatas geladak ditambah dengan isi ruangan beserta semua ruangan tertutup yang terletak diatas geladak paling atas (*superstructure*).

Net register tonnage (NRT) adalah perhitungan ruangan dalam kapal untuk muatan. Dinyatakan dalam ton yang merupakan representasi dari 100 kubik kaki yang setara dengan 2.833 m<sup>3</sup>

Untuk menghitung besarnya gross register tonnage dan netto register tonnage kapal dipakai peraturan internasional convention on tonnage measurment of ship 1969. Dimana gross tonnage dari sebuah kapal ditentukan dengan rumus sebagai berikut

Gross register tonnage (GRT) adalh perhitungan volume semua ruangan terletak dibawah geladak kapal ditambah dengan volume ruangaan tertutup yang terletak diatas geladak ditambah dengan isi ruangan beserta semua ruangan tertutup yang terletak diatas geladak paling atas (superstructere).

Net register tonnage (NRT) adalah perhitungan ruangan dalam kapal untuk muatan. Dinyatakan dalam ton yang merupakan respresentasi dari 100 kubik kaki yang setara dengan 2.833 m<sup>3</sup>

Untuk menghitung besarnya gross register tonnage dan netto register tonnage kapal dipakai peraturan internasional convention on tonnage measurment of ship 1969. Dimana gross tonnage dari sebuah kapal ditentukan dengan rumus sebagai berikut

$$G = K1 \times V$$

Dimana :

V = Volume total semua ruangan tertutupi dalam kapal (m<sup>3</sup>)

$$K1 = 0,2 + 0,02 \text{ Log } V$$

Sedangkan NRT dari sebuah kapal ditentukan dengan rumus sebagai berikut:

$$NT = K_2 \times V_c \times \left( \frac{4 \times T}{5 \times H} \right)^2$$

Dimana :

V<sub>c</sub> =Volume total dari ruangan muat dalam m<sup>3</sup>

$$K_2 = 0,2 + 0,02 \text{ Log } V$$

H = Tinggi Kapal (m)

T = Sarat air (m)

Perhitungan BRT

Perhitunan volume

- Volume Lambung

Kapal di bawah main deck = 10308,56247 m<sup>3</sup>

|                          |               |                  |
|--------------------------|---------------|------------------|
| - Volume Fore Castle     | = 229,12328   | m <sup>3</sup>   |
| - Volume Poop deck       | = 357,792     | m <sup>3</sup>   |
| - Volume Boat deck       | = 296,664     | m <sup>3</sup>   |
| - Volume navigation deck | = 153,24      | m <sup>3</sup>   |
| - Volume well house deck | = 109,464     | m <sup>3</sup>   |
| - Volume main deck       | = 639,864     | m <sup>3</sup> + |
| <hr/>                    |               |                  |
| Volume total             | = 12094,71927 | m <sup>3</sup>   |

$$GRT = K_1 \times V$$

Dimana :

$$K_1 = 0,2 + 0,02 \text{ Log } 12094,71927$$

$$K_1 = 0,281$$

$$GRT = 0,281 \times 12094,71927$$

$$GRT = 3398,616 \text{ RT}$$

$$NRT = 0,281 \times 12094,71927 \times \left( \frac{4 \times 6,78}{5 \times 8,26} \right)^2$$

$$NRT = 1465,485 \text{ RT}$$

## V.6 Stabilitas *Trim*

### V.6.1 Perkiraan letak titik vertical center of bouyancy ( VCB atau KB )

Menggunakan rumus Jagger Morrish.

$$KB = (d (5.Cw - 2.Cb)) / (6.Cw)$$

$$KB = (8,61(5 \times 0,83 - 2 \times 0,76)) / (6 \times 0,83)$$

$$KB = 4,55 \text{ m}$$

### V.6.2 Perkiraan letak titik metacentre melintang terhadap titik buoyancy kapal (BMT)

Menggunakan rumus Selentin.

$$BM_T = \frac{(B^2 \times CW^2)}{11,6 \times d \times cb}$$

$$BM_T = \frac{(18,49^2 \times 0,83^2)}{11,6 \times 8,61 \times 0,76}$$

$$BM_T = 3,10 \text{ m}$$

**V.6.3 Perkiraan jarak titik metacentre melintang terhadap garis dasar (KMT).**

$$KM_T = KB + BM_T$$

$$KM_T = 4,55 + 3,10$$

$$KM_T = 7,65 \text{ m}$$

Maka harga GMT dapat diketahui dengan jalan sebagai berikut :

$$GM_T = KM_T - KG$$

$$KG = 0,6 \times (0,6H)$$

$$GM_T = 0,67 \text{ m}$$

**V.6.4 Perkiraan jarak titik metacentre memanjang (BML).**

Menggunakan rumus Posdunine.

$$BM_l = \frac{L^2(5,55 \times CW + 1)^3}{3450 \times d \times Cb}$$

$$BM_l = \frac{125,93(5,55 \times 0,83 + 1)^3}{3450 \times 8,61 \times 0,76}$$

$$BM_l = 123,80 \text{ m}$$

**V.6.5 Perkiraan jarak titik metacentre memanjang terhadap garis dasar (KML).**

$$KM_l = KB + BM_l$$

$$KM_l = 4,55 + 123,80$$

$$KM_l = 128,35 \text{ m}$$

$$GM_l = KM_l + KG$$

$$GM_l = 121,37 \text{ m}$$

### V.6.6 Perkiraan harga moment to change of trim 1 cm ( MTC )

$$MTC = \frac{\Delta \times GML}{100 \times lpp}$$

$$MTC = \frac{15619,406 \times 121,37}{100 \times 125,93}$$

$$MTC = 150,54 \text{ ton/cm}$$

### V.6.7 Perkiraan Titik Tekan Memanjang (LCB)

Fr = 0,10 – 0,20 ; LCB = (0 – 2)% Lpp, di depan midship +

Fr = 0,20 – 0,23 ; LCB = di midship

Fr ≥ 0,23 ; LCB = 2% di belakang midship -

$$Fr = Vd/(\sqrt{gxL})$$

$$FR = \frac{lpp}{(9,81 \times vd)^2}$$

$$FR = \frac{125,93}{(9,81 \times 14,0)^2}$$

$$FR = 0,40 \text{ (LCB = 2% di belakang midship)}$$

$$LCB = (2 - 3)\% \times lpp$$

$$LCB = 2,51 \text{ m}$$

$$LCB = (2 - 3)\% \times lpp$$

$$= 3,78 \text{ m}$$

$$BG = LCG - LCB = 1,26 \text{ m (momen kapal ke arah belakang)}$$

$$Trim = \frac{(\Delta \times BG)}{100 \times lpp}$$

$$Trim = \frac{(15619,4 \times 1,26)}{100 \times 125,93}$$

$$Trim = 1,561940595 \text{ m (trim by stern)}$$

### V.6.8 TPC

$$TPC = \frac{(1,025 \times AW)}{100}$$

$$TPC = 19,81 \text{ ton/cm}$$

### V.6.9 Perkiraan waktu oleng.

$$t = (2 \times i) / (\sqrt{GMT})$$

Dimana :

$t$  = waktu keolengan kapal dalam detik.

$i$  = radius gerasi yang harganya berkisar antara  $(0,3 B - 0,45) B$  m

$i = 5,548$  m

$t = 9,03$  detik

Sedangkan harga periode oleng kapal yang baik menurut *Herner* adalah :

jika  $t \times \sqrt{(g)/B}$  terletak antara 8 – 14 detik.

$$\text{Periode oleng} = t \times \sqrt{(g)/B}$$

$$\text{Periode Oleng} = 7,46 \text{ detik}$$

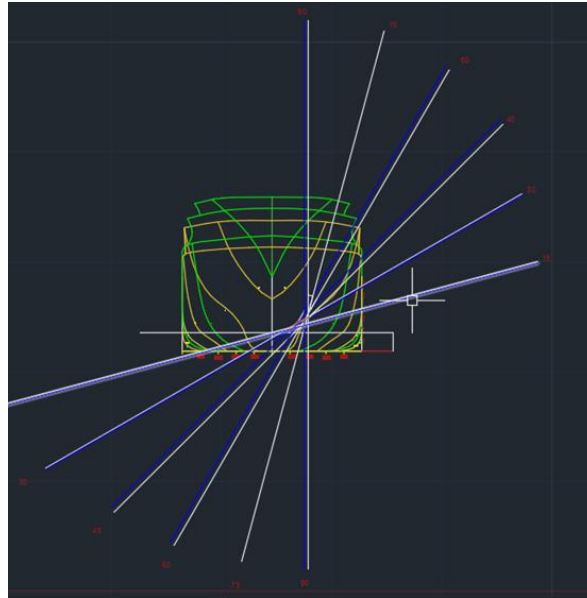
### V.6.9 Perhitungan Kurva Silang

Kurva silang adalah kurva/diagram yang dipergunakan untuk mengetahui besarnya  $NB \sin \theta$  dari kapal pada masing – masing kemiringan (kemiringan  $15^\circ - 90^\circ$ ) pada waktu kapal berlayar. Dari kurva silang ini selanjutnya dibuat kurva stabilitas kapal, perhitungan stabilitas dari kapal dimaksudkan agar kita dapat mengetahui bermacam–macam sudut oleng, berapakah kemampuan dari kapal tersebut (besarnya momen koppel atau momen penegak) untuk dapat tegak kembali.

Kurva silang adalah kumpulan kurva yang menunjukkan besarnya lengan penegak (momen koppel) pada berbagai kemiringan dengan, beberapa kondisi displasement ( $\Delta$ ). Perhitungan kurva silang ini menggunakan perhitungan dari metode A.N Krylof, yaitu dengan menentukan harga  $G$  zatau  $LC = NB \sin \theta \Delta$



## 1. Kondisi 25%



Gambar 27. Kurva Silang Kondisi 25%

Tabel 65. Kurva Silang Kondisi 25% 0°

|              |   |           |                |            |   |              |
|--------------|---|-----------|----------------|------------|---|--------------|
| T            | = | 2,152299  | m              |            |   |              |
| LPP          | = | 125,92903 | m              |            |   |              |
| Displacement | = | 3904,8515 | Ton            | Condition  | = | 25%          |
| Volume       | = | 3809,6112 | m <sup>3</sup> | h = Lpp/10 | = | 12,5929027 m |

| Nomor Section | $\varphi = 0^\circ$               |        |                 |                 |                 |                 |
|---------------|-----------------------------------|--------|-----------------|-----------------|-----------------|-----------------|
|               | Ya                                | Yb     | Ya <sup>2</sup> | Yb <sup>2</sup> | Ya <sup>3</sup> | Yb <sup>3</sup> |
| -5            | 0,000                             | 0,000  | 0,000           | 0,000           | 0,000           | 0,000           |
| -4            | 3,440                             | 3,440  | 11,834          | 11,834          | 40,708          | 40,708          |
| -3            | 6,310                             | 6,310  | 39,816          | 39,816          | 251,240         | 251,240         |
| -2            | 8,370                             | 8,370  | 70,057          | 70,057          | 586,376         | 586,376         |
| -1            | 9,310                             | 9,310  | 86,676          | 86,676          | 806,954         | 806,954         |
| 0             | 9,310                             | 9,310  | 86,676          | 86,676          | 806,954         | 806,954         |
| 1             | 9,310                             | 9,310  | 86,676          | 86,676          | 806,954         | 806,954         |
| 2             | 9,310                             | 9,310  | 86,676          | 86,676          | 806,954         | 806,954         |
| 3             | 8,230                             | 8,230  | 67,733          | 67,733          | 557,442         | 557,442         |
| 4             | 3,940                             | 3,940  | 15,524          | 15,524          | 61,163          | 61,163          |
| 5             | 0,000                             | 0,000  | 0,000           | 0,000           | 0,000           | 0,000           |
| $\Sigma$      | 67,530                            | 67,530 | 551,668         | 551,668         | 4724,746        | 4724,746        |
| I             | $\Sigma (Ya + Yb)$                | =      | 135,06          | m               |                 |                 |
| II            | $\Sigma (Ya^2 - Yb^2)$            | =      | 0,00            | m <sup>2</sup>  |                 |                 |
| III           | $\Sigma (Ya^3 + Yb^3)$            | =      | 9449,49         | m <sup>3</sup>  |                 |                 |
| IV            | $e = 1/2 \cdot (II)/(I)$          | =      | 0,00            | m               | e/2             | = 0,000 m       |
| V             | $I_o = 1/3 h (III)$               | =      | 39665,51        | m <sup>4</sup>  |                 |                 |
| VI            | $df = h \cdot (I) \cdot (IV)^2$   | =      | 0,00            | m <sup>4</sup>  |                 |                 |
| VII           | $I_f = (V) - (VI)$                | =      | 39665,51        | m <sup>4</sup>  |                 |                 |
| VIII          | $MB\theta (r\theta) = VII/Volume$ | =      | 10,41           | m               |                 |                 |

**Tabel 66. Kurva Silang Kondisi 25% 15°**

|              |   |           |                |            |   |              |
|--------------|---|-----------|----------------|------------|---|--------------|
| T            | = | 2,152299  | m              |            |   |              |
| LPP          | = | 125,92903 | m              |            |   |              |
| Displacement | = | 3904,8515 | Ton            | Condition  | = | 25%          |
| Volume       | = | 3809,6112 | m <sup>3</sup> | h = Lpp/10 | = | 12,5929027 m |

| Nomor Section | $\phi = 15^\circ$                 |        |                 |                 |                 |                 |
|---------------|-----------------------------------|--------|-----------------|-----------------|-----------------|-----------------|
|               | Ya                                | Yb     | Ya <sup>2</sup> | Yb <sup>2</sup> | Ya <sup>3</sup> | Yb <sup>3</sup> |
| -5            | 0,000                             | 0,000  | 0,000           | 0,000           | 0,000           | 0,000           |
| -4            | 4,020                             | 3,130  | 16,160          | 9,797           | 64,965          | 30,664          |
| -3            | 7,520                             | 5,340  | 56,550          | 28,516          | 425,259         | 152,273         |
| -2            | 9,260                             | 6,900  | 85,748          | 47,610          | 794,023         | 328,509         |
| -1            | 9,580                             | 7,860  | 91,776          | 61,780          | 879,218         | 485,588         |
| 0             | 9,580                             | 7,860  | 91,776          | 61,780          | 879,218         | 485,588         |
| 1             | 9,580                             | 7,860  | 91,776          | 61,780          | 879,218         | 485,588         |
| 2             | 9,580                             | 7,860  | 91,776          | 61,780          | 879,218         | 485,588         |
| 3             | 8,820                             | 6,900  | 77,792          | 47,610          | 686,129         | 328,509         |
| 4             | 4,400                             | 3,520  | 19,360          | 12,390          | 85,184          | 43,614          |
| 5             | 0,000                             | 0,000  | 0,000           | 0,000           | 0,000           | 0,000           |
| $\Sigma$      | 72,340                            | 57,230 | 622,716         | 393,041         | 5572,431        | 2825,920        |
| I             | $\Sigma (Ya + Yb)$                | =      | 129,57          | m               |                 |                 |
| II            | $\Sigma (Ya^2 - Yb^2)$            | =      | 229,68          | m <sup>2</sup>  |                 |                 |
| III           | $\Sigma (Ya^3 + Yb^3)$            | =      | 8398,35         | m <sup>3</sup>  |                 |                 |
| IV            | $e = 1/2 \cdot (II)/(I)$          | =      | 0,89            | m               | e/2             | = 0,44 m        |
| V             | $Io = 1/3 h (III)$                | =      | 35253,21        | m <sup>4</sup>  |                 |                 |
| VI            | $df = h \cdot (I) \cdot (IV)^2$   | =      | 1281,71         | m <sup>4</sup>  |                 |                 |
| VII           | $If = (V) - (VI)$                 | =      | 33971,50        | m <sup>4</sup>  |                 |                 |
| VIII          | $MB\theta (r\theta) = VII/Volume$ | =      | 8,92            | m               |                 |                 |

**Tabel 67. Kurva Silang Kondisi 25% 30°**

|              |   |          |                |            |   |           |
|--------------|---|----------|----------------|------------|---|-----------|
| T            | = | 2,152299 | m              |            |   |           |
| LPP          | = | 125,929  | m              |            |   |           |
| Displacement | = | 3904,851 | Ton            | Condition  | = | 25%       |
| Volume       | = | 3809,611 | m <sup>3</sup> | h = Lpp/10 | = | 12,5929 m |

| Nomor Section | $\phi = 30^\circ$                 |        |                 |                 |                 |                 |
|---------------|-----------------------------------|--------|-----------------|-----------------|-----------------|-----------------|
|               | Ya                                | Yb     | Ya <sup>2</sup> | Yb <sup>2</sup> | Ya <sup>3</sup> | Yb <sup>3</sup> |
| -5            | 0,000                             | 0,000  | 0,000           | 0,000           | 0,000           | 0,000           |
| -4            | 5,010                             | 3,230  | 25,100          | 10,433          | 125,752         | 33,698          |
| -3            | 9,190                             | 4,140  | 84,456          | 17,140          | 776,152         | 70,958          |
| -2            | 10,080                            | 4,290  | 101,606         | 18,404          | 1024,193        | 78,954          |
| -1            | 10,170                            | 4,290  | 103,429         | 18,404          | 1051,872        | 78,954          |
| 0             | 10,170                            | 4,290  | 103,429         | 18,404          | 1051,872        | 78,954          |
| 1             | 10,170                            | 4,290  | 103,429         | 18,404          | 1051,872        | 78,954          |
| 2             | 10,170                            | 4,290  | 103,429         | 18,404          | 1051,872        | 78,954          |
| 3             | 9,150                             | 4,290  | 83,723          | 18,404          | 766,061         | 78,954          |
| 4             | 4,580                             | 3,300  | 20,976          | 10,890          | 96,072          | 35,937          |
| 5             | 0,000                             | 0,000  | 0,000           | 0,000           | 0,000           | 0,000           |
| $\Sigma$      | 78,690                            | 36,410 | 729,577         | 148,887         | 6995,716        | 614,315         |
| I             | $\Sigma (Ya + Yb)$                | =      | 115,10          | m               |                 |                 |
| II            | $\Sigma (Ya^2 - Yb^2)$            | =      | 580,69          | m <sup>2</sup>  |                 |                 |
| III           | $\Sigma (Ya^3 + Yb^3)$            | =      | 7610,03         | m <sup>3</sup>  |                 |                 |
| IV            | $e = 1/2 \cdot (II)/(I)$          | =      | 2,52            | m               | e/2             | = 1,26 m        |
| V             | $Io = 1/3 h (III)$                | =      | 31944,13        | m <sup>4</sup>  |                 |                 |
| VI            | $df = h \cdot (I) \cdot (IV)^2$   | =      | 9223,15         | m <sup>4</sup>  |                 |                 |
| VII           | $If = (V) - (VI)$                 | =      | 22720,98        | m <sup>4</sup>  |                 |                 |
| VIII          | $MB\theta (r\theta) = VII/Volume$ | =      | 5,96            | m               |                 |                 |

**Tabel 68. Kurva Silang Kondisi 25% 45°**

|              |   |           |                |            |   |              |
|--------------|---|-----------|----------------|------------|---|--------------|
| T            | = | 2,152299  | m              |            |   |              |
| LPP          | = | 125,92903 | m              |            |   |              |
| Displacement | = | 3904,8515 | Ton            | Condition  | = | 25%          |
| Volume       | = | 3809,6112 | m <sup>3</sup> | h = Lpp/10 | = | 12,5929027 m |

| Nomor<br>Section | $\phi = 45^\circ$                 |        |                 |                 |                 |                 |
|------------------|-----------------------------------|--------|-----------------|-----------------|-----------------|-----------------|
|                  | Ya                                | Yb     | Ya <sup>2</sup> | Yb <sup>2</sup> | Ya <sup>3</sup> | Yb <sup>3</sup> |
| -5               | 0,000                             | 0,000  | 0,000           | 0,000           | 0,000           | 0,000           |
| -4               | 10,250                            | 3,470  | 105,063         | 12,041          | 1076,891        | 41,782          |
| -3               | 10,690                            | 3,500  | 114,276         | 12,250          | 1221,612        | 42,875          |
| -2               | 10,700                            | 3,500  | 114,490         | 12,250          | 1225,043        | 42,875          |
| -1               | 10,730                            | 3,500  | 115,133         | 12,250          | 1235,376        | 42,875          |
| 0                | 10,730                            | 3,500  | 115,133         | 12,250          | 1235,376        | 42,875          |
| 1                | 10,730                            | 3,500  | 115,133         | 12,250          | 1235,376        | 42,875          |
| 2                | 10,730                            | 3,500  | 115,133         | 12,250          | 1235,376        | 42,875          |
| 3                | 10,330                            | 3,500  | 106,709         | 12,250          | 1102,303        | 42,875          |
| 4                | 4,020                             | 3,430  | 16,160          | 11,765          | 64,965          | 40,354          |
| 5                | 0,000                             | 0,000  | 0,000           | 0,000           | 0,000           | 0,000           |
| $\Sigma$         | 88,910                            | 31,400 | 917,230         | 109,556         | 9632,317        | 382,261         |
| I                | $\Sigma (Ya + Yb)$                | =      | 120,31          | m               |                 |                 |
| II               | $\Sigma (Ya^2 - Yb^2)$            | =      | 807,67          | m <sup>2</sup>  |                 |                 |
| III              | $\Sigma (Ya^3 + Yb^3)$            | =      | 10014,58        | m <sup>3</sup>  |                 |                 |
| IV               | $e = 1/2 \cdot (II)/(I)$          | =      | 3,36            | m               | e/2             | = 1,68 m        |
| V                | $Io = 1/3 h (III)$                | =      | 42037,53        | m <sup>4</sup>  |                 |                 |
| VI               | $df = h \cdot (I) \cdot (IV)^2$   | =      | 17070,10        | m <sup>4</sup>  |                 |                 |
| VII              | $If = (V) - (VI)$                 | =      | 24967,44        | m <sup>4</sup>  |                 |                 |
| VIII             | $MB\theta (r\theta) = VII/Volume$ | =      | 6,55            | m               |                 |                 |

**Tabel 69. Kurva Silang Kondisi 25% 60°**

|              |   |           |                |            |   |              |
|--------------|---|-----------|----------------|------------|---|--------------|
| T            | = | 2,152299  | m              |            |   |              |
| LPP          | = | 125,92903 | m              |            |   |              |
| Displacement | = | 3904,8515 | Ton            | Condition  | = | 25%          |
| Volume       | = | 3809,6112 | m <sup>3</sup> | h = Lpp/11 | = | 12,5929027 m |

| Nomor<br>Section | $\phi = 60^\circ$                 |        |                 |                 |                 |                 |
|------------------|-----------------------------------|--------|-----------------|-----------------|-----------------|-----------------|
|                  | Ya                                | Yb     | Ya <sup>2</sup> | Yb <sup>2</sup> | Ya <sup>3</sup> | Yb <sup>3</sup> |
| -5               | 4,750                             | 3,740  | 22,563          | 13,988          | 107,172         | 52,314          |
| -4               | 9,580                             | 3,830  | 91,776          | 14,669          | 879,218         | 56,182          |
| -3               | 9,580                             | 3,830  | 91,776          | 14,669          | 879,218         | 56,182          |
| -2               | 9,580                             | 3,830  | 91,776          | 14,669          | 879,218         | 56,182          |
| -1               | 9,580                             | 3,830  | 91,776          | 14,669          | 879,218         | 56,182          |
| 0                | 9,580                             | 3,830  | 91,776          | 14,669          | 879,218         | 56,182          |
| 1                | 9,580                             | 3,830  | 91,776          | 14,669          | 879,218         | 56,182          |
| 2                | 9,580                             | 3,830  | 91,776          | 14,669          | 879,218         | 56,182          |
| 3                | 9,580                             | 3,830  | 91,776          | 14,669          | 879,218         | 56,182          |
| 4                | 2,880                             | 3,730  | 8,294           | 13,913          | 23,888          | 51,895          |
| 5                | 0,000                             | 0,000  | 0,000           | 0,000           | 0,000           | 0,000           |
| $\Sigma$         | 84,270                            | 38,110 | 765,068         | 145,252         | 7164,803        | 553,664         |
| I                | $\Sigma (Ya + Yb)$                | =      | 122,38          | m               |                 |                 |
| II               | $\Sigma (Ya^2 - Yb^2)$            | =      | 619,82          | m <sup>2</sup>  |                 |                 |
| III              | $\Sigma (Ya^3 + Yb^3)$            | =      | 7718,47         | m <sup>3</sup>  |                 |                 |
| IV               | $e = 1/2 \cdot (II)/(I)$          | =      | 2,53            | m               | e/2             | = 1,27 m        |
| V                | $Io = 1/3 h (III)$                | =      | 32399,30        | m <sup>4</sup>  |                 |                 |
| VI               | $df = h \cdot (I) \cdot (IV)^2$   | =      | 9882,83         | m <sup>4</sup>  |                 |                 |
| VII              | $If = (V) - (VI)$                 | =      | 22516,47        | m <sup>4</sup>  |                 |                 |
| VIII             | $MB\theta (r\theta) = VII/Volume$ | =      | 5,91            | m               |                 |                 |

**Tabel 70. Kurva Silang Kondisi 25% 75°**

|              |   |          |                |              |   |           |
|--------------|---|----------|----------------|--------------|---|-----------|
| T            | = | 2,152299 | m              |              |   |           |
| LPP          | = | 125,929  | m              |              |   |           |
| Displacement | = | 3904,851 | Ton            | Condition    | = | 25%       |
| Volume       | = | 3809,611 | m <sup>3</sup> | $h = Lpp/10$ | = | 12,5929 m |

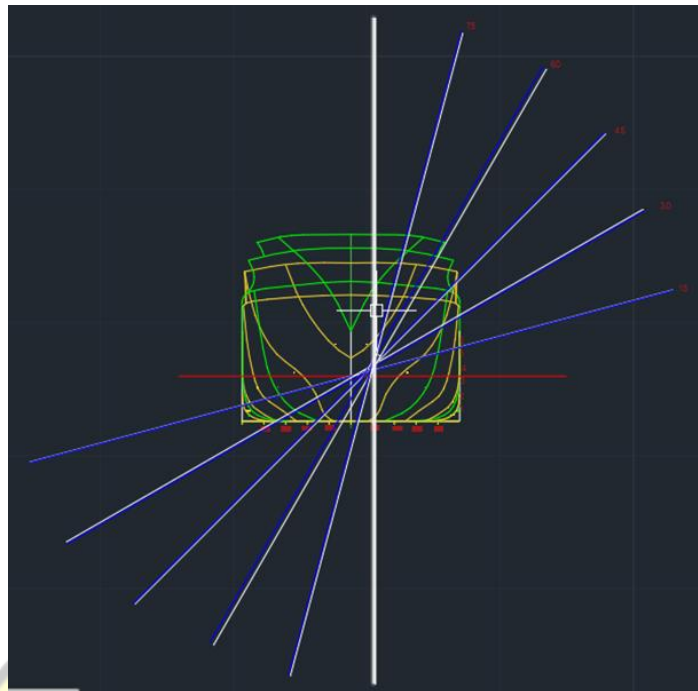
| Nomor<br>Section | $\phi = 75^\circ$                 |        |                 |                 |                 |                 |
|------------------|-----------------------------------|--------|-----------------|-----------------|-----------------|-----------------|
|                  | Ya                                | Yb     | Ya <sup>2</sup> | Yb <sup>2</sup> | Ya <sup>3</sup> | Yb <sup>3</sup> |
| -5               | 4,690                             | 0,000  | 21,996          | 0,000           | 103,162         | 0,000           |
| -4               | 7,690                             | 2,080  | 59,136          | 4,326           | 454,757         | 8,999           |
| -3               | 7,690                             | 4,300  | 59,136          | 18,490          | 454,757         | 79,507          |
| -2               | 7,690                             | 4,430  | 59,136          | 19,625          | 454,757         | 86,938          |
| -1               | 7,690                             | 4,430  | 59,136          | 19,625          | 454,757         | 86,938          |
| 0                | 7,690                             | 4,430  | 59,136          | 19,625          | 454,757         | 86,938          |
| 1                | 7,690                             | 4,430  | 59,136          | 19,625          | 454,757         | 86,938          |
| 2                | 7,690                             | 4,430  | 59,136          | 19,625          | 454,757         | 86,938          |
| 3                | 7,690                             | 4,430  | 59,136          | 19,625          | 454,757         | 86,938          |
| 4                | 4,690                             | 3,310  | 21,996          | 10,956          | 103,162         | 36,265          |
| 5                | 0,000                             | 0,000  | 0,000           | 0,000           | 0,000           | 0,000           |
| $\Sigma$         | 70,900                            | 36,270 | 517,081         | 151,522         | 3844,376        | 646,400         |
| I                | $\Sigma (Ya + Yb)$                | =      | 107,17          | m               |                 |                 |
| II               | $\Sigma (Ya^2 - Yb^2)$            | =      | 365,56          | m <sup>2</sup>  |                 |                 |
| III              | $\Sigma (Ya^3 + Yb^3)$            | =      | 4490,78         | m <sup>3</sup>  |                 |                 |
| IV               | $e = 1/2 \cdot (II)/(I)$          | =      | 1,71            | m               | $e/2$           | = 0,85 m        |
| V                | $Io = 1/3 h (III)$                | =      | 18850,64        | m <sup>4</sup>  |                 |                 |
| VI               | $df = h \cdot (I) \cdot (IV)^2$   | =      | 3925,62         | m <sup>4</sup>  |                 |                 |
| VII              | $If = (V) - (VI)$                 | =      | 14925,02        | m <sup>4</sup>  |                 |                 |
| VIII             | $MB\theta (r\theta) = VII/Volume$ | =      | 3,92            | m               |                 |                 |

**Tabel 71. Kurva Silang Kondisi 25% 90°**

|              |   |           |                |              |   |              |
|--------------|---|-----------|----------------|--------------|---|--------------|
| T            | = | 2,152299  | m              |              |   |              |
| LPP          | = | 125,92903 | m              |              |   |              |
| Displacement | = | 3904,8515 | Ton            | Condition    | = | 25%          |
| Volume       | = | 3809,6112 | m <sup>3</sup> | $h = Lpp/10$ | = | 12,5929027 m |

| Nomor<br>Section | $\phi = 90^\circ$                 |        |                 |                 |                 |                 |
|------------------|-----------------------------------|--------|-----------------|-----------------|-----------------|-----------------|
|                  | Ya                                | Yb     | Ya <sup>2</sup> | Yb <sup>2</sup> | Ya <sup>3</sup> | Yb <sup>3</sup> |
| -5               | 4,630                             | 0,000  | 21,437          | 0,000           | 99,253          | 0,000           |
| -4               | 6,690                             | 0,230  | 44,756          | 0,053           | 299,418         | 0,012           |
| -3               | 6,690                             | 0,770  | 44,756          | 0,593           | 299,418         | 0,457           |
| -2               | 6,690                             | 4,570  | 44,756          | 20,885          | 299,418         | 95,444          |
| -1               | 6,690                             | 4,920  | 44,756          | 24,206          | 299,418         | 119,095         |
| 0                | 6,690                             | 4,920  | 44,756          | 24,206          | 299,418         | 119,095         |
| 1                | 6,690                             | 4,920  | 44,756          | 24,206          | 299,418         | 119,095         |
| 2                | 6,690                             | 4,920  | 44,756          | 24,206          | 299,418         | 119,095         |
| 3                | 6,690                             | 4,920  | 44,756          | 24,206          | 299,418         | 119,095         |
| 4                | 6,690                             | 4,920  | 44,756          | 24,206          | 299,418         | 119,095         |
| 5                | 0,000                             | 4,920  | 0,000           | 24,206          | 0,000           | 119,095         |
| $\Sigma$         | 64,840                            | 40,010 | 424,242         | 190,976         | 2794,018        | 929,581         |
| I                | $\Sigma (Ya + Yb)$                | =      | 104,85          | m               |                 |                 |
| II               | $\Sigma (Ya^2 - Yb^2)$            | =      | 233,27          | m <sup>2</sup>  |                 |                 |
| III              | $\Sigma (Ya^3 + Yb^3)$            | =      | 3723,60         | m <sup>3</sup>  |                 |                 |
| IV               | $e = 1/2 \cdot (II)/(I)$          | =      | 1,11            | m               | $e/2$           | = 0,56 m        |
| V                | $Io = 1/3 h (III)$                | =      | 15630,31        | m <sup>4</sup>  |                 |                 |
| VI               | $df = h \cdot (I) \cdot (IV)^2$   | =      | 1633,81         | m <sup>4</sup>  |                 |                 |
| VII              | $If = (V) - (VI)$                 | =      | 13996,50        | m <sup>4</sup>  |                 |                 |
| VIII             | $MB\theta (r\theta) = VII/Volume$ | =      | 3,67            | m               |                 |                 |

2. Kondisi 50%



Gambar 28. Kurva Silang Kondisi 50%

Tabel 72. Kurva Silang Kondisi 50% 0°

T = 4,304598 m  
 LPP = 125,92903 m  
 Displacement = 7809,703 Ton      Condition = 50%  
 Volume = 7619,2224 m<sup>3</sup>      h = Lpp/10 = 12,5929027 m

| Nomor Section | $\phi = 0^\circ$                  |        |                 |                 |                 |                 |
|---------------|-----------------------------------|--------|-----------------|-----------------|-----------------|-----------------|
|               | Ya                                | Yb     | Ya <sup>2</sup> | Yb <sup>2</sup> | Ya <sup>3</sup> | Yb <sup>3</sup> |
| -5            | 0,000                             | 0,000  | 0,000           | 0,000           | 0,000           | 0,000           |
| -4            | 4,370                             | 4,370  | 19,097          | 19,097          | 83,453          | 83,453          |
| -3            | 7,360                             | 7,360  | 54,170          | 54,170          | 398,688         | 398,688         |
| -2            | 8,900                             | 8,900  | 79,210          | 79,210          | 704,969         | 704,969         |
| -1            | 9,240                             | 9,240  | 85,378          | 85,378          | 788,889         | 788,889         |
| 0             | 9,240                             | 9,240  | 85,378          | 85,378          | 788,889         | 788,889         |
| 1             | 9,240                             | 9,240  | 85,378          | 85,378          | 788,889         | 788,889         |
| 2             | 9,240                             | 9,240  | 85,378          | 85,378          | 788,889         | 788,889         |
| 3             | 8,500                             | 8,500  | 72,250          | 72,250          | 614,125         | 614,125         |
| 4             | 4,520                             | 4,520  | 20,430          | 20,430          | 92,345          | 92,345          |
| 5             | 0,000                             | 0,000  | 0,000           | 0,000           | 0,000           | 0,000           |
| $\Sigma$      | 70,610                            | 70,610 | 586,667         | 586,667         | 5049,137        | 5049,137        |
| I             | $\Sigma (Ya + Yb)$                | =      | 141,22          | m               |                 |                 |
| II            | $\Sigma (Ya^2 - Yb^2)$            | =      | 0,00            | m <sup>2</sup>  |                 |                 |
| III           | $\Sigma (Ya^3 + Yb^3)$            | =      | 10098,27        | m <sup>3</sup>  |                 |                 |
| IV            | $e = 1/2 \cdot (II)/(I)$          | =      | 0,00            | m               | $e/2$           | = 0,000 m       |
| V             | $Io = 1/3 h \cdot (III)$          | =      | 42388,86        | m <sup>4</sup>  |                 |                 |
| VI            | $df = h \cdot (I) \cdot (IV)^2$   | =      | 0,00            | m <sup>4</sup>  |                 |                 |
| VII           | $If = (V) - (VI)$                 | =      | 42388,86        | m <sup>4</sup>  |                 |                 |
| VIII          | $MB\theta (r\theta) = VII/Volume$ | =      | 5,56            | m               |                 |                 |

**Tabel 73. Kurva Silang Kondisi 50% 15°**

|              |   |           |                |            |   |              |
|--------------|---|-----------|----------------|------------|---|--------------|
| T            | = | 4,304598  | m              |            |   |              |
| LPP          | = | 125,92903 | m              |            |   |              |
| Displacement | = | 7809,703  | Ton            | Condition  | = | 50%          |
| Volume       | = | 7619,2224 | m <sup>3</sup> | h = Lpp/10 | = | 12,5929027 m |

| Nomor<br>Section | $\phi = 15^\circ$                 |        |                 |                 |                 |                 |
|------------------|-----------------------------------|--------|-----------------|-----------------|-----------------|-----------------|
|                  | Ya                                | Yb     | Ya <sup>2</sup> | Yb <sup>2</sup> | Ya <sup>3</sup> | Yb <sup>3</sup> |
| -5               | 0,000                             | 0,000  | 0,000           | 0,000           | 0,000           | 0,000           |
| -4               | 6,010                             | 4,040  | 36,120          | 16,322          | 217,082         | 65,939          |
| -3               | 8,590                             | 6,750  | 73,788          | 45,563          | 633,840         | 307,547         |
| -2               | 9,460                             | 8,630  | 89,492          | 74,477          | 846,591         | 642,736         |
| -1               | 9,460                             | 9,500  | 89,492          | 90,250          | 846,591         | 857,375         |
| 0                | 9,570                             | 9,500  | 91,585          | 90,250          | 876,467         | 857,375         |
| 1                | 9,570                             | 9,500  | 91,585          | 90,250          | 876,467         | 857,375         |
| 2                | 9,570                             | 9,500  | 91,585          | 90,250          | 876,467         | 857,375         |
| 3                | 8,960                             | 8,510  | 80,282          | 72,420          | 719,323         | 616,295         |
| 4                | 4,680                             | 4,350  | 21,902          | 18,923          | 102,503         | 82,313          |
| 5                | 0,000                             | 0,000  | 0,000           | 0,000           | 0,000           | 0,000           |
| $\Sigma$         | 75,870                            | 70,280 | 665,830         | 588,704         | 5995,331        | 5144,330        |
| I                | $\Sigma (Ya + Yb)$                | =      | 146,15          | m               |                 |                 |
| II               | $\Sigma (Ya^2 - Yb^2)$            | =      | 77,13           | m <sup>2</sup>  |                 |                 |
| III              | $\Sigma (Ya^3 + Yb^3)$            | =      | 11139,66        | m <sup>3</sup>  |                 |                 |
| IV               | $e = 1/2 \cdot (II)/(I)$          | =      | 0,26            | m               | e/2             | = 0,13 m        |
| V                | $Io = 1/3 h (III)$                | =      | 46760,22        | m <sup>4</sup>  |                 |                 |
| VI               | $df = h \cdot (I) \cdot (IV)^2$   | =      | 128,14          | m <sup>4</sup>  |                 |                 |
| VII              | $If = (V) - (VI)$                 | =      | 46632,09        | m <sup>4</sup>  |                 |                 |
| VIII             | $MB\theta (r\theta) = VII/Volume$ | =      | 6,12            | m               |                 |                 |

**Tabel 74. Kurva Silang Kondisi 50% 30°**

|              |   |          |                |            |   |           |
|--------------|---|----------|----------------|------------|---|-----------|
| T            | = | 4,304598 | m              |            |   |           |
| LPP          | = | 125,929  | m              |            |   |           |
| Displacement | = | 7809,703 | Ton            | Condition  | = | 50%       |
| Volume       | = | 7619,222 | m <sup>3</sup> | h = Lpp/11 | = | 12,5929 m |

| Nomor<br>Section | $\phi = 30^\circ$                 |        |                 |                 |                 |                 |
|------------------|-----------------------------------|--------|-----------------|-----------------|-----------------|-----------------|
|                  | Ya                                | Yb     | Ya <sup>2</sup> | Yb <sup>2</sup> | Ya <sup>3</sup> | Yb <sup>3</sup> |
| -5               | 0,000                             | 4,160  | 0,000           | 17,306          | 0,000           | 71,991          |
| -4               | 10,070                            | 6,510  | 101,405         | 42,380          | 1021,147        | 275,894         |
| -3               | 10,490                            | 6,610  | 110,040         | 43,692          | 1154,321        | 288,805         |
| -2               | 10,490                            | 7,870  | 110,040         | 61,937          | 1154,321        | 487,443         |
| -1               | 10,530                            | 8,150  | 110,881         | 66,423          | 1167,576        | 541,343         |
| 0                | 10,530                            | 8,150  | 110,881         | 66,423          | 1167,576        | 541,343         |
| 1                | 10,530                            | 8,150  | 110,881         | 66,423          | 1167,576        | 541,343         |
| 2                | 10,530                            | 8,150  | 110,881         | 66,423          | 1167,576        | 541,343         |
| 3                | 10,140                            | 7,870  | 102,820         | 61,937          | 1042,591        | 487,443         |
| 4                | 5,320                             | 4,260  | 28,302          | 18,148          | 150,569         | 77,309          |
| 5                | 0,000                             | 0,000  | 0,000           | 0,000           | 0,000           | 0,000           |
| $\Sigma$         | 88,630                            | 69,880 | 896,131         | 511,089         | 9193,252        | 3854,260        |
| I                | $\Sigma (Ya + Yb)$                | =      | 158,51          | m               |                 |                 |
| II               | $\Sigma (Ya^2 - Yb^2)$            | =      | 385,04          | m <sup>2</sup>  |                 |                 |
| III              | $\Sigma (Ya^3 + Yb^3)$            | =      | 13047,51        | m <sup>3</sup>  |                 |                 |
| IV               | $e = 1/2 \cdot (II)/(I)$          | =      | 1,21            | m               | e/2             | = 0,61 m        |
| V                | $Io = 1/3 h (III)$                | =      | 54768,68        | m <sup>4</sup>  |                 |                 |
| VI               | $df = h \cdot (I) \cdot (IV)^2$   | =      | 2944,59         | m <sup>4</sup>  |                 |                 |
| VII              | $If = (V) - (VI)$                 | =      | 51824,09        | m <sup>4</sup>  |                 |                 |
| VIII             | $MB\theta (r\theta) = VII/Volume$ | =      | 6,80            | m               |                 |                 |

**Tabel 75. Kurva Silang Kondisi 50% 45°**

|              |   |           |                |            |   |              |
|--------------|---|-----------|----------------|------------|---|--------------|
| T            | = | 4,304598  | m              |            |   |              |
| LPP          | = | 125,92903 | m              |            |   |              |
| Displacement | = | 7809,703  | Ton            | Condition  | = | 50%          |
| Volume       | = | 7619,2224 | m <sup>3</sup> | h = Lpp/10 | = | 12,5929027 m |

| Nomor<br>Section | $\phi = 45^\circ$                 |        |                 |                 |                 |                 |
|------------------|-----------------------------------|--------|-----------------|-----------------|-----------------|-----------------|
|                  | Ya                                | Yb     | Ya <sup>2</sup> | Yb <sup>2</sup> | Ya <sup>3</sup> | Yb <sup>3</sup> |
| -5               | 2,240                             | 4,950  | 5,018           | 24,503          | 11,239          | 121,287         |
| -4               | 10,130                            | 6,120  | 102,617         | 37,454          | 1039,509        | 229,221         |
| -3               | 10,130                            | 6,320  | 102,617         | 39,942          | 1039,509        | 252,436         |
| -2               | 10,130                            | 6,320  | 102,617         | 39,942          | 1039,509        | 252,436         |
| -1               | 10,130                            | 6,320  | 102,617         | 39,942          | 1039,509        | 252,436         |
| 0                | 10,130                            | 6,320  | 102,617         | 39,942          | 1039,509        | 252,436         |
| 1                | 10,130                            | 6,320  | 102,617         | 39,942          | 1039,509        | 252,436         |
| 2                | 10,130                            | 6,320  | 102,617         | 39,942          | 1039,509        | 252,436         |
| 3                | 10,130                            | 6,320  | 102,617         | 39,942          | 1039,509        | 252,436         |
| 4                | 7,730                             | 5,170  | 59,753          | 26,729          | 461,890         | 138,188         |
| 5                | 0,000                             | 0,000  | 0,000           | 0,000           | 0,000           | 0,000           |
| $\Sigma$         | 91,010                            | 60,480 | 885,706         | 368,283         | 8789,203        | 2255,748        |
| I                | $\Sigma (Ya + Yb)$                | =      | 151,49          | m               |                 |                 |
| II               | $\Sigma (Ya^2 - Yb^2)$            | =      | 517,42          | m <sup>2</sup>  |                 |                 |
| III              | $\Sigma (Ya^3 + Yb^3)$            | =      | 11044,95        | m <sup>3</sup>  |                 |                 |
| IV               | $e = 1/2 \cdot (II)/(I)$          | =      | 1,71            | m               | e/2             | = 0,85 m        |
| V                | $Io = 1/3 h (III)$                | =      | 46362,67        | m <sup>4</sup>  |                 |                 |
| VI               | $df = h \cdot (I) \cdot (IV)^2$   | =      | 5563,83         | m <sup>4</sup>  |                 |                 |
| VII              | $If = (V) - (VI)$                 | =      | 40798,84        | m <sup>4</sup>  |                 |                 |
| VIII             | $MB\theta (r\theta) = VII/Volume$ | =      | 5,35            | m               |                 |                 |

**Tabel 76. Kurva Silang Kondisi 50% 60°**

|              |   |           |                |            |   |              |
|--------------|---|-----------|----------------|------------|---|--------------|
| T            | = | 4,304598  | m              |            |   |              |
| LPP          | = | 125,92903 | m              |            |   |              |
| Displacement | = | 7809,703  | Ton            | Condition  | = | 50%          |
| Volume       | = | 7619,2224 | m <sup>3</sup> | h = Lpp/11 | = | 12,5929027 m |

| Nomor<br>Section | $\phi = 60^\circ$                 |        |                 |                 |                 |                 |
|------------------|-----------------------------------|--------|-----------------|-----------------|-----------------|-----------------|
|                  | Ya                                | Yb     | Ya <sup>2</sup> | Yb <sup>2</sup> | Ya <sup>3</sup> | Yb <sup>3</sup> |
| -5               | 1,230                             | 0,000  | 1,513           | 0,000           | 1,861           | 0,000           |
| -4               | 7,790                             | 5,540  | 60,684          | 30,692          | 472,729         | 170,031         |
| -3               | 7,790                             | 5,640  | 60,684          | 31,810          | 472,729         | 179,406         |
| -2               | 7,790                             | 5,640  | 60,684          | 31,810          | 472,729         | 179,406         |
| -1               | 7,790                             | 5,640  | 60,684          | 31,810          | 472,729         | 179,406         |
| 0                | 7,790                             | 5,640  | 60,684          | 31,810          | 472,729         | 179,406         |
| 1                | 7,790                             | 5,640  | 60,684          | 31,810          | 472,729         | 179,406         |
| 2                | 7,790                             | 5,640  | 60,684          | 31,810          | 472,729         | 179,406         |
| 3                | 7,790                             | 5,640  | 60,684          | 31,810          | 472,729         | 179,406         |
| 4                | 7,790                             | 5,540  | 60,684          | 30,692          | 472,729         | 170,031         |
| 5                | 0,000                             | 0,000  | 0,000           | 0,000           | 0,000           | 0,000           |
| $\Sigma$         | 71,340                            | 50,560 | 547,670         | 284,050         | 4256,423        | 1595,906        |
| I                | $\Sigma (Ya + Yb)$                | =      | 121,90          | m               |                 |                 |
| II               | $\Sigma (Ya^2 - Yb^2)$            | =      | 263,62          | m <sup>2</sup>  |                 |                 |
| III              | $\Sigma (Ya^3 + Yb^3)$            | =      | 5852,33         | m <sup>3</sup>  |                 |                 |
| IV               | $e = 1/2 \cdot (II)/(I)$          | =      | 1,08            | m               | e/2             | = 0,54 m        |
| V                | $Io = 1/3 h (III)$                | =      | 24565,94        | m <sup>4</sup>  |                 |                 |
| VI               | $df = h \cdot (I) \cdot (IV)^2$   | =      | 1794,80         | m <sup>4</sup>  |                 |                 |
| VII              | $If = (V) - (VI)$                 | =      | 22771,13        | m <sup>4</sup>  |                 |                 |
| VIII             | $MB\theta (r\theta) = VII/Volume$ | =      | 2,99            | m               |                 |                 |

**Tabel 77. Kurva Silang Kondisi 50% 75°**

|              |   |          |                |            |   |           |
|--------------|---|----------|----------------|------------|---|-----------|
| T            | = | 4,304598 | m              |            |   |           |
| LPP          | = | 125,929  | m              |            |   |           |
| Displacement | = | 7809,703 | Ton            | Condition  | = | 50%       |
| Volume       | = | 7619,222 | m <sup>3</sup> | h = Lpp/10 | = | 12,5929 m |

| Nomor<br>Section | $\phi = 75^\circ$                 |        |                 |                 |                 |                 |
|------------------|-----------------------------------|--------|-----------------|-----------------|-----------------|-----------------|
|                  | Ya                                | Yb     | Ya <sup>2</sup> | Yb <sup>2</sup> | Ya <sup>3</sup> | Yb <sup>3</sup> |
| -5               | 5,910                             | 0,000  | 34,928          | 0,000           | 206,425         | 0,000           |
| -4               | 6,950                             | 5,450  | 48,303          | 29,703          | 335,702         | 161,879         |
| -3               | 6,950                             | 5,450  | 48,303          | 29,703          | 335,702         | 161,879         |
| -2               | 6,950                             | 5,450  | 48,303          | 29,703          | 335,702         | 161,879         |
| -1               | 6,950                             | 5,450  | 48,303          | 29,703          | 335,702         | 161,879         |
| 0                | 6,950                             | 5,450  | 48,303          | 29,703          | 335,702         | 161,879         |
| 1                | 6,950                             | 5,450  | 48,303          | 29,703          | 335,702         | 161,879         |
| 2                | 6,950                             | 5,450  | 48,303          | 29,703          | 335,702         | 161,879         |
| 3                | 6,950                             | 5,450  | 48,303          | 29,703          | 335,702         | 161,879         |
| 4                | 6,950                             | 5,450  | 48,303          | 29,703          | 335,702         | 161,879         |
| 5                | 0,000                             | 0,000  | 0,000           | 0,000           | 0,000           | 0,000           |
| $\Sigma$         | 68,460                            | 49,050 | 469,651         | 267,323         | 3227,746        | 1456,908        |
| I                | $\Sigma(Ya + Yb)$                 | =      | 117,51          | m               |                 |                 |
| II               | $\Sigma(Ya^2 - Yb^2)$             | =      | 202,33          | m <sup>2</sup>  |                 |                 |
| III              | $\Sigma(Ya^3 + Yb^3)$             | =      | 4684,65         | m <sup>3</sup>  |                 |                 |
| IV               | $e = 1/2 \cdot (II)/(I)$          | =      | 0,86            | m               | e/2             | = 0,43 m        |
| V                | $Io = 1/3 h (III)$                | =      | 19664,46        | m <sup>4</sup>  |                 |                 |
| VI               | $df = h \cdot (I) \cdot (IV)^2$   | =      | 1096,74         | m <sup>4</sup>  |                 |                 |
| VII              | $If = (V) - (VI)$                 | =      | 18567,72        | m <sup>4</sup>  |                 |                 |
| VIII             | $MB\theta (r\theta) = VII/Volume$ | =      | 2,44            | m               |                 |                 |

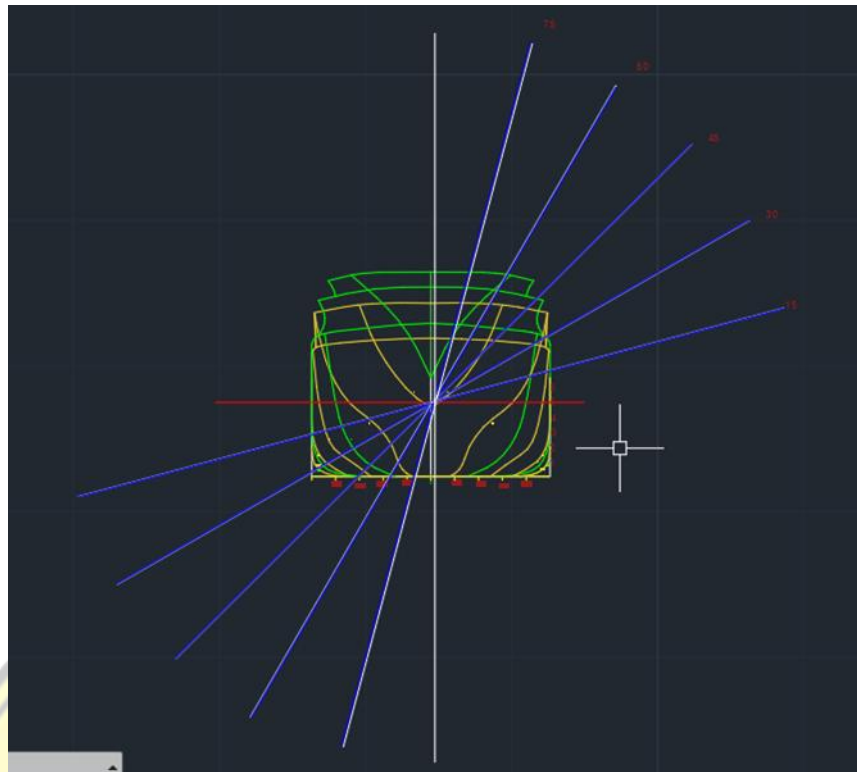
**Tabel 78. Kurva Silang Kondisi 50% 90°**

|              |   |           |                |            |   |              |
|--------------|---|-----------|----------------|------------|---|--------------|
| T            | = | 4,304598  | m              |            |   |              |
| LPP          | = | 125,92903 | m              |            |   |              |
| Displacement | = | 7809,703  | Ton            | Condition  | = | 50%          |
| Volume       | = | 7619,2224 | m <sup>3</sup> | h = Lpp/10 | = | 12,5929027 m |

| Nomor<br>Section | $\phi = 90^\circ$                 |        |                 |                 |                 |                 |
|------------------|-----------------------------------|--------|-----------------|-----------------|-----------------|-----------------|
|                  | Ya                                | Yb     | Ya <sup>2</sup> | Yb <sup>2</sup> | Ya <sup>3</sup> | Yb <sup>3</sup> |
| -5               | 5,680                             | 0,000  | 32,262          | 0,000           | 183,250         | 0,000           |
| -4               | 6,000                             | 5,290  | 36,000          | 27,984          | 216,000         | 148,036         |
| -3               | 6,000                             | 5,630  | 36,000          | 31,697          | 216,000         | 178,454         |
| -2               | 6,000                             | 5,630  | 36,000          | 31,697          | 216,000         | 178,454         |
| -1               | 6,000                             | 5,630  | 36,000          | 31,697          | 216,000         | 178,454         |
| 0                | 6,000                             | 5,630  | 36,000          | 31,697          | 216,000         | 178,454         |
| 1                | 6,000                             | 5,630  | 36,000          | 31,697          | 216,000         | 178,454         |
| 2                | 6,000                             | 5,630  | 36,000          | 31,697          | 216,000         | 178,454         |
| 3                | 6,000                             | 5,630  | 36,000          | 31,697          | 216,000         | 178,454         |
| 4                | 6,000                             | 5,320  | 36,000          | 28,302          | 216,000         | 150,569         |
| 5                | 0,230                             | 0,000  | 0,053           | 0,000           | 0,012           | 0,000           |
| $\Sigma$         | 59,910                            | 50,020 | 356,315         | 278,165         | 2127,263        | 1547,779        |
| I                | $\Sigma(Ya + Yb)$                 | =      | 109,93          | m               |                 |                 |
| II               | $\Sigma(Ya^2 - Yb^2)$             | =      | 78,15           | m <sup>2</sup>  |                 |                 |
| III              | $\Sigma(Ya^3 + Yb^3)$             | =      | 3675,04         | m <sup>3</sup>  |                 |                 |
| IV               | $e = 1/2 \cdot (II)/(I)$          | =      | 0,36            | m               | e/2             | = 0,18 m        |
| V                | $Io = 1/3 h (III)$                | =      | 15426,48        | m <sup>4</sup>  |                 |                 |
| VI               | $df = h \cdot (I) \cdot (IV)^2$   | =      | 174,91          | m <sup>4</sup>  |                 |                 |
| VII              | $If = (V) - (VI)$                 | =      | 15251,57        | m <sup>4</sup>  |                 |                 |
| VIII             | $MB\theta (r\theta) = VII/Volume$ | =      | 2,00            | m               |                 |                 |



## 3. Kondisi 75%



Gambar 29. Kurva Silang Kondisi 75%

Tabel 79. Kurva Silang Kondisi 75% 0°

|              |   |           |                |            |   |              |
|--------------|---|-----------|----------------|------------|---|--------------|
| T            | = | 6,4568971 | m              |            |   |              |
| LPP          | = | 125,92903 | m              |            |   |              |
| Displacement | = | 11714,554 | Ton            | Condition  | = | 75%          |
| Volume       | = | 11428,834 | m <sup>3</sup> | h = Lpp/10 | = | 12,5929027 m |

| Nomor Section | $\varphi = 0^\circ$               |        |                 |                 |                 |                 |
|---------------|-----------------------------------|--------|-----------------|-----------------|-----------------|-----------------|
|               | Ya                                | Yb     | Ya <sup>2</sup> | Yb <sup>2</sup> | Ya <sup>3</sup> | Yb <sup>3</sup> |
| -5            | 3,250                             | 3,250  | 10,563          | 10,563          | 34,328          | 34,328          |
| -4            | 6,440                             | 6,440  | 41,474          | 41,474          | 267,090         | 267,090         |
| -3            | 8,260                             | 8,260  | 68,228          | 68,228          | 563,560         | 563,560         |
| -2            | 9,120                             | 9,120  | 83,174          | 83,174          | 758,551         | 758,551         |
| -1            | 9,240                             | 9,240  | 85,378          | 85,378          | 788,889         | 788,889         |
| 0             | 9,240                             | 9,240  | 85,378          | 85,378          | 788,889         | 788,889         |
| 1             | 9,240                             | 9,240  | 85,378          | 85,378          | 788,889         | 788,889         |
| 2             | 9,240                             | 9,240  | 85,378          | 85,378          | 788,889         | 788,889         |
| 3             | 8,640                             | 8,640  | 74,650          | 74,650          | 644,973         | 644,973         |
| 4             | 4,640                             | 4,640  | 21,530          | 21,530          | 99,897          | 99,897          |
| 5             | 0,000                             | 0,000  | 0,000           | 0,000           | 0,000           | 0,000           |
| $\Sigma$      | 77,310                            | 77,310 | 641,128         | 641,128         | 5523,955        | 5523,955        |
| I             | $\Sigma (Ya + Yb)$                | =      | 154,62          | m               |                 |                 |
| II            | $\Sigma (Ya^2 - Yb^2)$            | =      | 0,00            | m <sup>2</sup>  |                 |                 |
| III           | $\Sigma (Ya^3 + Yb^3)$            | =      | 11047,91        | m <sup>3</sup>  |                 |                 |
| IV            | $e = 1/2 \cdot (II)/(I)$          | =      | 0,00            | m               | e/2             | = 0,000 m       |
| V             | $I_o = 1/3 h (III)$               | =      | 46375,08        | m <sup>4</sup>  |                 |                 |
| VI            | $df = h \cdot (I) \cdot (IV)^2$   | =      | 0,00            | m <sup>4</sup>  |                 |                 |
| VII           | $If = (V) - (VI)$                 | =      | 46375,08        | m <sup>4</sup>  |                 |                 |
| VIII          | $MB\theta (r\theta) = VII/Volume$ | =      | 4,06            | m               |                 |                 |

**Tabel 80. Kurva Silang Kondisi 75% 15°**

|              |   |           |                |            |   |            |   |
|--------------|---|-----------|----------------|------------|---|------------|---|
| T            | = | 6,4568971 | m              |            |   |            |   |
| LPP          | = | 125,92903 | m              |            |   |            |   |
| Displacement | = | 11714,554 | Ton            | Condition  | = | 75%        |   |
| Volume       | = | 11428,834 | m <sup>3</sup> | h = Lpp/10 | = | 12,5929027 | m |

| Nomor<br>Section | $\phi = 15^\circ$                 |        |                 |                 |                 |                 |        |
|------------------|-----------------------------------|--------|-----------------|-----------------|-----------------|-----------------|--------|
|                  | Ya                                | Yb     | Ya <sup>2</sup> | Yb <sup>2</sup> | Ya <sup>3</sup> | Yb <sup>3</sup> |        |
| -5               | 6,990                             | 2,020  | 48,860          | 4,080           | 341,532         | 8,242           |        |
| -4               | 9,090                             | 5,300  | 82,628          | 28,090          | 751,089         | 148,877         |        |
| -3               | 9,530                             | 7,690  | 90,821          | 59,136          | 865,523         | 454,757         |        |
| -2               | 9,570                             | 9,190  | 91,585          | 84,456          | 876,467         | 776,152         |        |
| -1               | 9,570                             | 9,570  | 91,585          | 91,585          | 876,467         | 876,467         |        |
| 0                | 9,570                             | 9,570  | 91,585          | 91,585          | 876,467         | 876,467         |        |
| 1                | 9,570                             | 9,570  | 91,585          | 91,585          | 876,467         | 876,467         |        |
| 2                | 9,570                             | 9,570  | 91,585          | 91,585          | 876,467         | 876,467         |        |
| 3                | 9,160                             | 8,790  | 83,906          | 77,264          | 768,575         | 679,151         |        |
| 4                | 5,170                             | 4,660  | 26,729          | 21,716          | 138,188         | 101,195         |        |
| 5                | 0,000                             | 0,000  | 0,000           | 0,000           | 0,000           | 0,000           |        |
| $\Sigma$         | 87,790                            | 75,930 | 790,868         | 641,082         | 7247,246        | 5674,244        |        |
| I                | $\Sigma (Ya + Yb)$                | =      | 163,72          | m               |                 |                 |        |
| II               | $\Sigma (Ya^2 - Yb^2)$            | =      | 149,79          | m <sup>2</sup>  |                 |                 |        |
| III              | $\Sigma (Ya^3 + Yb^3)$            | =      | 12921,49        | m <sup>3</sup>  |                 |                 |        |
| IV               | $e = 1/2 \cdot (II)/(I)$          | =      | 0,46            | m               | e/2             | =               | 0,23 m |
| V                | $Io = 1/3 h (III)$                | =      | 54239,69        | m <sup>4</sup>  |                 |                 |        |
| VI               | $df = h \cdot (I) \cdot (IV)^2$   | =      | 431,43          | m <sup>4</sup>  |                 |                 |        |
| VII              | $If = (V) - (VI)$                 | =      | 53808,26        | m <sup>4</sup>  |                 |                 |        |
| VIII             | $MB\theta (r\theta) = VII/Volume$ | =      | 4,71            | m               |                 |                 |        |

**Tabel 81. Kurva Silang Kondisi 75% 30°**

|              |   |          |                |            |   |         |   |
|--------------|---|----------|----------------|------------|---|---------|---|
| T            | = | 6,456897 | m              |            |   |         |   |
| LPP          | = | 125,929  | m              |            |   |         |   |
| Displacement | = | 11714,55 | Ton            | Condition  | = | 75%     |   |
| Volume       | = | 11428,83 | m <sup>3</sup> | h = Lpp/11 | = | 12,5929 | m |

| Nomor<br>Section | $\phi = 30^\circ$                 |        |                 |                 |                 |                 |        |
|------------------|-----------------------------------|--------|-----------------|-----------------|-----------------|-----------------|--------|
|                  | Ya                                | Yb     | Ya <sup>2</sup> | Yb <sup>2</sup> | Ya <sup>3</sup> | Yb <sup>3</sup> |        |
| -5               | 9,560                             | 1,720  | 91,394          | 2,958           | 873,723         | 5,088           |        |
| -4               | 10,360                            | 5,150  | 107,330         | 26,523          | 1111,935        | 136,591         |        |
| -3               | 10,360                            | 7,790  | 107,330         | 60,684          | 1111,935        | 472,729         |        |
| -2               | 10,360                            | 9,630  | 107,330         | 92,737          | 1111,935        | 893,056         |        |
| -1               | 10,360                            | 10,640 | 107,330         | 113,210         | 1111,935        | 1204,550        |        |
| 0                | 10,360                            | 10,640 | 107,330         | 113,210         | 1111,935        | 1204,550        |        |
| 1                | 10,360                            | 10,640 | 107,330         | 113,210         | 1111,935        | 1204,550        |        |
| 2                | 10,360                            | 10,640 | 107,330         | 113,210         | 1111,935        | 1204,550        |        |
| 3                | 10,360                            | 9,580  | 107,330         | 91,776          | 1111,935        | 879,218         |        |
| 4                | 6,830                             | 5,240  | 46,649          | 27,458          | 318,612         | 143,878         |        |
| 5                | 0,000                             | 0,000  | 0,000           | 0,000           | 0,000           | 0,000           |        |
| $\Sigma$         | 99,270                            | 81,670 | 996,679         | 754,974         | 10087,812       | 7348,761        |        |
| I                | $\Sigma (Ya + Yb)$                | =      | 180,94          | m               |                 |                 |        |
| II               | $\Sigma (Ya^2 - Yb^2)$            | =      | 241,71          | m <sup>2</sup>  |                 |                 |        |
| III              | $\Sigma (Ya^3 + Yb^3)$            | =      | 17436,57        | m <sup>3</sup>  |                 |                 |        |
| IV               | $e = 1/2 \cdot (II)/(I)$          | =      | 0,67            | m               | e/2             | =               | 0,33 m |
| V                | $Io = 1/3 h (III)$                | =      | 73192,36        | m <sup>4</sup>  |                 |                 |        |
| VI               | $df = h \cdot (I) \cdot (IV)^2$   | =      | 1016,49         | m <sup>4</sup>  |                 |                 |        |
| VII              | $If = (V) - (VI)$                 | =      | 72175,87        | m <sup>4</sup>  |                 |                 |        |
| VIII             | $MB\theta (r\theta) = VII/Volume$ | =      | 6,32            | m               |                 |                 |        |

**Tabel 82. Kurva Silang Kondisi 75% 45°**

|              |   |           |                |            |   |              |
|--------------|---|-----------|----------------|------------|---|--------------|
| T            | = | 6,4568971 | m              |            |   |              |
| LPP          | = | 125,92903 | m              |            |   |              |
| Displacement | = | 11714,554 | Ton            | Condition  | = | 75%          |
| Volume       | = | 11428,834 | m <sup>3</sup> | h = Lpp/10 | = | 12,5929027 m |

| Nomor<br>Section | $\phi = 45^\circ$                 |        |                 |                 |                 |                 |
|------------------|-----------------------------------|--------|-----------------|-----------------|-----------------|-----------------|
|                  | Ya                                | Yb     | Ya <sup>2</sup> | Yb <sup>2</sup> | Ya <sup>3</sup> | Yb <sup>3</sup> |
| -5               | 7,200                             | 1,780  | 51,840          | 3,168           | 373,248         | 5,640           |
| -4               | 7,200                             | 5,820  | 51,840          | 33,872          | 373,248         | 197,137         |
| -3               | 7,200                             | 8,130  | 51,840          | 66,097          | 373,248         | 537,368         |
| -2               | 7,200                             | 9,050  | 51,840          | 81,903          | 373,248         | 741,218         |
| -1               | 7,200                             | 9,260  | 51,840          | 85,748          | 373,248         | 794,023         |
| 0                | 7,200                             | 9,260  | 51,840          | 85,748          | 373,248         | 794,023         |
| 1                | 7,200                             | 9,260  | 51,840          | 85,748          | 373,248         | 794,023         |
| 2                | 7,200                             | 9,260  | 51,840          | 85,748          | 373,248         | 794,023         |
| 3                | 7,200                             | 9,050  | 51,840          | 81,903          | 373,248         | 741,218         |
| 4                | 7,200                             | 6,310  | 51,840          | 39,816          | 373,248         | 251,240         |
| 5                | 0,000                             | 0,000  | 0,000           | 0,000           | 0,000           | 0,000           |
| $\Sigma$         | 72,000                            | 77,180 | 518,400         | 649,749         | 3732,480        | 5649,911        |
| I                | $\Sigma (Ya + Yb)$                | =      | 149,18          | m               |                 |                 |
| II               | $\Sigma (Ya^2 - Yb^2)$            | =      | -131,35         | m <sup>2</sup>  |                 |                 |
| III              | $\Sigma (Ya^3 + Yb^3)$            | =      | 9382,39         | m <sup>3</sup>  |                 |                 |
| IV               | $e = 1/2 \cdot (II)/(I)$          | =      | -0,44           | m               | e/2             | = -0,22 m       |
| V                | $Io = 1/3 h (III)$                | =      | 39383,85        | m <sup>4</sup>  |                 |                 |
| VI               | $df = h \cdot (I) \cdot (IV)^2$   | =      | 364,09          | m <sup>4</sup>  |                 |                 |
| VII              | $If = (V) - (VI)$                 | =      | 39019,75        | m <sup>4</sup>  |                 |                 |
| VIII             | $MB\theta (r\theta) = VII/Volume$ | =      | 3,41            | m               |                 |                 |

**Tabel 83. Kurva Silang Kondisi 75% 60°**

|              |   |           |                |            |   |              |
|--------------|---|-----------|----------------|------------|---|--------------|
| T            | = | 6,4568971 | m              |            |   |              |
| LPP          | = | 125,92903 | m              |            |   |              |
| Displacement | = | 11714,554 | Ton            | Condition  | = | 75%          |
| Volume       | = | 11428,834 | m <sup>3</sup> | h = Lpp/11 | = | 12,5929027 m |

| Nomor<br>Section | $\phi = 60^\circ$                 |        |                 |                 |                 |                 |
|------------------|-----------------------------------|--------|-----------------|-----------------|-----------------|-----------------|
|                  | Ya                                | Yb     | Ya <sup>2</sup> | Yb <sup>2</sup> | Ya <sup>3</sup> | Yb <sup>3</sup> |
| -5               | 6,010                             | 1,570  | 36,120          | 2,465           | 217,082         | 3,870           |
| -4               | 6,010                             | 6,260  | 36,120          | 39,188          | 217,082         | 245,314         |
| -3               | 6,010                             | 7,310  | 36,120          | 53,436          | 217,082         | 390,618         |
| -2               | 6,010                             | 7,410  | 36,120          | 54,908          | 217,082         | 406,869         |
| -1               | 6,010                             | 7,410  | 36,120          | 54,908          | 217,082         | 406,869         |
| 0                | 6,010                             | 7,410  | 36,120          | 54,908          | 217,082         | 406,869         |
| 1                | 6,010                             | 7,410  | 36,120          | 54,908          | 217,082         | 406,869         |
| 2                | 6,010                             | 7,410  | 36,120          | 54,908          | 217,082         | 406,869         |
| 3                | 6,010                             | 7,410  | 36,120          | 54,908          | 217,082         | 406,869         |
| 4                | 6,010                             | 6,510  | 36,120          | 42,380          | 217,082         | 275,894         |
| 5                | 0,000                             | 0,000  | 0,000           | 0,000           | 0,000           | 0,000           |
| $\Sigma$         | 60,100                            | 66,110 | 361,201         | 466,917         | 2170,818        | 3356,911        |
| I                | $\Sigma (Ya + Yb)$                | =      | 126,21          | m               |                 |                 |
| II               | $\Sigma (Ya^2 - Yb^2)$            | =      | -105,72         | m <sup>2</sup>  |                 |                 |
| III              | $\Sigma (Ya^3 + Yb^3)$            | =      | 5527,73         | m <sup>3</sup>  |                 |                 |
| IV               | $e = 1/2 \cdot (II)/(I)$          | =      | -0,42           | m               | e/2             | = -0,21 m       |
| V                | $Io = 1/3 h (III)$                | =      | 23203,38        | m <sup>4</sup>  |                 |                 |
| VI               | $df = h \cdot (I) \cdot (IV)^2$   | =      | 278,78          | m <sup>4</sup>  |                 |                 |
| VII              | $If = (V) - (VI)$                 | =      | 22924,61        | m <sup>4</sup>  |                 |                 |
| VIII             | $MB\theta (r\theta) = VII/Volume$ | =      | 2,01            | m               |                 |                 |

**Tabel 84. Kurva Silang Kondisi 75% 75°**

|              |   |          |                |              |   |           |
|--------------|---|----------|----------------|--------------|---|-----------|
| T            | = | 6,456897 | m              |              |   |           |
| LPP          | = | 125,929  | m              |              |   |           |
| Displacement | = | 11714,55 | Ton            | Condition    | = | 75%       |
| Volume       | = | 11428,83 | m <sup>3</sup> | $h = Lpp/10$ | = | 12,5929 m |

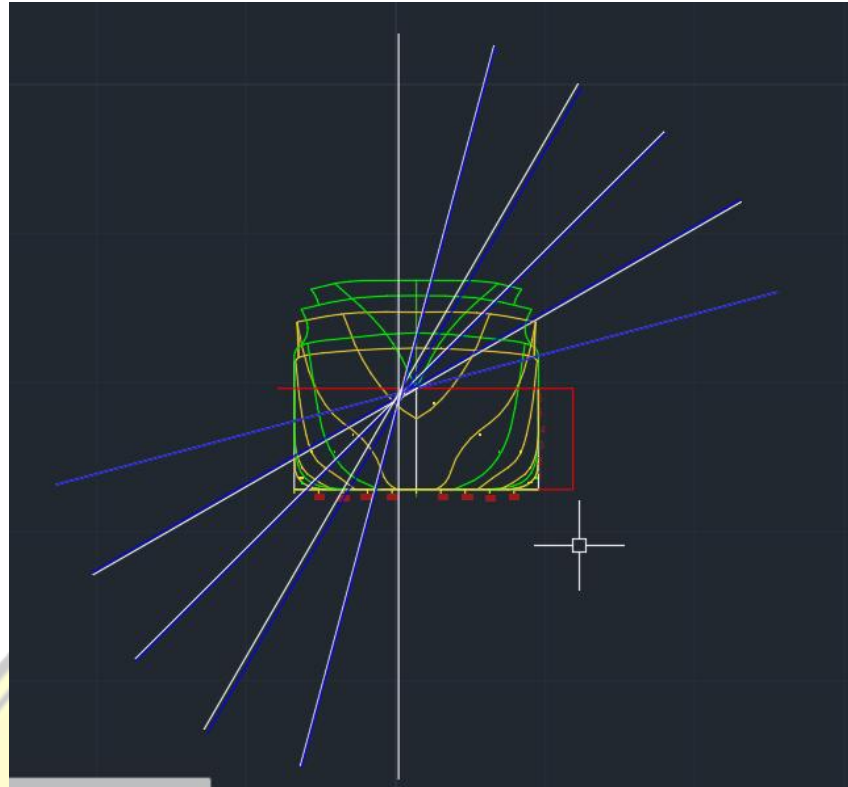
| Nomor Section | $\phi = 75^\circ$                 |        |                 |                 |                 |                 |
|---------------|-----------------------------------|--------|-----------------|-----------------|-----------------|-----------------|
|               | Ya                                | Yb     | Ya <sup>2</sup> | Yb <sup>2</sup> | Ya <sup>3</sup> | Yb <sup>3</sup> |
| -5            | 5,540                             | 1,490  | 30,692          | 2,220           | 170,031         | 3,308           |
| -4            | 5,540                             | 6,370  | 30,692          | 40,577          | 170,031         | 258,475         |
| -3            | 5,540                             | 6,510  | 30,692          | 42,380          | 170,031         | 275,894         |
| -2            | 5,540                             | 6,510  | 30,692          | 42,380          | 170,031         | 275,894         |
| -1            | 5,540                             | 6,510  | 30,692          | 42,380          | 170,031         | 275,894         |
| 0             | 5,540                             | 6,510  | 30,692          | 42,380          | 170,031         | 275,894         |
| 1             | 5,540                             | 6,510  | 30,692          | 42,380          | 170,031         | 275,894         |
| 2             | 5,540                             | 6,510  | 30,692          | 42,380          | 170,031         | 275,894         |
| 3             | 5,540                             | 6,510  | 30,692          | 42,380          | 170,031         | 275,894         |
| 4             | 5,540                             | 6,370  | 30,692          | 40,577          | 170,031         | 258,475         |
| 5             | 5,540                             | -4,630 | 30,692          | 21,437          | 170,031         | -99,253         |
| $\Sigma$      | 60,940                            | 55,170 | 337,608         | 401,472         | 1870,346        | 2352,266        |
| I             | $\Sigma (Ya + Yb)$                | =      | 116,11          | m               |                 |                 |
| II            | $\Sigma (Ya^2 - Yb^2)$            | =      | -63,86          | m <sup>2</sup>  |                 |                 |
| III           | $\Sigma (Ya^3 + Yb^3)$            | =      | 4222,61         | m <sup>3</sup>  |                 |                 |
| IV            | $e = 1/2 \cdot (II)/(I)$          | =      | -0,28           | m               | $e/2$           | = -0,14 m       |
| V             | $Io = 1/3 h (III)$                | =      | 17724,98        | m <sup>4</sup>  |                 |                 |
| VI            | $df = h \cdot (I) \cdot (IV)^2$   | =      | 110,59          | m <sup>4</sup>  |                 |                 |
| VII           | $If = (V) - (VI)$                 | =      | 17614,39        | m <sup>4</sup>  |                 |                 |
| VIII          | $MB\theta (r\theta) = VII/Volume$ | =      | 1,54            | m               |                 |                 |

**Tabel 85. Kurva Silang Kondisi 75% 90°**

|              |   |           |                |              |   |              |
|--------------|---|-----------|----------------|--------------|---|--------------|
| T            | = | 6,4568971 | m              |              |   |              |
| LPP          | = | 125,92903 | m              |              |   |              |
| Displacement | = | 11714,554 |                | Condition    | = | 75%          |
| Volume       | = | 11428,834 | m <sup>3</sup> | $h = Lpp/10$ | = | 12,5929027 m |

| Nomor Section | $\phi = 90^\circ$                 |        |                 |                 |                 |                 |
|---------------|-----------------------------------|--------|-----------------|-----------------|-----------------|-----------------|
|               | Ya                                | Yb     | Ya <sup>2</sup> | Yb <sup>2</sup> | Ya <sup>3</sup> | Yb <sup>3</sup> |
| -5            | 5,470                             | 6,160  | 29,921          | 37,946          | 163,667         | 233,745         |
| -4            | 5,470                             | 6,160  | 29,921          | 37,946          | 163,667         | 233,745         |
| -3            | 5,470                             | 6,160  | 29,921          | 37,946          | 163,667         | 233,745         |
| -2            | 5,470                             | 6,160  | 29,921          | 37,946          | 163,667         | 233,745         |
| -1            | 5,470                             | 6,160  | 29,921          | 37,946          | 163,667         | 233,745         |
| 0             | 5,470                             | 6,160  | 29,921          | 37,946          | 163,667         | 233,745         |
| 1             | 5,470                             | 6,160  | 29,921          | 37,946          | 163,667         | 233,745         |
| 2             | 5,470                             | 6,160  | 29,921          | 37,946          | 163,667         | 233,745         |
| 3             | 5,470                             | 6,160  | 29,921          | 37,946          | 163,667         | 233,745         |
| 4             | 5,470                             | 6,160  | 29,921          | 37,946          | 163,667         | 233,745         |
| 5             | 5,470                             | -3,760 | 29,921          | 14,138          | 163,667         | -53,157         |
| $\Sigma$      | 60,170                            | 57,840 | 329,130         | 393,594         | 1800,341        | 2284,292        |
| I             | $\Sigma (Ya + Yb)$                | =      | 118,01          | m               |                 |                 |
| II            | $\Sigma (Ya^2 - Yb^2)$            | =      | -64,46          | m <sup>2</sup>  |                 |                 |
| III           | $\Sigma (Ya^3 + Yb^3)$            | =      | 4084,63         | m <sup>3</sup>  |                 |                 |
| IV            | $e = 1/2 \cdot (II)/(I)$          | =      | -0,27           | m               | $e/2$           | = -0,14 m       |
| V             | $Io = 1/3 h (III)$                | =      | 17145,79        | m <sup>4</sup>  |                 |                 |
| VI            | $df = h \cdot (I) \cdot (IV)^2$   | =      | 110,86          | m <sup>4</sup>  |                 |                 |
| VII           | $If = (V) - (VI)$                 | =      | 17034,93        | m <sup>4</sup>  |                 |                 |
| VIII          | $MB\theta (r\theta) = VII/Volume$ | =      | 1,49            | m               |                 |                 |

4. Kondisi 100%



Gambar 30. Kurva Silang Kondisi 100%

Tabel 86. Kurva Silang Kondisi 100% 0°

|              |   |           |                |            |   |              |
|--------------|---|-----------|----------------|------------|---|--------------|
| T            | = | 8.6091961 | m              |            |   |              |
| LPP          | = | 125.92903 | m              |            |   |              |
| Displacement | = | 15619.406 | Ton            | Condition  | = | 100%         |
| Volume       | = | 15238.445 | m <sup>3</sup> | h = Lpp/10 | = | 12.5929027 m |

| Nomor Section | $\varphi = 0^\circ$               |        |                 |                 |                 |                 |
|---------------|-----------------------------------|--------|-----------------|-----------------|-----------------|-----------------|
|               | Ya                                | Yb     | Ya <sup>2</sup> | Yb <sup>2</sup> | Ya <sup>3</sup> | Yb <sup>3</sup> |
| -5            | 7,190                             | 7,190  | 51,696          | 51,696          | 371,695         | 371,695         |
| -4            | 8,760                             | 8,760  | 76,738          | 76,738          | 672,221         | 672,221         |
| -3            | 9,200                             | 9,200  | 84,640          | 84,640          | 778,688         | 778,688         |
| -2            | 9,240                             | 9,240  | 85,378          | 85,378          | 788,889         | 788,889         |
| -1            | 9,240                             | 9,240  | 85,378          | 85,378          | 788,889         | 788,889         |
| 0             | 9,240                             | 9,240  | 85,378          | 85,378          | 788,889         | 788,889         |
| 1             | 9,240                             | 9,240  | 85,378          | 85,378          | 788,889         | 788,889         |
| 2             | 9,240                             | 9,240  | 85,378          | 85,378          | 788,889         | 788,889         |
| 3             | 8,830                             | 8,830  | 77,969          | 77,969          | 688,465         | 688,465         |
| 4             | 5,390                             | 5,390  | 29,052          | 29,052          | 156,591         | 156,591         |
| 5             | 0,000                             | 0,000  | 0,000           | 0,000           | 0,000           | 0,000           |
| $\Sigma$      | 85,570                            | 85,570 | 746,983         | 746,983         | 6612,106        | 6612,106        |
| I             | $\Sigma (Ya + Yb)$                | =      | 171,14          | m               |                 |                 |
| II            | $\Sigma (Ya^2 - Yb^2)$            | =      | 0,00            | m <sup>2</sup>  |                 |                 |
| III           | $\Sigma (Ya^3 + Yb^3)$            | =      | 13224,21        | m <sup>3</sup>  |                 |                 |
| IV            | $e = 1/2 \cdot (II)/(I)$          | =      | 0,00            | m               | e/2             | = 0,000 m       |
| V             | $Io = 1/3 h \cdot (III)$          | =      | 55510,40        | m <sup>4</sup>  |                 |                 |
| VI            | $df = h \cdot (I) \cdot (IV)^2$   | =      | 0,00            | m <sup>4</sup>  |                 |                 |
| VII           | $If = (V) - (VI)$                 | =      | 55510,40        | m <sup>4</sup>  |                 |                 |
| VIII          | $MB\theta (r\theta) = VII/Volume$ | =      | 3,64            | m               |                 |                 |

**Tabel 87. Kurva Silang Kondisi 100% 15°**

|              |   |           |                |            |   |            |   |
|--------------|---|-----------|----------------|------------|---|------------|---|
| T            | = | 8,6091961 | m              |            |   |            |   |
| LPP          | = | 125,92903 | m              |            |   |            |   |
| Displacement | = | 15619,406 | Ton            | Condition  | = | 100%       |   |
| Volume       | = | 15238,445 | m <sup>3</sup> | h = Lpp/10 | = | 12,5929027 | m |

| Nomor<br>Section | $\phi = 15^\circ$                 |        |                 |                 |                 |                 |        |
|------------------|-----------------------------------|--------|-----------------|-----------------|-----------------|-----------------|--------|
|                  | Ya                                | Yb     | Ya <sup>2</sup> | Yb <sup>2</sup> | Ya <sup>3</sup> | Yb <sup>3</sup> |        |
| -5               | 8,560                             | 5,240  | 73,274          | 27,458          | 627,222         | 143,878         |        |
| -4               | 9,410                             | 7,050  | 88,548          | 49,703          | 833,238         | 350,403         |        |
| -3               | 9,540                             | 8,530  | 91,012          | 72,761          | 868,251         | 620,650         |        |
| -2               | 9,540                             | 9,410  | 91,012          | 88,548          | 868,251         | 833,238         |        |
| -1               | 9,540                             | 9,570  | 91,012          | 91,585          | 868,251         | 876,467         |        |
| 0                | 9,540                             | 9,570  | 91,012          | 91,585          | 868,251         | 876,467         |        |
| 1                | 9,540                             | 9,570  | 91,012          | 91,585          | 868,251         | 876,467         |        |
| 2                | 9,540                             | 9,570  | 91,012          | 91,585          | 868,251         | 876,467         |        |
| 3                | 9,460                             | 8,930  | 89,492          | 79,745          | 846,591         | 712,122         |        |
| 4                | 6,700                             | 5,000  | 44,890          | 25,000          | 300,763         | 125,000         |        |
| 5                | 0,000                             | 0,000  | 0,000           | 0,000           | 0,000           | 0,000           |        |
| $\Sigma$         | 91,370                            | 82,440 | 842,273         | 709,554         | 7817,317        | 6291,160        |        |
| I                | $\Sigma (Ya + Yb)$                | =      | 173,81          | m               |                 |                 |        |
| II               | $\Sigma (Ya^2 - Yb^2)$            | =      | 132,72          | m <sup>2</sup>  |                 |                 |        |
| III              | $\Sigma (Ya^3 + Yb^3)$            | =      | 14108,48        | m <sup>3</sup>  |                 |                 |        |
| IV               | $e = 1/2 \cdot (II)/(I)$          | =      | 0,38            | m               | e/2             | =               | 0,19 m |
| V                | $Io = 1/3 h (III)$                | =      | 59222,23        | m <sup>4</sup>  |                 |                 |        |
| VI               | $df = h \cdot (I) \cdot (IV)^2$   | =      | 319,05          | m <sup>4</sup>  |                 |                 |        |
| VII              | $If = (V) - (VI)$                 | =      | 58903,18        | m <sup>4</sup>  |                 |                 |        |
| VIII             | $MB\theta (r\theta) = VII/Volume$ | =      | 3,87            | m               |                 |                 |        |

**Tabel 88. Kurva Silang Kondisi 100% 30°**

|              |   |          |                |            |   |         |   |
|--------------|---|----------|----------------|------------|---|---------|---|
| T            | = | 8,609196 | m              |            |   |         |   |
| LPP          | = | 125,929  | m              |            |   |         |   |
| Displacement | = | 15619,41 | Ton            | Condition  | = | 100%    |   |
| Volume       | = | 15238,44 | m <sup>3</sup> | h = Lpp/11 | = | 12,5929 | m |

| Nomor<br>Section | $\phi = 30^\circ$                 |        |                 |                 |                 |                 |         |
|------------------|-----------------------------------|--------|-----------------|-----------------|-----------------|-----------------|---------|
|                  | Ya                                | Yb     | Ya <sup>2</sup> | Yb <sup>2</sup> | Ya <sup>3</sup> | Yb <sup>3</sup> |         |
| -5               | 6,040                             | 4,170  | 36,482          | 17,389          | 220,349         | 72,512          |         |
| -4               | 6,040                             | 6,440  | 36,482          | 41,474          | 220,349         | 267,090         |         |
| -3               | 6,040                             | 8,700  | 36,482          | 75,690          | 220,349         | 658,503         |         |
| -2               | 6,040                             | 10,350 | 36,482          | 107,123         | 220,349         | 1108,718        |         |
| -1               | 6,040                             | 10,800 | 36,482          | 116,640         | 220,349         | 1259,712        |         |
| 0                | 6,040                             | 10,800 | 36,482          | 116,640         | 220,349         | 1259,712        |         |
| 1                | 6,040                             | 10,800 | 36,482          | 116,640         | 220,349         | 1259,712        |         |
| 2                | 6,040                             | 10,800 | 36,482          | 116,640         | 220,349         | 1259,712        |         |
| 3                | 6,040                             | 9,980  | 36,482          | 99,600          | 220,349         | 994,012         |         |
| 4                | 6,040                             | 5,480  | 36,482          | 30,030          | 220,349         | 164,567         |         |
| 5                | 0,000                             | 0,000  | 0,000           | 0,000           | 0,000           | 0,000           |         |
| $\Sigma$         | 60,400                            | 88,320 | 364,816         | 837,866         | 2203,489        | 8304,249        |         |
| I                | $\Sigma (Ya + Yb)$                | =      | 148,72          | m               |                 |                 |         |
| II               | $\Sigma (Ya^2 - Yb^2)$            | =      | -473,05         | m <sup>2</sup>  |                 |                 |         |
| III              | $\Sigma (Ya^3 + Yb^3)$            | =      | 10507,74        | m <sup>3</sup>  |                 |                 |         |
| IV               | $e = 1/2 \cdot (II)/(I)$          | =      | -1,59           | m               | e/2             | =               | -0,80 m |
| V                | $Io = 1/3 h (III)$                | =      | 44107,64        | m <sup>4</sup>  |                 |                 |         |
| VI               | $df = h \cdot (I) \cdot (IV)^2$   | =      | 4737,07         | m <sup>4</sup>  |                 |                 |         |
| VII              | $If = (V) - (VI)$                 | =      | 39370,57        | m <sup>4</sup>  |                 |                 |         |
| VIII             | $MB\theta (r\theta) = VII/Volume$ | =      | 2,58            | m               |                 |                 |         |

**Tabel 89. Kurva Silang Kondisi 100% 45°**

|              |   |           |                |            |   |              |
|--------------|---|-----------|----------------|------------|---|--------------|
| T            | = | 8,6091961 | m              |            |   |              |
| LPP          | = | 125,92903 | m              |            |   |              |
| Displacement | = | 15619,406 | Ton            | Condition  | = | 100%         |
| Volume       | = | 15238,445 | m <sup>3</sup> | h = Lpp/10 | = | 12,5929027 m |

| Nomor<br>Section | $\phi = 45^\circ$                 |        |                 |                 |                 |                 |
|------------------|-----------------------------------|--------|-----------------|-----------------|-----------------|-----------------|
|                  | Ya                                | Yb     | Ya <sup>2</sup> | Yb <sup>2</sup> | Ya <sup>3</sup> | Yb <sup>3</sup> |
| -5               | 4,570                             | 3,060  | 20,885          | 9,364           | 95,444          | 28,653          |
| -4               | 4,570                             | 5,660  | 20,885          | 32,036          | 95,444          | 181,321         |
| -3               | 4,570                             | 8,350  | 20,885          | 69,723          | 95,444          | 582,183         |
| -2               | 4,570                             | 10,190 | 20,885          | 103,836         | 95,444          | 1058,090        |
| -1               | 4,570                             | 11,120 | 20,885          | 123,654         | 95,444          | 1375,037        |
| 0                | 4,570                             | 11,120 | 20,885          | 123,654         | 95,444          | 1375,037        |
| 1                | 4,570                             | 11,120 | 20,885          | 123,654         | 95,444          | 1375,037        |
| 2                | 4,570                             | 11,120 | 20,885          | 123,654         | 95,444          | 1375,037        |
| 3                | 4,570                             | 10,190 | 20,885          | 103,836         | 95,444          | 1058,090        |
| 4                | 4,570                             | 5,460  | 20,885          | 29,812          | 95,444          | 162,771         |
| 5                | 0,000                             | 0,000  | 0,000           | 0,000           | 0,000           | 0,000           |
| $\Sigma$         | 45,700                            | 87,390 | 208,849         | 843,223         | 954,440         | 8571,256        |
| I                | $\Sigma (Ya + Yb)$                | =      | 133,09          | m               |                 |                 |
| II               | $\Sigma (Ya^2 - Yb^2)$            | =      | -634,37         | m <sup>2</sup>  |                 |                 |
| III              | $\Sigma (Ya^3 + Yb^3)$            | =      | 9525,70         | m <sup>3</sup>  |                 |                 |
| IV               | $e = 1/2 \cdot (II)/(I)$          | =      | -2,38           | m               | e/2             | = -1,19 m       |
| V                | $Io = 1/3 h (III)$                | =      | 39985,39        | m <sup>4</sup>  |                 |                 |
| VI               | $df = h \cdot (I) \cdot (IV)^2$   | =      | 9519,44         | m <sup>4</sup>  |                 |                 |
| VII              | $If = (V) - (VI)$                 | =      | 30465,95        | m <sup>4</sup>  |                 |                 |
| VIII             | $MB\theta (r\theta) = VII/Volume$ | =      | 2,00            | m               |                 |                 |

**Tabel 90. Kurva Silang Kondisi 100% 60°**

|              |   |           |                |            |   |              |
|--------------|---|-----------|----------------|------------|---|--------------|
| T            | = | 8,6091961 | m              |            |   |              |
| LPP          | = | 125,92903 | m              |            |   |              |
| Displacement | = | 15619,406 | Ton            | Condition  | = | 100%         |
| Volume       | = | 15238,445 | m <sup>3</sup> | h = Lpp/11 | = | 12,5929027 m |

| Nomor<br>Section | $\phi = 60^\circ$                 |        |                 |                 |                 |                 |
|------------------|-----------------------------------|--------|-----------------|-----------------|-----------------|-----------------|
|                  | Ya                                | Yb     | Ya <sup>2</sup> | Yb <sup>2</sup> | Ya <sup>3</sup> | Yb <sup>3</sup> |
| -5               | 4,400                             | 1,900  | 19,360          | 3,610           | 85,184          | 6,859           |
| -4               | 4,400                             | 4,890  | 19,360          | 23,912          | 85,184          | 116,930         |
| -3               | 4,400                             | 7,810  | 19,360          | 60,996          | 85,184          | 476,380         |
| -2               | 4,400                             | 8,830  | 19,360          | 77,969          | 85,184          | 688,465         |
| -1               | 4,400                             | 9,020  | 19,360          | 81,360          | 85,184          | 733,871         |
| 0                | 4,400                             | 9,020  | 19,360          | 81,360          | 85,184          | 733,871         |
| 1                | 4,400                             | 9,020  | 19,360          | 81,360          | 85,184          | 733,871         |
| 2                | 4,400                             | 9,020  | 19,360          | 81,360          | 85,184          | 733,871         |
| 3                | 4,400                             | 8,830  | 19,360          | 77,969          | 85,184          | 688,465         |
| 4                | 4,400                             | 5,210  | 19,360          | 27,144          | 85,184          | 141,421         |
| 5                | 4,400                             | -2,500 | 19,360          | 6,250           | 85,184          | -15,625         |
| $\Sigma$         | 48,400                            | 71,050 | 212,960         | 603,292         | 937,024         | 5038,378        |
| I                | $\Sigma (Ya + Yb)$                | =      | 119,45          | m               |                 |                 |
| II               | $\Sigma (Ya^2 - Yb^2)$            | =      | -390,33         | m <sup>2</sup>  |                 |                 |
| III              | $\Sigma (Ya^3 + Yb^3)$            | =      | 5975,40         | m <sup>3</sup>  |                 |                 |
| IV               | $e = 1/2 \cdot (II)/(I)$          | =      | -1,63           | m               | e/2             | = -0,82 m       |
| V                | $Io = 1/3 h (III)$                | =      | 25082,55        | m <sup>4</sup>  |                 |                 |
| VI               | $df = h \cdot (I) \cdot (IV)^2$   | =      | 4015,57         | m <sup>4</sup>  |                 |                 |
| VII              | $If = (V) - (VI)$                 | =      | 21066,98        | m <sup>4</sup>  |                 |                 |
| VIII             | $MB\theta (r\theta) = VII/Volume$ | =      | 1,38            | m               |                 |                 |

**Tabel 91. Kurva Silang Kondisi 100% 75°**

|              |   |          |                |            |   |           |
|--------------|---|----------|----------------|------------|---|-----------|
| T            | = | 8,609196 | m              |            |   |           |
| LPP          | = | 125,929  | m              |            |   |           |
| Displacement | = | 15619,41 | Ton            | Condition  | = | 100%      |
| Volume       | = | 15238,44 | m <sup>3</sup> | h = Lpp/10 | = | 12,5929 m |

| Nomor Section | $\varphi = 75^\circ$              |        |                 |                 |                 |                 |
|---------------|-----------------------------------|--------|-----------------|-----------------|-----------------|-----------------|
|               | Ya                                | Yb     | Ya <sup>2</sup> | Yb <sup>2</sup> | Ya <sup>3</sup> | Yb <sup>3</sup> |
| -5            | 4,600                             | 1,140  | 21,160          | 1,300           | 97,336          | 1,482           |
| -4            | 4,600                             | 5,100  | 21,160          | 26,010          | 97,336          | 132,651         |
| -3            | 4,600                             | 7,220  | 21,160          | 52,128          | 97,336          | 376,367         |
| -2            | 4,600                             | 7,470  | 21,160          | 55,801          | 97,336          | 416,833         |
| -1            | 4,600                             | 7,470  | 21,160          | 55,801          | 97,336          | 416,833         |
| 0             | 4,600                             | 7,470  | 21,160          | 55,801          | 97,336          | 416,833         |
| 1             | 4,600                             | 7,470  | 21,160          | 55,801          | 97,336          | 416,833         |
| 2             | 4,600                             | 7,470  | 21,160          | 55,801          | 97,336          | 416,833         |
| 3             | 4,600                             | 7,470  | 21,160          | 55,801          | 97,336          | 416,833         |
| 4             | 4,600                             | 5,800  | 21,160          | 33,640          | 97,336          | 195,112         |
| 5             | 4,600                             | -3,500 | 21,160          | 12,250          | 97,336          | -42,875         |
| $\Sigma$      | 50,600                            | 60,580 | 232,760         | 460,133         | 1070,696        | 3163,733        |
| I             | $\Sigma (Ya + Yb)$                | =      | 111,18          | m               |                 |                 |
| II            | $\Sigma (Ya^2 - Yb^2)$            | =      | -227,37         | m <sup>2</sup>  |                 |                 |
| III           | $\Sigma (Ya^3 + Yb^3)$            | =      | 4234,43         | m <sup>3</sup>  |                 |                 |
| IV            | $e = 1/2 \cdot (II)/(I)$          | =      | -1,02           | m               | e/2             | = -0,51 m       |
| V             | $Io = 1/3 h (III)$                | =      | 17774,58        | m <sup>4</sup>  |                 |                 |
| VI            | $df = h \cdot (I) \cdot (IV)^2$   | =      | 1463,92         | m <sup>4</sup>  |                 |                 |
| VII           | $If = (V) - (VI)$                 | =      | 16310,66        | m <sup>4</sup>  |                 |                 |
| VIII          | $MB\theta (r\theta) = VII/Volume$ | =      | 1,07            | m               |                 |                 |

**Tabel 92. Kurva Silang Kondisi 100% 90°**

|              |   |           |                |            |   |              |
|--------------|---|-----------|----------------|------------|---|--------------|
| T            | = | 8,6091961 | m              |            |   |              |
| LPP          | = | 125,92903 | m              |            |   |              |
| Displacement | = | 15619,406 | Ton            | Condition  | = | 100%         |
| Volume       | = | 15238,445 | m <sup>3</sup> | h = Lpp/10 | = | 12,5929027 m |

| Nomor Section | $\varphi = 90^\circ$              |        |                 |                 |                 |                 |
|---------------|-----------------------------------|--------|-----------------|-----------------|-----------------|-----------------|
|               | Ya                                | Yb     | Ya <sup>2</sup> | Yb <sup>2</sup> | Ya <sup>3</sup> | Yb <sup>3</sup> |
| -5            | 4,840                             | 0,680  | 23,426          | 0,462           | 113,380         | 0,314           |
| -4            | 4,840                             | 6,180  | 23,426          | 38,192          | 113,380         | 236,029         |
| -3            | 4,840                             | 6,780  | 23,426          | 45,968          | 113,380         | 311,666         |
| -2            | 4,840                             | 6,780  | 23,426          | 45,968          | 113,380         | 311,666         |
| -1            | 4,840                             | 6,780  | 23,426          | 45,968          | 113,380         | 311,666         |
| 0             | 4,840                             | 6,780  | 23,426          | 45,968          | 113,380         | 311,666         |
| 1             | 4,840                             | 6,780  | 23,426          | 45,968          | 113,380         | 311,666         |
| 2             | 4,840                             | 6,780  | 23,426          | 45,968          | 113,380         | 311,666         |
| 3             | 4,840                             | 6,780  | 23,426          | 45,968          | 113,380         | 311,666         |
| 4             | 4,840                             | 6,310  | 23,426          | 39,816          | 113,380         | 251,240         |
| 5             | 4,840                             | 0,000  | 23,426          | 0,000           | 113,380         | 0,000           |
| $\Sigma$      | 53,240                            | 60,630 | 257,682         | 400,250         | 1247,179        | 2669,243        |
| I             | $\Sigma (Ya + Yb)$                | =      | 113,87          | m               |                 |                 |
| II            | $\Sigma (Ya^2 - Yb^2)$            | =      | -142,57         | m <sup>2</sup>  |                 |                 |
| III           | $\Sigma (Ya^3 + Yb^3)$            | =      | 3916,42         | m <sup>3</sup>  |                 |                 |
| IV            | $e = 1/2 \cdot (II)/(I)$          | =      | -0,63           | m               | e/2             | = -0,31 m       |
| V             | $Io = 1/3 h (III)$                | =      | 16439,71        | m <sup>4</sup>  |                 |                 |
| VI            | $df = h \cdot (I) \cdot (IV)^2$   | =      | 561,95          | m <sup>4</sup>  |                 |                 |
| VII           | $If = (V) - (VI)$                 | =      | 15877,75        | m <sup>4</sup>  |                 |                 |
| VIII          | $MB\theta (r\theta) = VII/Volume$ | =      | 1,04            | m               |                 |                 |



5. Perhitungan Lengan Stabilitas

Tabel 93. Lengan Stabilitas Kondisi 25% dan 50%

Kondisi = 25%  
 Displacement = 3904,851487 Ton      3,904851487       $d\theta/2 = (\text{Interval sudut} \times \pi)/360$   
 Volume = 3809,611 m<sup>3</sup>       $= (10^\circ \times \pi)/360$   
 Sarat air = 2,152 m       $= 0,0873$

|          |             |              |              |                          |                          |                          |                          | Koordinat Titik Bouyancy |                      |                         |                              |          | Koordinat Titik Metacentre |         |  |
|----------|-------------|--------------|--------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|----------------------|-------------------------|------------------------------|----------|----------------------------|---------|--|
| $\theta$ | MB $\theta$ | Cos $\theta$ | Sin $\theta$ | MB $\theta$ Cos $\theta$ | MB $\theta$ Cos $\theta$ | MB $\theta$ Sin $\theta$ | MB $\theta$ Sin $\theta$ | Y $\theta$               | Z $\theta$ - Zc      | Y $\theta$ Cos $\theta$ | (Z $\theta$ -Zc)Sin $\theta$ | LC       | Ym                         | Zm - ZC |  |
| 1        | 2           | 3            | 4            | 5=2x3                    | 6                        | 7=2x4                    | 8                        | 9=(d $\theta$ /2)x6      | 10=(d $\theta$ /2)x3 | 11=9x3                  | 12=10x4                      | 13=11+12 | 14=9x7                     | 15=10x5 |  |
| 0        | 10,412      | 1,000        | 0,000        | 10,412                   | 0,000                    | 0,000                    | 0,000                    | 0,000                    | 0,000                | 0,000                   | 0,000                        | 0,000    | 0,000                      | 0,000   |  |
| 15       | 8,917       | 0,966        | 0,259        | 8,613                    | 19,025                   | 2,308                    | 2,308                    | 1,660                    | 0,201                | 1,604                   | 0,052                        | 1,656    | 3,832                      | 1,735   |  |
| 30       | 5,964       | 0,866        | 0,500        | 5,165                    | 32,804                   | 2,982                    | 7,598                    | 2,863                    | 0,663                | 2,479                   | 0,332                        | 2,811    | 8,537                      | 3,425   |  |
| 45       | 6,554       | 0,707        | 0,707        | 4,634                    | 42,603                   | 4,634                    | 15,214                   | 3,718                    | 1,328                | 2,629                   | 0,939                        | 3,568    | 17,229                     | 6,153   |  |
| 60       | 5,910       | 0,500        | 0,866        | 2,955                    | 50,193                   | 5,119                    | 24,967                   | 4,380                    | 2,179                | 2,190                   | 1,887                        | 4,077    | 22,420                     | 6,439   |  |
| 75       | 3,918       | 0,259        | 0,966        | 1,014                    | 54,162                   | 3,784                    | 33,870                   | 4,727                    | 2,956                | 1,223                   | 2,855                        | 4,078    | 17,886                     | 2,997   |  |
| 90       | 3,674       | 0,000        | 1,000        | 0,000                    | 55,176                   | 3,674                    | 41,328                   | 4,815                    | 3,607                | 0,000                   | 3,607                        | 3,607    | 17,690                     | 0,000   |  |

Kondisi = 50%  
 Displacement = 7809,702973 Ton      7,809702973       $d\theta/2 = (\text{Interval sudut} \times \pi)/360$   
 Volume = 7619,222 m<sup>3</sup>       $= (10^\circ \times \pi)/360$   
 Sarat air = 4,305 m       $= 0,0873$

|          |             |              |              |                          |                          |                          |                          | Koordinat Titik Bouyancy |                      |                         |                              |          | Koordinat Titik Metacentre |         |  |
|----------|-------------|--------------|--------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|----------------------|-------------------------|------------------------------|----------|----------------------------|---------|--|
| $\theta$ | MB $\theta$ | Cos $\theta$ | Sin $\theta$ | MB $\theta$ Cos $\theta$ | MB $\theta$ Cos $\theta$ | MB $\theta$ Sin $\theta$ | MB $\theta$ Sin $\theta$ | Y $\theta$               | Z $\theta$ - Zc      | Y $\theta$ Cos $\theta$ | (Z $\theta$ -Zc)Sin $\theta$ | LC       | Ym                         | Zm - ZC |  |
| 1        | 2           | 3            | 4            | 5=2x3                    | 6                        | 7=2x4                    | 8                        | 9=(d $\theta$ /2)x6      | 10=(d $\theta$ /2)x3 | 11=9x3                  | 12=10x4                      | 13=11+12 | 14=9x7                     | 15=10x5 |  |
| 0        | 5,563       | 1,000        | 0,000        | 5,563                    | 0,000                    | 0,000                    | 0,000                    | 0,000                    | 0,000                | 0,000                   | 0,000                        | 0,000    | 0,000                      | 0,000   |  |
| 15       | 6,120       | 0,966        | 0,259        | 5,912                    | 11,475                   | 1,584                    | 1,584                    | 1,001                    | 0,138                | 0,967                   | 0,036                        | 1,003    | 1,586                      | 0,817   |  |
| 30       | 6,802       | 0,866        | 0,500        | 5,890                    | 23,277                   | 3,401                    | 6,569                    | 2,031                    | 0,573                | 1,759                   | 0,287                        | 2,046    | 6,908                      | 3,377   |  |
| 45       | 5,355       | 0,707        | 0,707        | 3,786                    | 32,954                   | 3,786                    | 13,756                   | 2,876                    | 1,200                | 2,034                   | 0,849                        | 2,882    | 10,889                     | 4,545   |  |
| 60       | 2,989       | 0,500        | 0,866        | 1,494                    | 38,235                   | 2,588                    | 20,131                   | 3,337                    | 1,757                | 1,668                   | 1,521                        | 3,190    | 8,636                      | 2,625   |  |
| 75       | 2,437       | 0,259        | 0,966        | 0,631                    | 40,360                   | 2,354                    | 25,073                   | 3,522                    | 2,188                | 0,912                   | 2,113                        | 3,025    | 8,291                      | 1,380   |  |
| 90       | 2,002       | 0,000        | 1,000        | 0,000                    | 40,991                   | 2,002                    | 29,429                   | 3,577                    | 2,568                | 0,000                   | 2,568                        | 2,568    | 7,160                      | 0,000   |  |

Tabel 94. Lengan Stabilitas Kondisi 75% dan 100%

Kondisi = 75%  
 Displacement = 11714,55446 Ton  
 Volume = 11428,834 m<sup>3</sup>  
 Sarat air = 6,457 m

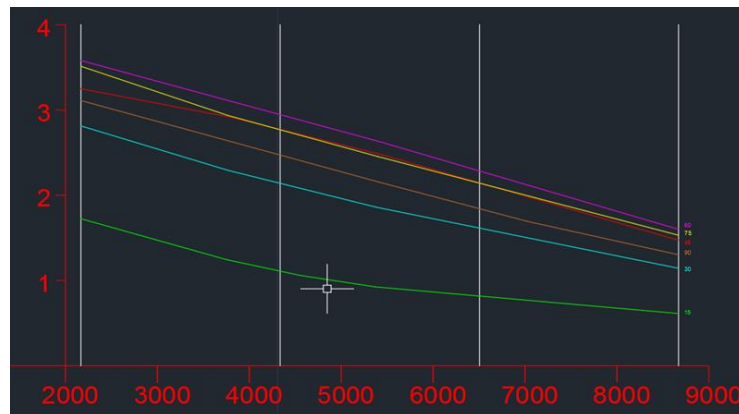
$d\theta/2 = (\text{Interval sudut} \times \pi)/360$   
 $= (10^\circ \times \pi)/360$   
 $= 0,0873$

|          |             |              |              |                          |                          |                          |                          | Koordinat Titik Bouyancy |                      |                          |                              |          | Koordinat Titik Metacentre |         |
|----------|-------------|--------------|--------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|----------------------|--------------------------|------------------------------|----------|----------------------------|---------|
| $\theta$ | MB $\theta$ | Cos $\theta$ | Sin $\theta$ | MB $\theta$ Cos $\theta$ | MB $\theta$ Cos $\theta$ | MB $\theta$ Sin $\theta$ | MB $\theta$ Sin $\theta$ | Y $\theta$               | Z $\theta$ - Zc      | Y $\theta$ .Cos $\theta$ | (Z $\theta$ -Zc)Sin $\theta$ | LC       | Ym                         | Zm - ZC |
| 1        | 2           | 3            | 4            | 5=2x3                    | 6                        | 7=2x4                    | 8                        | 9=(d $\theta/2$ )x6      | 10=(d $\theta/2$ )x8 | 11=9x3                   | 12=10x4                      | 13=11+12 | 14=9x7                     | 15=10x5 |
| 0        | 4,058       | 1,000        | 0,000        | 4,058                    | 0,000                    | 0,000                    | 0,000                    | 0,000                    | 0,000                | 0,000                    | 0,000                        | 0,000    | 0,000                      | 0,000   |
| 15       | 4,708       | 0,966        | 0,259        | 4,548                    | 8,605                    | 1,219                    | 1,219                    | 0,751                    | 0,106                | 0,725                    | 0,028                        | 0,753    | 0,915                      | 0,484   |
| 30       | 6,315       | 0,866        | 0,500        | 5,469                    | 18,622                   | 3,158                    | 5,595                    | 1,625                    | 0,488                | 1,407                    | 0,244                        | 1,651    | 5,131                      | 2,670   |
| 45       | 3,414       | 0,707        | 0,707        | 2,414                    | 26,506                   | 2,414                    | 11,167                   | 2,313                    | 0,974                | 1,636                    | 0,689                        | 2,325    | 5,584                      | 2,353   |
| 60       | 2,006       | 0,500        | 0,866        | 1,003                    | 29,923                   | 1,737                    | 15,318                   | 2,611                    | 1,337                | 1,306                    | 1,158                        | 2,463    | 4,536                      | 1,341   |
| 75       | 1,541       | 0,259        | 0,966        | 0,399                    | 31,325                   | 1,489                    | 18,544                   | 2,734                    | 1,618                | 0,708                    | 1,563                        | 2,271    | 4,070                      | 0,646   |
| 90       | 1,491       | 0,000        | 1,000        | 0,000                    | 31,723                   | 1,491                    | 21,523                   | 2,768                    | 1,878                | 0,000                    | 1,878                        | 1,878    | 4,126                      | 0,000   |

Kondisi = 100%  
 Displacement = 15619,40595 Ton  
 Volume = 15238,445 m<sup>3</sup>  
 Sarat air = 8,609 m

$d\theta/2 = (\text{Interval sudut} \times \pi)/360$   
 $= (10^\circ \times \pi)/360$   
 $= 0,0873$

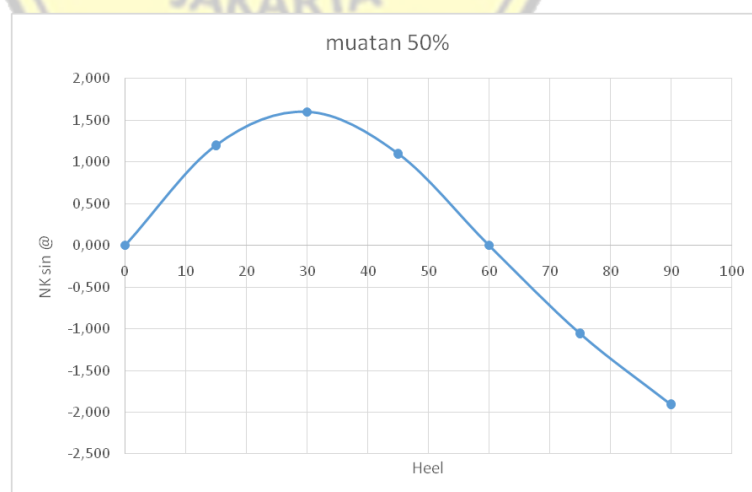
|          |             |              |              |                          |                          |                          |                          | Koordinat Titik Bouyancy |                      |                          |                              |          | Koordinat Titik Metacentre |         |
|----------|-------------|--------------|--------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|----------------------|--------------------------|------------------------------|----------|----------------------------|---------|
| $\theta$ | MB $\theta$ | Cos $\theta$ | Sin $\theta$ | MB $\theta$ Cos $\theta$ | MB $\theta$ Cos $\theta$ | MB $\theta$ Sin $\theta$ | MB $\theta$ Sin $\theta$ | Y $\theta$               | Z $\theta$ - Zc      | Y $\theta$ .Cos $\theta$ | (Z $\theta$ -Zc)Sin $\theta$ | LC       | Ym                         | Zm - ZC |
| 1        | 2           | 3            | 4            | 5=2x3                    | 6                        | 7=2x4                    | 8                        | 9=(d $\theta/2$ )x6      | 10=(d $\theta/2$ )x8 | 11=9x3                   | 12=10x4                      | 13=11+12 | 14=9x7                     | 15=10x5 |
| 0        | 3,643       | 1,000        | 0,000        | 3,643                    | 0,000                    | 0,000                    | 0,000                    | 0,000                    | 0,000                | 0,000                    | 0,000                        | 0,000    | 0,000                      | 0,000   |
| 15       | 3,865       | 0,966        | 0,259        | 3,734                    | 7,377                    | 1,000                    | 1,000                    | 0,644                    | 0,087                | 0,622                    | 0,023                        | 0,644    | 0,644                      | 0,326   |
| 30       | 2,584       | 0,866        | 0,500        | 2,237                    | 13,348                   | 1,292                    | 3,293                    | 1,165                    | 0,287                | 1,009                    | 0,144                        | 1,152    | 1,505                      | 0,643   |
| 45       | 1,999       | 0,707        | 0,707        | 1,414                    | 16,999                   | 1,414                    | 5,998                    | 1,483                    | 0,523                | 1,049                    | 0,370                        | 1,419    | 2,097                      | 0,740   |
| 60       | 1,382       | 0,500        | 0,866        | 0,691                    | 19,104                   | 1,197                    | 8,609                    | 1,667                    | 0,751                | 0,834                    | 0,651                        | 1,484    | 1,996                      | 0,519   |
| 75       | 1,070       | 0,259        | 0,966        | 0,277                    | 20,072                   | 1,034                    | 10,840                   | 1,752                    | 0,946                | 0,453                    | 0,914                        | 1,367    | 1,811                      | 0,262   |
| 90       | 1,042       | 0,000        | 1,000        | 0,000                    | 20,349                   | 1,042                    | 12,916                   | 1,776                    | 1,127                | 0,000                    | 1,127                        | 1,127    | 1,850                      | 0,000   |



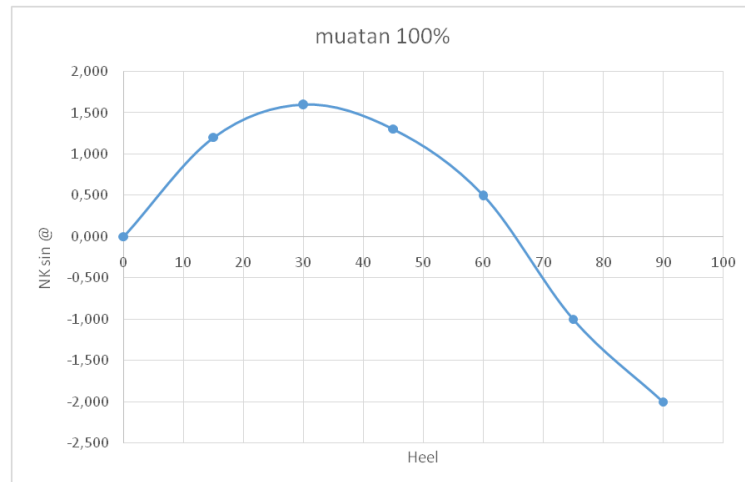
**Gambar 31. Kurva Lengan Stabilitas**



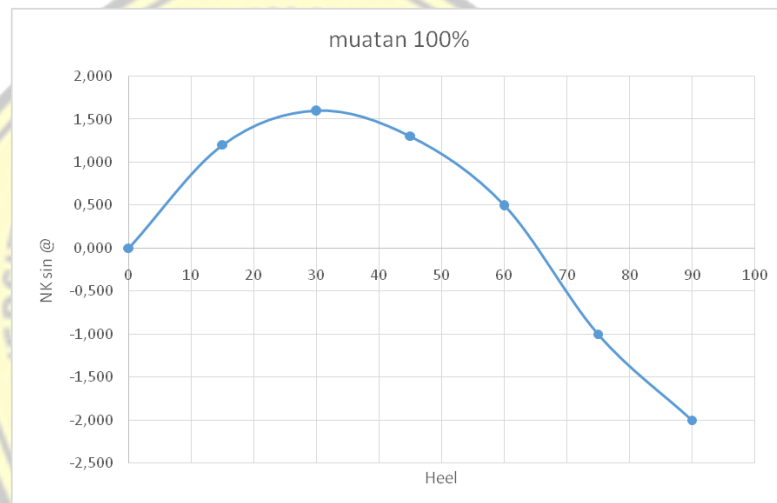
**Gambar 32. Kurva Stabilitas Muatan Kosong**



**Gambar 33. Kurva Stabilitas Muatan 50%**



**Gambar 34. Kurva Stabilitas Muatan 75%**



**Gambar 35. Kurva Stabilitas Muatan 100%**

## V.7 Kontruksi

### V.7.1 Perkiraan Beban

#### 1. Beban geladak cuaca (Load on Cargo Deck)

Yang dianggap sebagai geladak cuaca adalah semua geladak yang bebas kecuali geladak yang tidak efektif yang terletak di belakang 0,15L dari garis tegak haluan. (*BKI 2001 Vol. II Sec. C.1*)

Beban geladak cuaca dihitung berdasar formula :

$$P_D = P_o \frac{20.T}{(10 + z - T)H} \cdot C_D \quad (\text{kN/m}^2)$$

Dimana :

$P_o$  = Basis external dinamic load (section 4.A.2.2 BKI 2001)

$$P_o = 2,1 \times (C_B + 0,7) \times C_o \times C_L \times f \times C_{RW} \text{ kN/m}^2$$

$$C_B = 0,76$$

$$C_o = 10,75 \left[ \frac{300 \times L}{100} \right]^{1,5} \text{ untuk } 90 \leq L \leq 300 \text{ m}$$

$$= 10,75 \left[ \frac{300 \times 110,30}{100} \right]^{1,5}$$

$$C_o = 8,45 \text{ m}$$

$$C_L = 1,0 \text{ untuk } L \geq 90 \text{ m}$$

$$C_{RW} = 1,0$$

$f_1$  = 1,00 faktor kemungkinan untuk plat kulit dan geladak cuaca

$f_2$  = 0,75 faktor kemungkinan untuk gading dan stiffener

$f_3$  = 0,60 faktor kemungkinan untuk deck girder

$Z$  = jarak vertikal dari pusat beban ke baseline

= H (Tinggi kapal)

= 11,63 m

Jadi

- Untuk Plat Kulit

$$P_{o1} = 2,1 \times (C_B + 0,7) \times C_o \times C_L \times f_1 \times C_{RW} \text{ kN/m}^2$$

$$P_{o1} = 2,1 \times (0,76 + 0,7) \times 8,45 \times 1 \times 1 \times 1$$

$$= \mathbf{25,918 \text{ KN/m}^2}$$

- Untuk frame, stiffener, beam, web dan strong

$$P_{o2} = 2,1 \times (C_B + 0,7) \times C_o \times C_L \times f_2 \times C_{RW} \text{ kN/m}^2$$

$$P_{o2} = 2,1 \times (0,76 + 0,7) \times 8,45 \times 1 \times 0,75 \times 1$$

$$= \mathbf{19,439 \text{ KN/m}^2}$$

- Untuk center deck girder, center girder, dan stringger

$$P_{o3} = 2,1 \times (C_B + 0,7) \times C_o \times C_L \times f_3 \times C_{RW} \text{ kN/m}^2$$

$$P_{o3} = 2,1 \times (0,76 + 0,7) \times 8,45 \times 1 \times 0,60 \times 1$$

$$= \mathbf{15,551 \text{ KN/m}^2}$$

$C_D$  = faktor distribusi (tabel 4.1 BKI 2001 sec 4.B 1.2)

$$C_{D1} = 1,2 - X/L \text{ dimana } X/L = 0,08 \text{ (untuk buritan kapal)}$$

$$C_{D1} = 1,2 - 0,08$$

$$C_{D1} = 1,2$$

$$C_{D2} = 1,0 \quad (\text{ untuk tengah kapal } )$$

$$C_{D3} = 1,0 + [ C/3 ( X/L - 0,7 ) ] \text{ dimana } X/L = 0,85 \text{ ( untuk haluan kapal )}$$

$$\text{Dimana nilai } C = 0,15L - 10$$

$$\text{Apabila } L_{\min} = 100 \text{ m}$$

$$L_{\max} = 200 \text{ m}$$

$$C = (0,15 \times 125,93) - 10$$

$$C = 8,89 \text{ m}$$

$$C_{D3} = 1,0 + [ 8,89 / 3 ( 0,85 - 0,7 ) ]$$

$$C_{D3} = 1,65 \text{ m}$$

a. Beban geladak cuaca untuk menghitung plat kulit

$$P_D = P_0 \frac{20T}{(10 + z - T)H} \times C_D \quad (\text{kN/m}^2)$$

- Beban geladak untuk daerah  $0 \leq X/L < 0,2$  buritan kapal adalah :

$$Pd_1 = P_0 \times \frac{20T}{(10 + Z - T) \times H} \times C_D$$

$$Pd_1 = 25,918 \times \frac{20 \times 8,61}{(10 + 11,63 - 8,61) \times 11,63} \times 1,12$$

$$Pd_1 = 25,9951 \text{ kN/m}^2$$

- Beban geladak untuk daerah  $0,2 \leq X/L < 0,7$  tengah kapal adalah :

$$Pd_2 = P_0 \times \frac{20T}{(10 + Z - T) \times H} \times C_D$$

$$Pd_2 = 25,918 \times \frac{20 \times 8,61}{(10 + 11,63 - 8,61) \times 11,63} \times 1,0$$

$$Pd_2 = 23,2099 \text{ kN/m}^2$$

- Beban geladak untuk daerah  $0,7 \leq X/L \leq 1,0$  haluan kapal adalah :

$$Pd_3 = P_0 \times \frac{20T}{(10 + Z - T) \times H} \times C_D$$

$$Pd_3 = 25,918 \times \frac{20 \times 8,61}{(10 + 11,63 - 8,61) \times 11,63} \times 1,0$$

$$Pd_2 = 23,2099 \text{ kN/m}^2$$

- b. Beban geladak cuaca untuk menghitung beam, stiffener dan strong

$$P_D = P_0 \frac{20T}{(10 + z - T)H} \times C_D \text{ (kN/m}^2\text{)}$$

- Beban geladak untuk daerah  $0 \leq X/L < 0,2$  buritan kapal adalah :

$$Pd_1 = P_0 \times \frac{20T}{(10 + Z - T) \times H} \times C_D$$

$$Pd_1 = 19,439 \times \frac{20 \times 8,61}{(10 + 11,63 - 8,61) \times 11,63} \times 1,12$$

$$Pd_1 = 19,4963 \text{ kN/m}^2$$

- Beban geladak untuk daerah  $0,2 \leq X/L < 0,7$  tengah kapal adalah :

$$Pd_2 = P_0 \times \frac{20T}{(10 + Z - T) \times H} \times C_D$$

$$Pd_2 = 19,439 \times \frac{20 \times 8,61}{(10 + 11,63 - 8,61) \times 11,63} \times 1,0$$

$$Pd_2 = 17,4074 \text{ kN/m}^2$$

- Beban geladak untuk daerah  $0,7 \leq X/L \leq 1,0$  haluan kapal adalah :

$$Pd_3 = P_0 \times \frac{20T}{(10 + Z - T) \times H} \times C_D$$

$$Pd_3 = 19,439 \times \frac{20 \times 8,61}{(10 + 11,63 - 8,61) \times 11,63} \times 1,37$$

$$Pd_3 = 28,7551 \text{ kN/m}^2$$

- c. Beban geladak cuaca untuk menghitung girder

$$P_D = P_0 \frac{20T}{(10+z-T)H} \times C_D \quad (\text{kN/m}^2)$$

- Beban geladak untuk daerah  $0 \leq X/L < 0,2$  buritan kapal adalah :

$$Pd_1 = P_0 \times \frac{20T}{(10+Z-T) \times H} \times C_D$$

$$Pd_1 = 15,551 \times \frac{20 \times 8,61}{(10 + 11,63 - 8,61) \times 11,63} \times 1,12$$

$$Pd_1 = 15,5971 \text{ kN/m}^2$$

- Beban geladak untuk daerah  $0,2 \leq X/L < 0,7$  tengah kapal adalah :

$$Pd_2 = P_0 \times \frac{20T}{(10+Z-T) \times H} \times C_D$$

$$Pd_2 = 15,551 \times \frac{20 \times 8,61}{(10 + 11,63 - 8,61) \times 11,63} \times 1,0$$

$$Pd_2 = 19,9259 \text{ kN/m}^2$$

- Beban geladak untuk daerah  $0,7 \leq X/L \leq 1,0$  haluan kapal adalah :

$$Pd_3 = P_0 \times \frac{20T}{(10+Z-T) \times H} \times C_D$$

$$Pd_2 = 15,551 \times \frac{20 \times 8,61}{(10 + 11,63 - 8,61) \times 11,63} \times 1,37$$

$$Pd_3 = 23,0041 \text{ kN/m}^2$$

## 2. Beban Pada Bangunan Atas dan Rumah Geladak (Sec. 4.B.5.1)

Untuk geladak-geladak bangunan atas dan rumah geladak berdasar formula sebagai berikut :

$$P_{DA} = P_D \times n \quad (\text{kN/m}^2)$$

dimana :

$$P_{DA} = P_{D1}$$

$$n = 1 - \{(Z - H)/10\}$$

$$n = 1 \text{ untuk forecastle deck}$$

$$n_{\min} = 0,5$$



a. Beban bangunan atas untuk menghitung plat kulit

- Untuk geladak poop deck

$$PD_A = PD \times n \text{ (kN/m}^2\text{)}$$

Di mana :

$$PD = Pd_1 = 25,9951 \text{ kN/m}^2$$

$$n = 1 - ((Z-H)/10) \quad Z = H + \frac{1}{2} h$$

$$n = 1 - ((12,82-11,63)/10) \quad Z = 11,63 + (\frac{1}{2} \times 2,4)$$

h = tinggi bangunan atas

$$n = 0,88 \quad Z = 12,82 \text{ m}$$

$$n_{\min} = 0,5$$

$$PD_A = PD \times n$$

$$PD_A = 25,9951 \times 0,88$$

$$PD_A = 22,8757 \text{ kN/m}^2$$

- Untuk geladak boot deck

$$PD_A = PD \times n \text{ (kN/m}^2\text{)}$$

Di mana :

$$PD = Pd_1 = 25,9951 \text{ kN/m}^2$$

$$n = 1 - ((Z-H)/10) \quad Z = H + \frac{1}{2} h$$

$$n = 1 - ((16,63-11,63)/10) \quad Z = 11,63 + (\frac{1}{2} \times 2,4)$$

h = tinggi bangunan atas

$$n = 0,64 \quad Z = 16,63 \text{ m}$$

$$n_{\min} = 0,5$$

$$PD_A = PD \times n$$

$$PD_A = 25,9951 \times 0,64$$

$$PD_A = 16,6369 \text{ kN/m}^2$$

- Beban geladak navigation deck

$$PD_A = PD \times n \text{ (kN/m}^2\text{)}$$

Di mana :

$$PD = Pd_1 = 25,9951 \text{ kN/m}^2$$

$$n = 1 - ((Z-H)/10) \quad Z = H + \frac{2}{2} h$$

$$n = 1 - ((17,62-11,63)/10) \quad Z = 11,63 + (2 \times 2,4)$$

h = tinggi bangunan atas

$$n = 0,4 \quad Z = 17,62 \text{ m}$$

$$n_{\min} = 0,5$$

$$PD_A = PD \times n$$

$$PD_A = 25,9951 \times 0,4$$

$$PD_A = 10,398 \text{ kN/m}^2$$

- Beban geladak kompas deck

$$PD_A = PD \times n \text{ (kN/m}^2\text{)}$$

Di mana :

$$PD = Pd_1 = 25,9951 \text{ kN/m}^2$$

$$n = 1 - ((Z-H)/10) \quad Z = H + 3\frac{1}{2} h$$

$$n = 1 - ((20,02-11,63)/10) \quad Z = 11,63 + (3\frac{1}{2} \times 2,4)$$

h = tinggi bangunan atas

$$n = 0,16 \quad Z = 20,02 \text{ m}$$

$$n_{\min} = 0,5$$

$$PD_A = PD \times n$$

$$PD_A = 25,9951 \times 0,16$$

$$PD_A = 4,15921 \text{ kN/m}^2$$

- Beban geladak pada forecastle deck

$$PD_A = PD \times n \text{ (kN/m}^2\text{)}$$

Di mana :

$$n = 1,0$$

$$PD = Pd_3 = 38,3401 \text{ kN/m}^2$$

$$PD_A = PD \times n$$

$$PD_A = 25,9951 \times 1,0$$

$$PD_A = 38,3401 \text{ kN/m}^2$$

- b. Beban bangunan atas untuk menghitung beam, stiffener dan strong

- Untuk geladak poop deck

$$PD_A = PD \times n \text{ (kN/m}^2\text{)}$$

Di mana :

$$PD = Pd_1 = 19,4963 \text{ kN/m}^2$$

$$n = 1 - ((Z-H)/10) \quad Z = H + \frac{1}{2} h$$

$$n = 1 - ((12,82-11,63)/10) \quad Z = 11,63 + (1/2 \times 2,4)$$

h = tinggi bangunan atas

$$n = 0,88 \quad Z = 12,82 \text{ m}$$

$$n_{\min} = 0,5$$

$$PD_A = PD \times n$$

$$PD_A = 19,4963 \times 0,88$$

$$PD_A = 17,1568 \text{ kN/m}^2$$

- Untuk geladak boot deck

$$PD_A = PD \times n \text{ (kN/m}^2\text{)}$$

Di mana :

$$PD = Pd_1 = 19,4963 \text{ kN/m}^2$$

$$n = 1 - ((Z-H)/10) \quad Z = H + 1/2 h$$

$$n = 1 - ((15,22-11,63)/10) \quad Z = 11,63 + (1/2 \times 2,4)$$

h = tinggi bangunan atas

$$n = 0,64 \quad Z = 11,86 \text{ m}$$

$$n_{\min} = 0,5$$

$$PD_A = PD \times n$$

$$PD_A = 19,49631 \times 0,64$$

$$PD_A = 12,4776 \text{ kN/m}^2$$

- Beban geladak navigation deck

$$PD_A = PD \times n \text{ (kN/m}^2\text{)}$$

Di mana :

$$PD = Pd_1 = 19,4963 \text{ kN/m}^2$$

$$n = 1 - ((Z-H)/10) \quad Z = H + 2/2 h$$

$$n = 1 - ((17,62-11,63)/10) \quad Z = 11,63 + (2/2 \times 2,4)$$

h = tinggi bangunan atas

$$n = 0,4 \quad Z = 17,62 \text{ m}$$

$$n_{\min} = 0,5$$

$$PD_A = PD \times n$$

$$PD_A = 19,4963 \times 0,4$$

$$PD_A = 7,79853 \text{ kN/m}^2$$

- Beban geladak kompas deck

$$PD_A = PD \times n \text{ (kN/m}^2\text{)}$$

Di mana :

$$PD = Pd_1 = 19,4963 \text{ kN/m}^2$$

$$n = 1 - ((Z-H)/10) \quad Z = H + 3\frac{1}{2} h$$

$$n = 1 - ((20,02-11,63)/10) \quad Z = 11,63 + (3\frac{1}{2} \times 2,4) \quad h = \text{tinggi bangunan atas}$$

$$n = 0,16 \quad Z = 20,02 \text{ m}$$

$$n_{\min} = 0,5$$

$$PD_A = PD \times n$$

$$PD_A = 19,4963 \times 0,16$$

$$PD_A = 3,11941 \text{ kN/m}^2$$

- Beban geladak pada forecastle deck

$$PD_A = PD \times n \text{ (kN/m}^2\text{)}$$

Di mana :

$$n = 1,0$$

$$PD = Pd_3 = 28,7551 \text{ kN/m}^2$$

$$PD_A = PD \times n$$

$$PD_A = 28,7551 \times 1,0$$

$$PD_A = 28,7551 \text{ kN/m}^2$$

c. Beban bangunan atas untuk menghitung girder

- Untuk geladak poop deck

$$PD_A = PD \times n \text{ (kN/m}^2\text{)}$$

Di mana :

$$PD = Pd_1 = 15,5971 \text{ kN/m}^2$$

$$n = 1 - ((Z-H)/10) \quad Z = H + \frac{1}{2} h$$

$$n = 1 - ((12,82-11,63)/10) \quad Z = 11,63 + (\frac{1}{2} \times 2,4) \quad h = \text{tinggi bangunan atas}$$

$$n = 0,88 \quad Z = 12,82 \text{ m}$$

$$n_{\min} = 0,5$$

$$PD_A = PD \times n$$

$$PD_A = 15,5971 \times 0,88$$

$$PD_A = 13,7254 \text{ kN/m}^2$$

- Untuk geladak boot deck

$$PD_A = PD \times n \text{ (kN/m}^2\text{)}$$

Di mana :

$$PD = Pd_1 = 15,5971 \text{ kN/m}^2$$

$$n = 1 - ((Z-H)/10) \quad Z = H + 1\frac{1}{2} h$$

$$n = 1 - ((15,22-11,63)/10) \quad Z = 11,63 + (1\frac{1}{2} \times 2,4) h =$$

tinggi bangunan atas

$$n = 0,64 \quad Z = 15,22 \text{ m}$$

$$n_{\min} = 0,5$$

$$PD_A = PD \times n$$

$$PD_A = 15,5971 \times 0,64$$

$$PD_A = 9,98211 \text{ kN/m}^2$$

- Beban geladak navigation deck

$$PD_A = PD \times n \text{ (kN/m}^2\text{)}$$

Di mana :

$$PD = Pd_1 = 15,5971 \text{ kN/m}^2$$

$$n = 1 - ((Z-H)/10) \quad Z = H + 2\frac{1}{2} h$$

$$n = 1 - ((17,62-11,63)/10) \quad Z = 11,63 + (2\frac{1}{2} \times 2,4)$$

h = tinggi bangunan atas

$$n = 0,4 \quad Z = 17,62 \text{ m}$$

$$n_{\min} = 0,5$$

$$PD_A = PD \times n$$

$$PD_A = 15,5971 \times 0,4$$

$$PD_A = 6,23882 \text{ kN/m}^2$$

- Beban geladak kompas deck

$$PD_A = PD \times n \text{ (kN/m}^2\text{)}$$

Di mana :

$$PD = Pd_1 = 15,5971 \text{ kN/m}^2$$

$$n = 1 - ((Z-H)/10) \quad Z = H + 3\frac{1}{2} h$$

$$n = 1 - ((20,02 - 11,63) / 10) \quad Z = 11,63 + (3\frac{1}{2} \times 2)$$

h = tinggi bangunan atas

$$n = 0,16 \quad Z = 20,02 \text{ m}$$

$$n_{\min} = 0,5$$

$$PD_A = PD \times n$$

$$PD_A = 15,5971 \times 0,16$$

$$PD_A = 2,49553 \text{ kN/m}$$

- Beban geladak pada forecastle deck

$$PD_A = PD \times n \text{ (kN/m}^2\text{)}$$

Di mana :

$$n = 1,0$$

$$PD = Pd_3 = 23,0041 \text{ kN/m}^2$$

$$PD_A = PD \times n$$

$$PD_A = 23,0041 \times 1$$

$$PD_A = 23,0041 \text{ kN/m}^2$$

3. Beban sisi kapal (BKI 2001 Vol. Sec. 4. B. 2. 1)

Dibawah garis air muat (LWL)

$$P_s = 10 \cdot (T - Z) + P_o \cdot CF \cdot \left(1 + \frac{Z}{T}\right) \text{ (kN/m}^2\text{)}$$

Di mana

- Untuk plat kulit

$$P_{o1} = 25,918 \text{ KN/m}^2$$

- Untuk frame dan stiffener beam

$$P_{o2} = 19,439 \text{ KN/m}^2$$

- Untuk girder, web dan stringer

$$P_{o3} = 15,551 \text{ KN/m}^2$$

Z = jarak vertikal dari pusat beban ke baseline

$$= 1/3 \times T$$

$$= 1/3 \times 8,61$$

$$= 2,86 \text{ m}$$

$C_f = 1,0 + ((5/C_b) \times (0,2 - x/L))$  untuk  $0 \leq X/L \leq 0,2$  pada daerah buritan kapal

$$C_f = 1,0 + ((5/0,76) \times (0,2 - 0,08))$$

$$C_f = 1,79$$

$C_f = 1,0$  untuk  $0,2 \leq X/L \leq 0,8$  pada daerah tengah kapal

$C_f = 1,0 + ((20/C_b) \times (x/L - 0,7)^2)$  untuk  $0,8 \leq X/L \leq 1,0$  pada daerah haluan kapal

$$C_f = 1,0 + ((20/0,76) \times (0,92 - 0,7)^2)$$

$$C_f = 2,27$$

a. Beban sisi kapal untuk menghitung plat kulit

$$P_s = 10 \times (T - Z) + P_{o1} \cdot C_f \cdot \left(1 + \frac{Z}{T}\right) \text{ (kN/m}^2\text{)}$$

- Beban sisi kapal daerah buritan kapal

$$P_{s1} = 10(T - Z) + P_0 \times C_{f1} \times \left(1 + \frac{Z}{T}\right)$$

$$P_{s1} = 10(8,61 - 2,86) + 25,918 \times 1,79 \times \left(1 + \frac{2,86}{8,61}\right)$$

$$P_{s1} = 119,234 \text{ kN/m}^2$$

- Beban sisi kapal daerah tengah kapal

$$P_{s1} = 10(T - Z) + P_0 \times C_{f1} \times \left(1 + \frac{Z}{T}\right)$$

$$P_{s1} = 10(8,61 - 2,86) + 25,918 \times 1,00 \times \left(1 + \frac{2,86}{8,61}\right)$$

$$P_{s1} = 91,952 \text{ kN/m}^2$$

- Beban sisi kapal daerah haluan kapal

$$P_{s1} = 10(T - Z) + P_0 \times C_{f1} \times \left(1 + \frac{Z}{T}\right)$$

$$P_{s1} = 10(8,61 - 2,86) + 25,918 \times 2,27 \times \left(1 + \frac{2,86}{8,61}\right)$$

$$P_{s1} = 135,967 \text{ kN/m}^2$$

b. Beban sisi kapal untuk menghitung frame dan stiffener

$$P_s = 10 \times (T - Z) + P_{o2} \cdot C_f \cdot \left(1 + \frac{Z}{T}\right) \text{ (kN/m}^2\text{)}$$

- Beban sisi kapal daerah buritan kapal

$$Ps_1 = 10(T - Z) + P_0 \times C_{f1} \times (1 + \frac{Z}{T})$$

$$Ps_1 = 10(8,61 - 2,86) + 19,439 \times 1,79 \times (1 + \frac{2,86}{8,61})$$

$$Ps_1 = 103,774 \text{ kN} / \text{m}^2$$

- Beban sisi kapal daerah tengah kapal

$$Ps_1 = 10(T - Z) + P_0 \times C_{f1} \times (1 + \frac{Z}{T})$$

$$Ps_1 = 10(8,61 - 2,86) + 19,439 \times 1,00 \times (1 + \frac{2,86}{8,61})$$

$$Ps_1 = 83,3127 \text{ kN} / \text{m}^2$$

- Beban sisi kapal daerah haluan kapal

$$Ps_1 = 10(T - Z) + P_0 \times C_{f1} \times (1 + \frac{Z}{T})$$

$$Ps_1 = 10(8,61 - 2,86) + 19,439 \times 2,27 \times (1 + \frac{2,86}{8,61})$$

$$Ps_1 = 116,324 \text{ kN} / \text{m}^2$$

c. Beban sisi kapal untuk menghitung Web dan stringer

- Beban sisi kapal daerah buritan kapal

$$Ps_1 = 10(T - Z) + P_0 \times C_{f1} \times (1 + \frac{Z}{T})$$

$$Ps_1 = 10(8,61 - 2,86) + 15,551 \times 1,79 \times (1 + \frac{2,86}{8,61})$$

$$Ps_1 = 94,4984 \text{ kN} / \text{m}^2$$

- Beban sisi kapal daerah tengah kapal

$$Ps_1 = 10(T - Z) + P_0 \times C_{f1} \times (1 + \frac{Z}{T})$$

$$Ps_1 = 10(8,61 - 2,86) + 15,551 \times 1,00 \times (1 + \frac{2,86}{8,61})$$

$$Ps_1 = 78,1291 \text{ kN} / \text{m}^2$$

- Beban sisi kapal daerah haluan kapal

$$Ps_1 = 10(T - Z) + P_0 \times C_{f1} \times (1 + \frac{Z}{T})$$

$$Ps_1 = 10(8,61 - 2,86) + 15,551 \times 2,27 \times (1 + \frac{2,86}{8,61})$$

$$Ps_1 = 104,538 \text{ kN} / \text{m}^2$$

Diatas garis air muat (LWL) (Section 4. B. 2. 1. 2 BKI 2001)

$$Ps = P_0 \times C_F \times \frac{20}{(10 + Z - T)} \quad \text{kN/m}^2$$

$$C_{F1} = 1,79$$

$$C_{F2} = 1,00$$

$$C_{F3} = 2,27$$



$$z = \text{Jarak vertikal dari pusat beban ke base line}$$

$$= T + \frac{1}{2} (H - T) = 8,61 + \frac{1}{2} (11,63 - 8,61) = 10,11 \text{ m}$$

$$P_o = 25,918 \text{ kN/m}^2$$

4. Beban sisi kapal untuk menghitung plat kulit

$$P_s = P_o \times C_F \times \left( \frac{20}{10 + Z - T} \right) \text{ kN/m}^2$$

• Beban sisi daerah buritan kapal

$$P_{s1} = P_o \times \frac{C_{f1} \times 20}{10 + Z - T}$$

$$P_{s1} = 25,918 \times \frac{1,79 \times 20}{10 + 10,11 - 8,61}$$

$$P_{s1} = 80,5888 \text{ kN/m}^2$$

• Beban sisi daerah tengah kapal

$$P_{s1} = P_o \times \frac{C_{f1} \times 20}{10 + Z - T}$$

$$P_{s1} = 25,918 \times \frac{1,00 \times 20}{10 + 10,11 - 8,61}$$

$$P_{s1} = 45,0349 \text{ kN/m}^2$$

• Beban sisi daerah haluan kapal

$$P_{s1} = P_o \times \frac{C_{f1} \times 20}{10 + Z - T}$$

$$P_{s1} = 25,918 \times \frac{2,27 \times 20}{10 + 10,11 - 8,61}$$

$$P_{s1} = 102,395 \text{ kN/m}^2$$

5. Beban bangunan atas untuk menghitung Web dan stringer

$$P_{SA} = P_o \times C_F \times \frac{20}{(10 + Z - T)} \text{ kN/m}^2$$

• Beban pada Poop Deck

$$P_s = P_o \times \frac{C_{f1} \times 20}{10 + Z_4 - T}$$

$$P_s = 15,551 \times \frac{1,79 \times 20}{10 + 12,82 - 8,61}$$

$$P_s = 39,13 \text{ kN/m}^2$$

- Beban pada Boat Deck

$$P_s = P_0 \times \frac{C_{f1} \times 20}{10 + Z_4 - T}$$

$$P_s = 15,551 \times \frac{1,79 \times 20}{10 + 15,22 - 8,61}$$

$$P_s = 33,48 \text{ kN/m}^2$$

- Beban pada Navigation Deck

$$P_s = P_0 \times \frac{C_{f1} \times 20}{10 + Z_4 - T}$$

$$P_s = 15,551 \times \frac{1,79 \times 20}{10 + 17,62 - 8,61}$$

$$P_s = 29,26 \text{ kN/m}^2$$

- Beban pada Compass Deck

$$P_s = P_0 \times \frac{C_{f1} \times 20}{10 + Z_4 - T}$$

$$P_s = 15,551 \times \frac{1,79 \times 20}{10 + 20,02 - 8,61}$$

$$P_s = 25,98 \text{ kN/m}^2$$

- Beban pada Fore Castle Deck

$$P_s = P_0 \times \frac{C_{f1} \times 20}{10 + Z_4 - T}$$

$$P_s = 15,551 \times \frac{2,27 \times 20}{10 + 12,82 - 8,61}$$

$$P_s = 49,72 \text{ kN/m}^2$$

## 6. Beban Alas Kapal

- a. Beban luar alas kapal ( Load on the ship's bottom )

Beban luar alas kapal dihitung untuk menentukan konstruksi alas kapal (BKI 2001 Vol. II Sec. 4 B. 3)

$$P_B = 10 \cdot T + P_o \cdot C_f \quad \text{kN/m}^2$$

Dimana :

$$T = 8,61 \text{ m}$$

$$P_{o1} = 25,918 \text{ kN/m}^2$$

$$P_{o2} = 19,439 \text{ kN/m}^2$$

$$P_{O3} = 15,551 \text{ kN/m}^2$$

$$C_{F1} = 1,79 \quad \text{Buritan kapal}$$

$$C_{F2} = 1,00 \text{ untuk } 0,2 < X/L < 0,7 \text{ (tengah kapal)}$$

$$C_{F3} = 2,27 \text{ Haluan kapal}$$

b. Beban alas kapal untuk menghitung plat kulit,

- Beban alas buritan kapal

$$Pb_1 = 10 \times T + P_0 \times C_f$$

$$Pb_1 = 10 \times 8,61 + 25,918 \times 1,79$$

$$Pb_1 = 132,47 \text{ kN/m}^2$$

- Beban alas tengah kapal

$$Pb_1 = 10 \times T + P_0 \times C_f$$

$$Pb_1 = 8,61 + 25,918 \times 1,00$$

$$Pb_1 = 112,01 \text{ kN/m}^2$$

- Beban alas haluan kapal

$$Pb_1 = 10 \times T + P_0 \times C_f$$

$$Pb_1 = 10 \times 8,61 + 25,918 \times 2,27$$

$$Pb_1 = 145,02 \text{ kN/m}^2$$

## V.7.2 Perhitungan Plat geladak Kekuatan dan Plat kulit (Section .7.A.7.1 BKI 2001)

$$T_G = 1,21 \times a + \sqrt{P_D \times k} + t_k$$

Data-data rumus sebagai berikut :

$$a_{ap} = 0,6 \text{ (jarak gading)}$$

$$a_m = 0,7 \text{ (jarak gading)}$$

$$a_{fp} = 0,6 \text{ (jarak gading)}$$

$$k = 1 \text{ (faktor bahan)}$$

$$t_k = 1,5 \text{ (faktor korosi) .}$$

$$P_{D1} = 25,99509 \text{ kN/m}^2$$

$$P_{D2} = 23,2099 \text{ kN/m}^2$$

$$P_{D3} = 38,34 \text{ kN/m}^2$$

## 1. Pelat Geladak (Sec. 7.A. 7.1)

$$T_G = 1,21 \times a + \sqrt{P_D \times k} + t_k$$

$$T_{Gmin} = (5,5 + 0,02L) \sqrt{k}$$

$$\begin{aligned} T_{Gmin} &= (5,5 + (0,02 \times 125,93)) \sqrt{1} \\ &= 8,018581 \text{ mm} \approx 8 \text{ mm} \end{aligned}$$

- Tebal plat geladak daerah buritan

$$t_{G1} = 1,21 \times a \times \sqrt{P_{D1} \times k} + t_k$$

$$t_{G1} = 1,21 \times 0,6 \times \sqrt{25,99 \times 1} + 1,5$$

$$t_{G1} = 5,201538 \text{ mm} \approx 5 \text{ mm}$$

- Tebal plat geladak kekuatan pada daerah tengah

$$t_{G2} = 1,21 \times a \times \sqrt{P_{D2} \times k} + t_k$$

$$t_{G2} = 1,21 \times 0,7 \times \sqrt{23,20 \times 1} + 1,5$$

$$t_{G2} = 4,997625 \text{ mm} \approx 5 \text{ mm}$$

- Tebal plat geladak kekuatan pada daerah haluan

$$t_{G3} = 1,21 \times a \times \sqrt{P_{D3} \times k} + t_k$$

$$t_{G3} = 1,21 \times 0,6 \times \sqrt{38,34 \times 1} + 1,5$$

$$t_{G3} = 5,995347 \text{ mm} \approx 6 \text{ mm}$$

## 2. Plat Geladak Bangunan Atas

$$T_G = 1,21 \times a \times \sqrt{P_{DA} \times k} + t_k$$

$$P_{DA1} = 22,875 \text{ kN/m}^2$$

$$P_{DA2} = 16,636 \text{ kN/m}^2$$

$$P_{DA3} = 10,398 \text{ kN/m}^2$$

$$P_{DA4} = 4,159 \text{ kN/m}^2$$

$$P_{DA5} = 38,340 \text{ kN/m}^2$$

- Tebal plat Poop Deck

$$t_{GA} = 1,21 \times a \times \sqrt{P_{DA1} \times k} + t_k$$

$$t_{GA} = 1,21 \times 0,7 \times \sqrt{22,87 \times 1} + 1,5$$

$$t_{GA} = 5,7 \text{ mm} \approx 6 \text{ mm}$$

- Tebal plat Boat Deck

$$t_{GA} = 1,21 \times a \times \sqrt{P_{DA1} \times k} + t_k$$

$$t_{GA} = 1,21 \times 0,7 \times \sqrt{16,63 \times 1} + 1,5$$

$$t_{GA} = 5,1 \text{ mm} \approx 5 \text{ mm}$$

- Tebal plat pada Navigasi Deck

$$t_{GA} = 1,21 \times a \times \sqrt{P_{DA1} \times k} + t_k$$

$$t_{GA} = 1,21 \times 0,7 \times \sqrt{10,39 \times 1} + 1,5$$

$$t_{GA} = 4,3 \text{ mm} \approx 4 \text{ mm}$$

- Tebal plat pada Compass Deck

$$t_{GA} = 1,21 \times a \times \sqrt{P_{DA1} \times k} + t_k$$

$$t_{GA} = 1,21 \times 0,7 \times \sqrt{4,15 \times 1} + 1,5$$

$$t_{GA} = 3,3 \text{ mm} \approx 3 \text{ mm}$$

- Tebal plat pada Fore Castle Deck

$$t_{GA} = 1,21 \times a \times \sqrt{P_{DA1} \times k} + t_k$$

$$t_{GA} = 1,21 \times 0,7 \times \sqrt{38,34 \times 1} + 1,5$$

$$t_{GA} = 6,9 \text{ mm} \approx 7 \text{ mm}$$

### 3. Plat Alas Kapal (Bottom Plate) (Sec. 6.B. 1-1)

Dimana

$$t_{b_i} = 1,83 \times n_f \times a \times \sqrt{\frac{P_B}{\sigma_{pf}}} + t_k$$

$$t_{b_{ii}} = 1,21 \times a \sqrt{P_B \times k} + t_k$$

$$n_f = 1 \text{ (sistem gading melintang)}$$

$$n_f = 0,83 \text{ (sistem gading memanjang)}$$

$$\sigma_{perm} = \frac{230}{k} = 230 \text{ N/mm}^2$$

$$\sigma_{LB} = \frac{120}{k} = 120 \text{ N/mm}^2$$

$$\sigma_{pf} = \sqrt{\sigma_{perm}^2 - (3 \times \tau_L^2)} - (0,89 \times \sigma_{LB}) \quad \tau_L = 0$$

$$\sigma_{pf} = \sqrt{(230)^2 - (3 \times 0)} - (0,89 \times 120)$$

$$\sigma_{pf} = 123,2 \text{ N/mm}^2$$

$$P_{B1} = 132,471 \text{ kN/m}^2$$

$$P_{B2} = 112,01 \text{ kN/m}^2$$

$$P_{B3} = 145,021 \text{ kN/m}^2$$

- a = 0,6 (jarak buritan gading)
- a = 0,7 (jarak mid gading)
- a = 0,6 (jarak aluangading)
- k = 1 (faktor bahan)
- tk = 1,5 (faktor korosi)

- Tebal plat alas untuk daerah buritan

$$t_{b_i} = 1,83 \times n_f \times a \times \sqrt{\frac{P_{B1}}{\sigma_{pf}}} + t_k$$

$$t_{b_i} = 1,83 \times 1 \times 0,6 \times \sqrt{\frac{132,471}{123,2}} + 1,5$$

$$t_{b_i} = 2,6 \text{ mm}$$

$$t_{b_{ii}} = 1,21 \times a \times \sqrt{P_{B1} \times k} + t_k$$

$$t_{b_{ii}} = 1,21 \times 0,6 \times \sqrt{132,471 \times 1} + 1,5$$

$$t_{b_{ii}} = 9,8 \text{ mm}$$

$$t_{b_i} = 9,18 \text{ mm} \approx 9 \text{ mm}$$

- Tebal plat alas untuk daerah tengah

$$t_{b_i} = 1,83 \times n_f \times a \times \sqrt{\frac{P_{B2}}{\sigma_{pf}}} + t_k$$

$$t_{b_i} = 1,83 \times 0,83 \times 0,7 \times \sqrt{\frac{112,01}{123,2}} + 1,5$$

$$t_{b_i} = 2,5 \text{ mm}$$

$$t_{b_{ii}} = 1,21 \times a \times \sqrt{P_{B2} \times k} + t_k$$

$$t_{b_{ii}} = 1,21 \times 0,7 \times \sqrt{112,01 \times 1} + 1,5$$

$$t_{b_{ii}} = 10,872 \text{ mm}$$

$$t_{b_2} = 10,872 \text{ mm} \approx 11 \text{ mm}$$

- Tebal pelat alas untuk daerah haluan

$$t_{b_i} = 1,83 \times n_f \times a \times \sqrt{\frac{P_{B3}}{\sigma_{pf}}} + t_k$$

$$t_{b_i} = 1,83 \times 1 \times 0,6 \times \sqrt{\frac{145,021}{123,2}} + 1,5$$

$$t_{b_i} = 2,6 \text{ mm}$$

$$t_{b_{ii}} = 1,21 \times a \times \sqrt{P_{B3} \times k} + t_k$$

$$t_{b_{ii}} = 1,21 \times 0,6 \times \sqrt{145,021 \times 1} + 1,5$$

$$t_{b_{ii}} = 10,24 \text{ mm}$$

$$t_{b_3} = 10,24 \text{ mm} \approx 10 \text{ mm}$$

4. Plat Sisi Kapal ( Side Shell Plating ) (sec. 6-3 C.1.2)

$$t_{S1} = 18,3 \times n_f \times a \times \sqrt{\frac{P_S}{\sigma_{pl}}} + t_k \text{ (mm)}$$

untuk  $L \geq 90 \text{ m}$

$$t_{S2} = 1,21 \times a \times \sqrt{P_S \times k} + t_k \text{ (mm)}$$

Di mana :

$$\sigma_{pl} = \sigma_{perm} - (0,89 \times \sigma_{LS}) \text{ (N/mm}^2\text{)} \quad \sigma_{perm} = 230/k \quad \sigma_{LS} = 120/k$$

$$\sigma_{pl} = 230 - (0,89 \times 120) \quad \sigma_{perm} = 230/1 \quad \sigma_{LS} = 120/1$$

$$\sigma_{pl} = 123,2 \text{ mm}^3$$

$$P_{S1} = 119,2342$$

$$P_{S2} = 91,95205$$

$$P_{S3} = 135,9673$$

a) Tebal pelat sisi kapal dibawah garis muat

- Tebal pelat sisi buritan kapal

$$t_{SI} = 18,3 \times n_f \times a \times \sqrt{\frac{P_{S1}}{\sigma_{pl}}} + t_k$$

$$t_{SI} = 18,3 \times 1,0 \times 0,6 \times \sqrt{\frac{119,234}{123,2}} + 1,5$$

$$t_{SI} = 12,301 \text{ mm} \approx 11 \text{ mm}$$

$$t_{SII} = 1,21 \times a \times \sqrt{P_{S1} \times k} + t_k$$

$$t_{SII} = 1,21 \times 0,6 \times \sqrt{119,234 \times 1} + 1,5$$

$$t_{SII} = 9,427 \text{ mm} \approx 9 \text{ mm}$$

$$t_{S1} = 11 \text{ mm}$$

- Tebal pelat sisi tengah kapal

$$t_{SI} = 18,3 \times n_f \times a \times \sqrt{\frac{P_{S2}}{\sigma_{pl}}} + t_k$$

$$t_{SI} = 18,3 \times 0,83 \times 0,6 \times \sqrt{\frac{91,952}{123,2}} + 1,5$$

$$t_{SI} = 9,3732 \text{ mm} \approx 9 \text{ mm}$$

$$t_{SII} = 1,21 \times a \times \sqrt{P_{S2} \times k} + t_k$$

$$t_{SII} = 1,21 \times 0,6 \times \sqrt{91,952 \times 1} + 1,5$$

$$t_{SII} = 8,461 \text{ mm} \approx 8 \text{ mm}$$

$$t_{S2} = 9 \text{ mm}$$

- Tebal pelat sisi haluan kapal

$$t_{SI} = 18,3 \times n_f \times a \times \sqrt{\frac{P_{S3}}{\sigma_{pl}}} + t_k$$

$$t_{SI} = 18,3 \times 1,0 \times 0,6 \times \sqrt{\frac{135,967}{123,2}} + 1,5$$

$$t_{SI} = 13,034 \text{ mm} \approx 12 \text{ mm}$$

$$t_{SII} = 1,21 \times a \times \sqrt{P_{S3} \times k} + t_k$$

$$t_{SII} = 1,21 \times 0,6 \times \sqrt{135,967 \times 1} + 1,5$$

$$t_{SII} = 9,965 \text{ mm}$$

$$t_{S3} = 12 \text{ mm}$$



b) Tebal pelat sisi kapal diatas garis muat

$$t_{s1} = 18,3 \times n_f \times a \times \sqrt{\frac{P_s}{\sigma_{pl}}} + t_k \text{ (mm)}$$

untuk  $L \geq 90 \text{ m}$

$$t_{s2} = 1,21 \times a \times \sqrt{P_s \times k} + t_k \text{ (mm)}$$

Di mana :

$$\sigma_{pl} = 123,2 \text{ mm}$$

$$P_{s1} = 80,58884 \text{ kN/m}^2$$

$$P_{s2} = 45,03494 \text{ kN/m}^2$$

$$P_{s3} = 102,3952 \text{ kN/m}^2$$

• Tebal pelat sisi buritan kapal

$$t_{sI} = 18,3 \times n_f \times a \times \sqrt{\frac{P_{s1}}{\sigma_{pl}}} + t_k$$

$$t_{sI} = 18,3 \times 1,0 \times 0,6 \times \sqrt{\frac{80,58884}{123,2}} + 1,5$$

$$t_{sI} = 10,38044 \text{ mm} \approx 10 \text{ mm}$$

$$t_{sII} = 1,21 \times a \times \sqrt{P_{s1} \times k} + t_k$$

$$t_{sII} = 1,21 \times 0,6 \times \sqrt{80,58884 \times 1} + 1,5$$

$$t_{sII} = 8,017 \text{ mm} \approx 8 \text{ mm}$$

$$t_{sI} = 10 \text{ mm}$$

• Tebal pelat sisi tengah kapal

$$t_{sI} = 18,3 \times n_f \times a \times \sqrt{\frac{P_{s2}}{\sigma_{pl}}} + t_k$$

$$t_{sI} = 18,3 \times 0,83 \times 0,6 \times \sqrt{\frac{45,03494}{123,2}} + 1,5$$

$$t_{sI} = 7,009978 \text{ mm} \approx 7 \text{ mm}$$

$$t_{sII} = 1,21 \times a \times \sqrt{P_{s2} \times k} + t_k$$

$$t_{sII} = 1,21 \times 0,6 \times \sqrt{45,03494 \times 1} + 1,5$$

$$t_{sII} = 6,3720 \text{ mm} \approx 6 \text{ mm}$$

$$t_{s2} = 7 \text{ mm}$$

- Tebal pelat sisi tengah kapal

$$t_{SI} = 18,3 \times n_f \times a \times \sqrt{\frac{P_{S3}}{\sigma_{pl}} + t_k}$$

$$t_{SI} = 18,3 \times 1,0 \times 0,6 \times \sqrt{\frac{102,395}{123,2}} + 1,5$$

$$t_{SI} = 11,51006 \text{ mm} \approx 11 \text{ mm}$$

$$t_{SU} = 1,21 \times a \times \sqrt{P_{S3} \times k + t_k}$$

$$t_{SU} = 1,21 \times 0,6 \times \sqrt{102,395 \times 1} + 1,5$$

$$t_{SU} = 6,3720 \text{ mm} \approx 6 \text{ mm}$$

$$t_{S3} = 11 \text{ mm}$$

- c) Tebal pelat sisi kapal pada Bangunan atas

$$t_{S1} = 18,3 \times n_f \times a \times \sqrt{\frac{P_S}{\sigma_{pl}} + t_k} \text{ (mm)} \quad \text{untuk } L \geq 90 \text{ m}$$

$$t_{S2} = 1,21 \times a \times \sqrt{P_S \times k + t_k} \text{ (mm)}$$

$$t_{S1} = 65,22979 \text{ kN/m}^2$$

$$t_{S2} = 55,81055 \text{ kN/m}^2$$

$$t_{S3} = 48,76836 \text{ kN/m}^2$$

$$t_{S4} = 43,30422 \text{ kN/m}^2$$

$$t_{S5} = 82,8802 \text{ kN/m}^2$$

- Tebal plat sisi pada poop deck

$$t_{SI} = 18,3 \times n_f \times a \times \sqrt{\frac{P_S}{\sigma_{pl}} + t_k}$$

$$t_{SI} = 18,3 \times 0,83 \times 0,7 \times \sqrt{\frac{65,22979}{123,2}} + 1,5$$

$$t_{SI} = 9,588606 \text{ mm} \approx 9 \text{ mm}$$

$$t_{SII} = 1,21 \times a \times \sqrt{P_s \times k} + t_k$$

$$t_{SII} = 1,21 \times 0,7 \times \sqrt{68,66565 \times 1} + 1,5$$

$$t_{SII} = 8,652127 \text{ mm} \approx 8 \text{ mm}$$

$$t_s = 9 \text{ mm}$$

- Tebal plat sisi pada boot deck

$$t_{SI} = 18,3 \times n_f \times a \times \sqrt{\frac{P_s}{\sigma_{pl}}} + t_k$$

$$t_{SI} = 18,3 \times 0,83 \times 0,7 \times \sqrt{\frac{55,81055}{123,2}} + 1,5$$

$$t_{SI} = 8,98 \text{ mm} \approx 9 \text{ mm}$$

$$t_{SII} = 1,21 \times a \times \sqrt{P_s \times k} + t_k$$

$$t_{SII} = 1,21 \times 0,7 \times \sqrt{55,81055 \times 1} + 1,5$$

$$t_{SII} = 8,11 \text{ mm} \approx 8 \text{ mm}$$

$$t_s = 9 \text{ mm}$$

- Tebal plat sisi pada navigation deck

$$t_{SI} = 18,3 \times n_f \times a \times \sqrt{\frac{P_s}{\sigma_{pl}}} + t_k$$

$$t_{SI} = 18,3 \times 0,83 \times 0,7 \times \sqrt{\frac{48,76836}{123,2}} + 1,5$$

$$t_{SI} = 8,49 \text{ mm} \approx 8 \text{ mm}$$

$$t_{SII} = 1,21 \times a \times \sqrt{P_s \times k} + t_k$$

$$t_{SII} = 1,21 \times 0,7 \times \sqrt{48,76836 \times 1} + 1,5$$

$$t_{SII} = 7,68 \text{ mm} \approx 8 \text{ mm}$$

$$t_s = 8 \text{ mm}$$

- Tebal plat sisi pada forecastle deck

$$t_{s1} = 18,3 \times n_f \times a \times \sqrt{\frac{P_s}{\sigma_{pl}}} + t_k$$

$$t_{s1} = 18,3 \times 0,83 \times 0,7 \times \sqrt{\frac{43,30422}{123,2}} + 1,5$$

$$t_{s1} = 8,09 \text{ mm} \approx 8 \text{ mm}$$

$$t_{s2} = 1,21 \times a \times \sqrt{P_s \times k} + t_k$$

$$t_{s2} = 1,21 \times 0,7 \times \sqrt{43,30422 \times 1} + 1,5$$

$$t_{s2} = 7,32 \text{ mm} \approx 7 \text{ mm}$$

$$t_s = 8 \text{ mm}$$

- Tebal plat sisi pada kompas deck

$$t_{sI} = 18,3 \times n_f \times a \times \sqrt{\frac{P_s}{\sigma_{pl}}} + t_k$$

$$t_{sI} = 18,3 \times 1,0 \times 0,6 \times \sqrt{\frac{82,8802}{123,2}} + 1,5$$

$$t_{sI} = 10,61 \text{ mm} \approx 10 \text{ mm}$$

$$t_{sII} = 1,21 \times a \times \sqrt{P_s \times k} + t_k$$

$$t_{sII} = 1,21 \times 0,6 \times \sqrt{82,8802 \times 1} + 1,5$$

$$t_{sII} = 9,56 \text{ mm} \approx 9 \text{ mm}$$

$$t_s = 10 \text{ mm}$$

## 5. Plat Lajur Bilga ( sec. 6-2 B.4.1 )

Tebal plat lajur bilga

- ❖ Pada sistem gading lintang sama dengan tebal plat sisi

Daerah buritan = 11 mm

Daerah midship = 11 mm

Daerah haluan = 12 mm

- ❖ Pada sistem gading bujur sama dengan tebal plat alas

Daerah haluan = 9 mm

Daerah midship = 9 mm

Daerah haluan = 10 mm

Lebar plat lajur bilga (BKI Vol. II 2001 Sec. 6 Chap.B.4.2)

$$b = 800 + 5L \qquad b_{\max} = 1800 \text{ mm}$$

$$b = 800 + (5 \times 125,93)$$

$$b = 1429,6 \text{ mm} = 1400 \text{ mm}$$

#### 6. Plat Lunas Rata

- Tebal plat lunas pada 0,7L midship (BKI Vol. II 2001 Sec. 6 Chap.B.5.1)

$$t_{FK} = t + 2,0 \text{ (mm)}$$

Di mana :

$t$  = tebal plat alas pada 0,4L midship

$$t_{FK} = t + 2,0$$

$$t_{FK} = 9 + 2,0$$

$$t_{FK} = 11 \text{ mm}$$

- Tebal plat lunas 0,15L dari AP dan dari FP

$$t_{FK}' = 90\% t_{FK}$$

$$t_{FK}' = 90\% \times 11$$

$$t_{FK}' = 9,9 \text{ mm} \approx 10 \text{ mm}$$

- Lebar plat lunas

$$b = 800 + 5L \qquad b_{\max} = 1800 \text{ mm}$$

$$b = 800 + (5 \times 125,93)$$

$$b = 1429,6 \text{ mm} \approx 1400 \text{ mm}$$

#### 7. Plat Lajur Atas

- Umumnya plat lajur atas pada 0,4L midships tak boleh kurang dari plat sisi yaitu tidak boleh kurang dari 8 mm
- Tebal plat lajur atas di luar 0,4L midships, umumnya sama tebal dengan pelat sisi daerah ujung-ujung kapal tetapi tidak lebih besar dari 10%. Tebal plat lajur atas pada 0,1L dari AP (buritan) sama dengan tebal plat sisi daerah buritan. Tebal plat lajur atas pada 0,05L dari FP sama dengan tebal plat sisi pada daerah haluan
- Lebar plat lajur atas

$$b = 800 + 5L \quad b_{\max} = 1800 \text{ mm}$$

$$b = 800 + (5 \times 125,93)$$

$$b = 1429,6 \text{ mm} = 1400 \text{ mm}$$

8. Plat Penguat/Penyangga linggi buritan, Baling-baling dan Lunas Bilga (sec. 6. F.1.1)

- Tebal plat kulit linggi buritan sekurang-kurangnya sama dengan plat sisi tengah kapal = 8 mm.
- Tebal penyangga baling-baling harus dipertebal menjadi :

$$t = 1,5 + t_1$$

$$= 1,5 + 8 = 9,5 \text{ mm}$$

- Lunas Bilga dipasang pada plat kulit bagian bawah yang sekelilingnya dilas kedap air, sehingga jika ada sentuhan dengan dasar air laut pada plat tidak akan rusak

9. Bukaan Pada Plat Kulit

- Bukaan untuk jendela, lubang udara dan lubang pembuangan katup laut sudut-sudutnya harus dibulatkan dengan konstruksi kedap air.
- Pada lubang jangkar di haluan plat kulit harus dipertebal dengan doubling.
- Di bawah konstruksi pipa duga, pipa limbah, pipa udara dan alas diberi doubling plat.

10. Kotak laut (Sea Chest) (sec 8-4 B.5.3)

Tebal plat sea chest tidak boleh kurang dari :

$$T = 12 \cdot a \sqrt{P \times k} + tk$$

$$P = 2 \text{ bar}$$

$$T = 12 \times 0,7 \sqrt{2 \times 1} + 1,5$$

$$= 13,920 \text{ mm} = 13,00 \text{ mm.}$$

### 11. Plat Senta Geladak

Plat senta geladak digunakan bila tebal geladak lebih kecil dari plat sisi kapal dimana ukurannya sebagai berikut :

- Tebal : setebal plat sisi = 8 mm
- Lebar : selebar plat lajur atas = 1500 mm

### V.7.3 Kontruksi Dasar Ganda

#### 1. Secara umum

- Pada kapal General Cargo, dasar ganda terletak antara sekat tubrukan dengan sekat kamar mesin
- Dalam tangki ceruk haluan dan ceruk buritan tidak perlu dipasang alas ganda.

#### 2. Penumpu Tengah (Centre Girder)

- Penumpu tengah harus kedap air sekurang-kurangnya 0,5 L tengah kapal, jika alas ganda tidak dibagi kedap air oleh penumpu samping.
- Penumpu tengah pada 0,7 L tengah kapal tidak boleh kurang dari (*sec.8.B.2.2*) :

Tinggi penumpu tengah

$$\begin{aligned} h &= 350 + 45 B \\ &= 350 + (45 \times 18,49) \\ &= 1182,2 \text{ mm} = 1100 \text{ mm} \end{aligned}$$

Tebal penumpu tengah

$$\begin{aligned} t &= (h/100+1) \sqrt{k} \\ &= (1182,2 / 100 +1) \sqrt{1} \\ &= 12,82 \text{ mm} = 13 \text{ mm} \end{aligned}$$

Untuk 0,15 L pada ujung kapal, tebal penumpu tengah ditambah 10 %.

$$\begin{aligned} t &= 10 + 10\% (13) \\ &= 11,18 \text{ mm} = 11,18 \text{ mm} \end{aligned}$$

### 3. Penumpu Samping (Side Girder)

- Penumpu samping sekurang-kurangnya dipasang dalam kamar mesin dan 0,25 L bagian haluan. Satu penumpu samping dipasang apabila lebar horizontal dari sisi bawah plat tepi ke penumpu tengah lebih dari 4,5 m.
- Penentuan jumlah side girder

**Tabel 95. Penentuan Side Girder**

| 0,5    | Side Girder |
|--------|-------------|
| ➤ 4,5  | 1           |
| ➤ 8    | 2           |
| ➤ 10,5 | 3           |

Dari tabel diatas, direncanakan jumlah side girder sebanyak 2 pasang

- Tebal penumpu samping tidak boleh kurang dari : ( sec.8-B.3.2 )

$$\begin{aligned}
 t &= h^2 / 120.h \\
 &= 1084,4^2 / 120 \times 1084,4 \\
 &= 9,8250 \text{ mm} = 10 \text{ mm}
 \end{aligned}$$

- Tebal plat alas dalam tidak boleh kurang dari

$$\begin{aligned}
 t_{Bi} &= 1,1 \times a \times \sqrt{P.K} + t_k \\
 t_{Bi} &= 1,1 \times 0,7 \times \sqrt{40,7 \times 1} + 1,5 \\
 &= 7,792 \text{ mm} = 8 \text{ mm}
 \end{aligned}$$

tebal plat alas dalam pada kamar mesin

$$\begin{aligned}
 t &= 8 + 2 \\
 &= 8 + 2 = 10 \text{ mm}
 \end{aligned}$$



#### 4. Alas Ganda dalam Sistem Gading Melintang

- Wrang Alas penuh (Wrang Plate)

- Pada sistim gading melintang pada alas ganda dianjurkan untuk memasang wrang alas penuh pada setiap gading, dimana sistem gadingnya adalah :
  - di bagian penguat alas haluan
  - di dalam kamar mesin
  - di bawah ruang muat
  - pondasi ketel.
- Wrang alas penuh harus dipasang dibawah sekat melintang, dibawah topang ruang muat.
- Jarak terbesar wrang alas penuh tidak melebihi :
  - 3,2 m untuk kapal  $L \geq 60$  m
  - 2,9 m untuk kapal  $L \geq 100$  m
  - 2,6 m untuk kapal  $L \leq 140$  m
  - 2,4 m untuk kapal  $L > 140$  m

- Tebal wrang penuh

- Tebal wrang penuh tidak boleh kurang dari ( sec.8 B.6.2 ):

$$\begin{aligned} t &= t_m - 2,0 \\ &= 12,0 - 2,0 \\ &= 10,0 \text{ mm} \end{aligned}$$

- Lubang Peringan

Lubang peringan wrang penuh adalah :

$$\text{Panjang max} = 0,75 \times h$$

$$= 0,75 \times 1,2 = 0,9 \text{ mm}$$

$$\text{Tinggi max} = 0,5 \times h$$

$$= 0,5 \times 1,2 = 0,6 \text{ mm}$$

- Jarak max. lubang peringan dari penumpu tengah dan plat tepi tidak boleh melebihi dari 0,4 tinggi penumpu tengah.

- Wrang Alas Kedap Air
  - Tebal wrang alas kedap air tidak boleh kurang dari tebal wrang alas penuh = 10,0 mm.
  - Ukuran stiffener pada wrang kedap air

$$W = n \times c \times a \times l^2 \times p \times k \quad (\text{cm}^3)$$

dimana

$$n = 0,55$$

$$c = 1,0$$

$$l = \text{panjang penegar wrang alas} = 1,0$$

$$p = 98,673 \text{ kN/m}^2$$

$$k = 1$$

$$w = 0,55 \times 1 \times 0,6 \times (1,0)^2 \times 40,7 \times 1,0 (\text{cm}^3)$$

$$w = 52,799 \text{ cm}^3$$

Profil di ambil L = 90 x 60 x 8

#### V.7.4 Perhitungan profil profil gading gading

##### 1. Gading Utama ( Frame )

Menurut BKI '01 jarak gading normal antara 0,2 L dari FP sampai sekat ceruk buritan adalah = 600 mm

Di depan sekat tubrukan dan di belakang sekat ceruk buritan jarak gading tidak boleh melebihi 600 mm

Perhitungan gading utama sesuai dengan ketentuan (BKl 2001 sec 9. A.2.1)

Modulus gading utama tidak boleh kurang dari:

$$W = n \cdot c \cdot a \cdot l^2 \cdot Ps \cdot Cr \cdot k \quad (\text{cm}^3)$$

Dimana :

$$a = 0,6 \text{ m} = \text{jarak gading ap}$$

$$a = 0,7 \text{ m} = \text{jarak gading mid}$$

$$a = 0,6 \text{ m} = \text{jarak gading fp}$$

$$l = (H - h) / 5$$

$$= (8,26 - 1,3) / 5 = 2,34$$

$$Cr = 0,75$$

$$\begin{aligned}
 n &= 0,90 - 0,0035 L \text{ untuk } L < 100 \\
 &= 0,90 - 0,0035 \times 100,62 \\
 &= 0,55 \\
 c &= 1
 \end{aligned}$$

### 1.1 Gading-gading pada daerah buritan

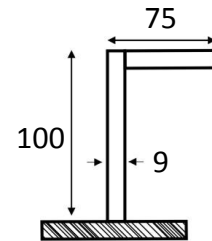
Dimana;

$$P_{S1} = 103,7743 \text{ kN/m}^2$$

Jadi :

$$\begin{aligned}
 W &= 0,55 \times 1 \times 0,6 \times (2)^2 \times 103,7743 \times 0,75 \times 1 \\
 &= 102,7366 \text{ cm}^3
 \end{aligned}$$

Profil yang di ambil L = 100 x 65 x 9



### 1.2 Gading-gading pada daerah tengah

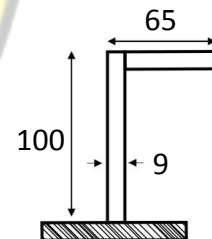
Dimana;

$$P_{S2} = 83,3127 \text{ kN/m}^2$$

Jadi :

$$\begin{aligned}
 W &= 0,55 \times 1 \times 0,7 \times (2)^2 \times 83,3127 \times 0,75 \times 1 \\
 &= 100,6056 \text{ cm}^3
 \end{aligned}$$

Profil yang di ambil L = 100 x 65 x 9



### 1.3 Gading-gading pada daerah haluan

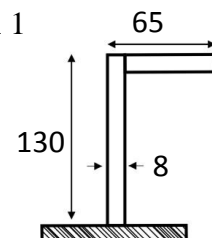
Dimana;

$$P_{S3} = 116,3241 \text{ kN/m}^2$$

Jadi :

$$\begin{aligned}
 W &= 0,55 \times 1 \times 0,6 \times (2)^2 \times 116,3241 \times 0,75 \times 1 \\
 &= 115,1609 \text{ cm}^3
 \end{aligned}$$

Profil yang di ambil L = 130 x 65 x 8



## 2. Gading-gading bangunan atas ( sec.9-A.3.2 )

Perhitungan gading utama pada bangunan atas sesuai dengan ketentuan (*BKI 2001 sec 9-2. A.2.1*)

Modulus gading bangunan atas tidak boleh kurang dari:

$$W = 0,55 \times a \times l^2 \times P \times Cr \times k \quad (\text{cm}^3)$$

Dimana :

$$a = 0,6 \text{ m ( jarak gading )}$$

$l$  = panjang tak ditumpu

$$= 2,4 \text{ m}$$

$$f = 0,75$$

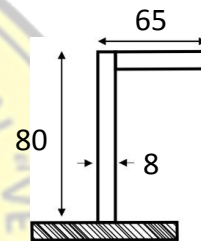
### 2.1 Poop deck

$$P_{s1} = 48,922 \text{ KN/m}^2$$

Jadi :

$$W = 59,07694 \text{ cm}^3$$

Profil yang di ambil  $L = 80 \times 65 \times 8$



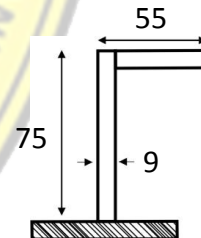
### 2.2 Boat Deck

$$P_{s2} = 41,858 \text{ KN/m}^2$$

Jadi :

$$W = 50,54618 \text{ cm}^3$$

Profil yang di ambil  $L = 75 \times 55 \times 9$



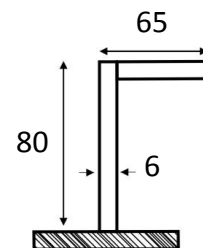
### Navigation Deck

$$P_{s3} = 36,576 \text{ KN/m}^2$$

Jadi :

$$W = 44,16825 \text{ cm}^3$$

Profil yang di ambil  $L = 80 \times 65 \times 6$



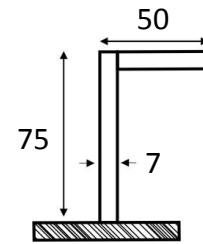
### 2.3 Compass Deck

$$P_{S3} = 32,478 \text{ KN/m}^2$$

Jadi :

$$W = 39,21952 \text{ cm}^3$$

Profil yang di ambil L = 75 x 50 x 7



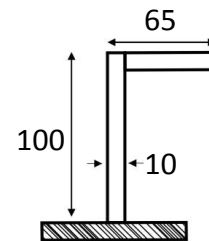
### 2.4 Fore Castle Deck

$$P_{S5} = 62,16 \text{ KN/m}^2$$

Jadi :

$$\begin{aligned} W &= \\ &= 75,06247 \text{ cm}^3 \end{aligned}$$

Profil yang di ambil L = 100 x 65 x 10



### 3. Gading Memanjang pada ruang muat (Side Longitudinal)

Modulus penampang gading memanjang pada daerah tengah kapal adalah:

$$W = n \cdot c \cdot a \cdot l^2 \cdot Pl \cdot Cr \cdot k \quad (\text{cm}^3)$$

Dimana :

$$a = 0,6 \text{ m jarak gading}$$

$$\begin{aligned} l &= (H - h) / 5 \\ &= (8,26 - 1,3) / 5 = 1,39 \end{aligned}$$

$$l_{\min} = 2$$

$$Cr = 0,75$$

$$n = 0,90 - 0,0035 L \text{ untuk } L < 100$$

$$= 0,90 - 0,0035 \times 100,62$$

$$= 0,55$$

$$c = 1$$

$$Pl = 9,81 \times h_1 \times p (1 - av) + 100 Pv \quad (\text{KN/m}^2)$$

$$h_1 = 10,33$$

$$p = 1$$

$$av = F \times M$$

$$Vo = 12,5$$

$$F = 0,11 \times Vo / \sqrt{L}$$

$$= 0,122529$$

$$a_v = 0,122529$$

$$P_{V_{\min}} = 0,2 \text{ bar} = 0,275 \text{ kN/m}^2$$

$$k = 1$$

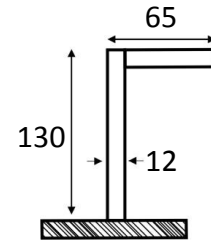
$$P_l = 116,417 \text{ KN/m}^2$$

Jadi :

W

$$= 192,0881 \text{ cm}^3$$

Profil yang di ambil L = 130 x 65 x 12



#### 4. Gading besar (Web frame)

Perhitungan gading besar sesuai dengan ketentuan (*BKI 2001 sec 9-4*

*A.6.2.1*)

Modulus gading utama tidak boleh kurang dari:

$$W = 0,8 \times e \times l^2 \times P_s \times k \quad (\text{cm}^3)$$

Dimana :

$$k = 1$$

e = Lebar Pembebanan

$$= 4 \times 0,6 = 2,4 \text{ m}$$

$$l = \text{panjang tak ditumpu} = 2,34 \text{ m}$$

##### a. Gading besar pada daerah kamar mesin

$$P_s = 94,49838 \text{ kN/m}^2$$

Jadi :

$$\begin{aligned} W &= 0,8 \times 2,4 \times (2,34)^2 \times 94,49838 \times 1 \\ &= 993,4759 \text{ cm}^3 \end{aligned}$$

Profil yang direncanakan T 320 x 13 FP 120 x 13

Tebal plat = 11,0

Koreksi modulus (40 ~ 50) t = 50 x 11 = 550

$$F = 50 \times 1,1 = 55$$

$$f_s = 32 \times 1,3 = 41,6$$

$$f = 12 \times 1,3 = 15,6$$

$$f_s/F = 0,756$$

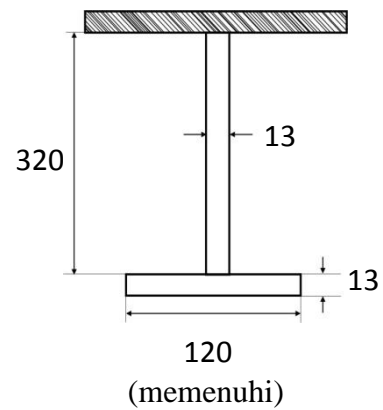
$$f/F = 0,284$$

$$w = 0,45$$

maka

$$W = w \times F \times h$$

$$= 0,45 \times 55 \times 32 = 792 \text{ cm}^3$$



W rencana > W perhitungan

b. Gading besar pada daerah tengah kapal

$$P_s = 68,872 \text{ kN/m}^2$$

Jadi :

$$W = 0,8 \times 2,4 \times (2,34)^2 \times 68,872 \times 1$$

$$= 821,383 \text{ cm}^3$$

Profil yang direncanakan T 300 x 14 FP 120 x 14

Tebal plat = 11,0

Koreksi modulus (40 ~ 50) t = 50 x 11,0 = 550

$$F = 50 \times 1,1 = 55$$

$$f_s = 30 \times 1,4 = 42$$

$$f = 12 \times 1,4 = 16,8$$

$$f_s/F = 0,764$$

$$f/F = 0,305$$

$$w = 0,48$$

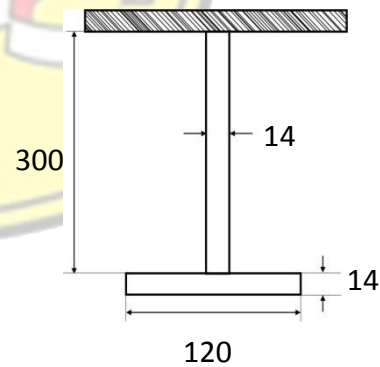
maka

$$W = w \times F \times h$$

$$= 0,48 \times 55 \times 30 = 792 \text{ cm}^3$$

W rencana > W perhitungan

(memenuhi)



c. Gading besar pada daerah haluan kapal

$$P_s = 104,5382 \text{ kN/m}^2$$

Jadi :

$$W = 0,8 \times 2,4 \times (2,34)^2 \times 104,5382 \times 1$$

$$= 1099,026 \text{ cm}^3$$

Profil yang direncanakan T 320 x 14 FP 140 x 14

Tebal plat = 12,0

Koreksi modulus (40 ~ 50)  $t = 50 \times 12 = 600$

$$F = 50 \times 1,2 = 60$$

$$f_s = 32 \times 1,6 = 51,2$$

$$f = 14 \times 1,6 = 22,4$$

$$f_s/F = 0,85$$

$$f/F = 0,37$$

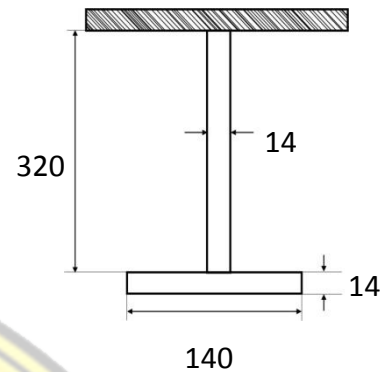
$$w = 0,57$$

maka

$$W = w \times F \times h$$

$$= 0,57 \times 60 \times 32 = 1094,4 \text{ cm}^3$$

$W_{\text{rencana}} > W_{\text{perhitungan}}$  (memenuhi)



#### 5. Gading Besar pada Bangunan Atas

Perhitungan gading besar pada bangunan atas sesuai dengan ketentuan (*BKI 2001 sec 9-4 A.6.2.1*)

Modulus gading bangunan atas tidak boleh kurang dari:

$$W = 0,8 \cdot e \cdot l^2 \cdot P_s \cdot k \quad (\text{cm}^3)$$

Dimana :

$$k = 1$$

$e$  = Lebar Pembebanan

$$= 4 \times 0,6$$

$$= 2,4 \text{ m}$$

$l$  = panjang tak ditumpu

$$= 2,4 \text{ m}$$

#### 5.1. Poop Deck

$$P_s = \text{beban sisi kapal} = 39,13787 \text{ KN/m}^2$$

Jadi :



$$W = 0,8 \times 2,4 \times (2,4)^2 \times 39,13787 \times 1,0 \times 1$$

$$= 432,8 \text{ cm}^3$$

Profil yang direncanakan T 260 x 11 FP 160 x 11

Tebal plat = 9

Koreksi modulus (40 ~ 50 ) t = 50 x 9 = 400

$$F = 50 \times 0,9 = 45$$

$$f_s = 20 \times 1,1 = 28$$

$$f = 6 \times 1,1 = 17,6$$

$$f_s/F = 0,64$$

$$f/F = 0,39$$

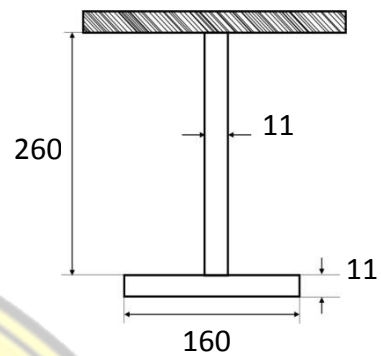
$$w = 0,14$$

maka

$$W = w \times F \times h$$

$$= 0,14 \times 45 \times 26 = 479,7 \text{ cm}^3$$

W rencana > W perhitungan (memenuhi)



## 5.2. Boat Deck

Dimana :

Ps = beban sisi kapal = 34,64 KN/m<sup>2</sup>

Jadi :

$$W = 0,8 \times 2,4 \times (2,4)^2 \times 34,64 \times 1,0 \times 1$$

$$= 383,11 \text{ cm}^3$$

Profil yang direncanakan T 260 x 17 FP 120 x 17

Tebal plat = 8

Koreksi modulus (40 ~ 50 ) t = 50 x 8 = 40

$$F = 50 \times 0,8 = 40$$

$$f_s = 26 \times 1,7 = 4,4$$

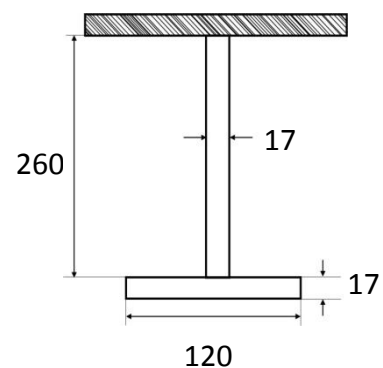
$$f = 12 \times 1,7 = 5,75$$

$$f_s/F = 0,11$$

$$f/F = 0,51$$

$$w = 0,51$$

maka



$$W = w \times F \times h$$

$$= 0,51 \times 40 \times 26 = 530,4 \text{ cm}^3$$

W rencana > W perhitungan (memenuhi)

### 5.3. Navigation Deck,

$$Ps = \text{beban sisi kapal} = 29 \text{ KN/m}^2$$

Jadi :

$$W = 0,8 \times 2,4 \times (2,4)^2 \times 29 \times 1,0 \times 1$$

$$= 330,5 \text{ cm}^3$$

Profil yang direncanakan T 240 x 17 FP 120 x 17

Tebal plat = 8

$$\text{Koreksi modulus (40 ~ 50) } t = 50 \times 8 = 400$$

$$F = 50 \times 0,8 = 40$$

$$fs = 24 \times 1,7 = 4,08$$

$$f = 12 \times 1,7 = 20,4$$

$$fs/F = 0,10$$

$$f/F = 0,51$$

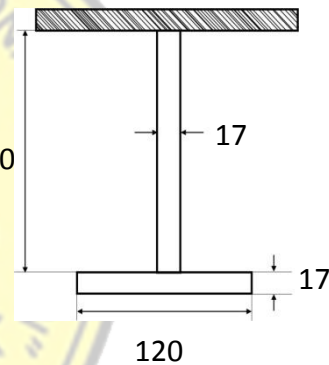
$$w = 0,52$$

maka

$$W = w \times F \times h$$

$$= 0,51 \times 40 \times 24 = 499,2 \text{ cm}^3$$

W rencana > W perhitungan (memenuhi)



### 5.4. Compas Deck,

$$Ps = \text{beban sisi kapal} = 26,27 \text{ KN/m}^2$$

Jadi : 220

$$W = 0,8 \times 2,4 \times (2,4)^2 \times 26,27 \times 1$$

$$= 290,61 \text{ cm}^3$$

Profil yang direncanakan T 220 x 18 FP 120 x 18

Tebal plat = 7

$$\text{Koreksi modulus (40 ~ 50) } t = 50 \times 7 = 350$$

$$F = 50 \times 0,7 = 35$$

$$f_s = 22 \times 1,8 = 3,96$$

$$f = 12 \times 1,8 = 21,6$$

$$f_s/F = 0,52$$

$$f/F = 0,62$$

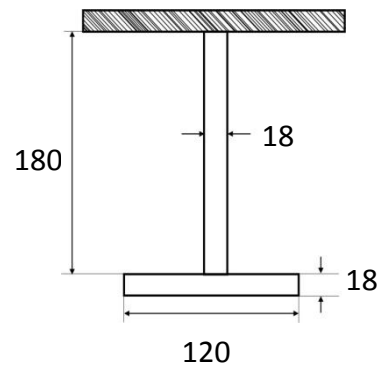
$$w = 0,52$$

maka

$$W = w \times F \times h$$

$$= 0,52 \times 35 \times 22 = 320 \text{ cm}^3$$

W rencana > W perhitungan (memenuhi)



### 5.5. Fore Castle Deck

Ps = beban sisi kapal 52,34 KN/m<sup>2</sup>

Jadi :

$$W = 0,8 \times 2,4 \times (2,4)^2 \times 52,34 \times 1$$

$$= 578,9 \text{ c}$$

Profil yang direncanakan T 280 x 12 FP1 80x 12

Tebal plat = 10

Koreksi modulus (40 ~ 50 ) t = 50 x 1 = 500

$$F = 50 \times 1 = 50$$

$$f_s = 28 \times 1,2 = 25,3$$

$$f = 18 \times 1,2 = 2,1$$

$$f_s/F = 0,07$$

$$f/F = 0,43$$

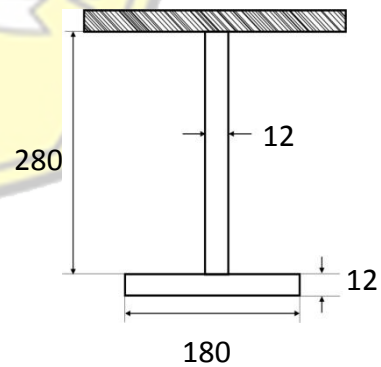
$$w = 0,48$$

maka

$$W = w \times F \times h$$

$$= 0,48 \times 50 \times 22 = 672 \text{ cm}^3$$

W rencana > W perhitungan (memenuhi)



### V.7.5 Perhitungan profil Balok-Balok

#### 1. Balok geladak ( Deck beam )

Perhitungan balok geladak sesuai dengan ketentuan (BKI 2001 Sec.10.1.B)

Modulus penampang balok geladak tidak boleh kurang :

$$W = c \cdot a \cdot P_D \cdot l^2 \cdot k \quad (\text{cm}^3)$$

dimana :

$$c = 0,75 \text{ untuk beam}$$

$$a = \text{Jarak gading yang direncanakan} = 0,6 \text{ m}$$

$$k = \text{Faktor material} = 1,00$$

$$l = \text{Panjang tak ditumpu} \\ = (0,5 \times B) / 4 = 2,31\text{m}$$

#### 1.1 Balok Geladak pada kamar mesin, ceruk buritan 0,1 L dari AP

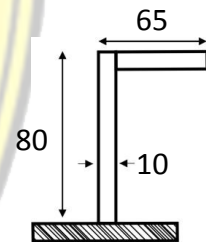
Dimana;

$$P_{D1} = 35,8 \text{ kN/m}^2$$

Jadi :

$$W = 0,75 \times 0,6 \times 35,8 \times (2,31)^2 \times 1,0 \\ = 67,11 \text{ cm}^3$$

Profil yang di ambil L = 80 x 65 x 10



#### 1.2 Balok geladak pada daerah 0,1 dari FP :

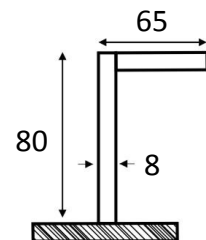
Dimana;

$$P_{D3} = 29,22 \text{ kN/m}^2$$

Jadi :

$$W = 0,75 \times 0,6 \times 29,22 \times (2,31)^2 \times 1,0 \\ = 54 \text{ cm}^3$$

Profil yang di ambil L = 80 x 65 x 8



#### 2. Balok geladak pada ruang muat (deck longitudinal)

Perhitungan balok geladak sesuai dengan ketentuan (BKI 2001 VOL II sec 9. )

Modulus penampang balok geladak tidak boleh kurang :

$$W = c \cdot a \cdot P_D \cdot l^2 \cdot k \quad (\text{cm}^3)$$

Dimana :

$$c = 0,75$$

$$a = \text{jarak gading} = 0,6 \text{ m mid} = 0,7 \text{ m}$$

$$l = \text{panjang tak ditumpu} = 2,31 \text{ m}$$

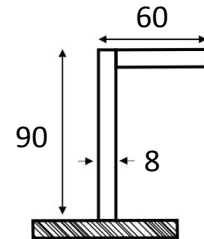
$$P_{D2} = \text{untuk pembujur geladak} = 26,09 \text{ kN/m}^2$$

Jadi :

$$W = 0,75 \times 0,7 \times 26,09 \times (2,31)^2 \times 1,0$$

$$= 55,47 \text{ cm}^3$$

Profil yang di ambil L = 90 x 60 x 8



### 3. Balok geladak bangunan atas

Perhitungan balok geladak pada bangunan atas sesuai dengan ketentuan

Modulus gading bangunan atas tidak boleh kurang dari:

$$W = c \cdot a \cdot P_{DA1} \cdot l^2 \cdot k \quad (\text{cm}^3)$$

Dimana :

$$c = 0,75$$

$$a = \text{Jarak gading mid yang direncanakan} = 0,7 \text{ m}$$

$$k = 1 \quad (\text{Faktor material})$$

$$l = \text{Panjang tak ditumpu} = 2,31 \text{ m}$$

#### 3.1 Poop Deck

$$W = c \cdot a \cdot P_{DA} \cdot l^2 \cdot k \quad (\text{cm}^3)$$

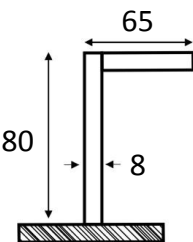
Di mana :

$$P_{DA} = 25,7 \text{ kN/m}^2$$

$$W = 0,75 \times 0,7 \times 25,7 \times (2,31)^2 \times 1,0$$

$$= 54,67 \text{ cm}^3$$

Profil yang di ambil L = 80 x 65 x 8



### 3.2 Boat Deck

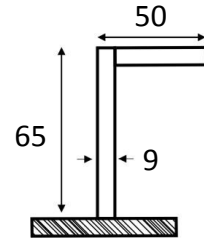
$$W = c \cdot a \cdot P_{DA} \cdot l^2 \cdot k \quad (\text{cm}^3)$$

dimana :

$$P_{DA} = 18,7 \text{ kN/m}^2$$

$$\begin{aligned} W &= 0,75 \times 0,7 \times 18,7 \times (2,31)^2 \times 1,0 \\ &= 39,7 \text{ cm}^3 \end{aligned}$$

Profil yang di ambil L = 65 x 50 x 9



### 3.3 Navigation deck, compass deck

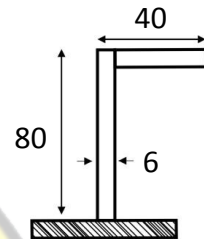
$$W = c \cdot a \cdot P_{DA} \cdot l^2 \cdot k \quad (\text{cm}^3)$$

dimana :

$$P_{DA} = 14 \text{ kN/m}^2$$

$$\begin{aligned} W &= 0,75 \times 0,7 \times 14 \times (2,31)^2 \times 1,0 \\ &= 31,1 \text{ cm}^3 \end{aligned}$$

Profil yang di ambil L = 80 x 40 x 6



### 3.4 Fore Castle Deck

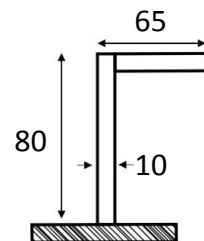
$$W = c \cdot a \cdot P_{DA5} \cdot l^2 \cdot k \quad (\text{cm}^3)$$

dimana :

$$P_{DA} = 35,8 \text{ kN/m}^2$$

$$\begin{aligned} W &= 0,75 \times 0,7 \times 35,8 \times (2,31)^2 \times 1,0 \\ &= 67,11 \text{ cm}^3 \end{aligned}$$

Profil yang di ambil L = 80 x 65 x 10



## 4. Balok geladak besar ( strong beam )

Perhitungan balok geladak besar sesuai dengan ketentuan (*BKI 2001 Sec.10.1.B*)

Modulus penampang balok geladak tidak boleh kurang :

$$W = c \cdot e \cdot l^2 \cdot P_D \cdot k \quad (\text{cm}^3)$$

dimana :

$$k = 1$$

$$\begin{aligned}
 c &= 0,75 \text{ untuk beam} \\
 e &= \text{jarak gading besar} &= 2,4 \text{ m} \\
 l &= \text{Panjang tak ditumpu} &= 2,04 \text{ m}
 \end{aligned}$$

#### 4.1 Modulus penampang strong beam untuk daerah 0,1 L dari AP

Dimana;

$$P_D = 29,2 \text{ KN/m}^2$$

Jadi

$$\begin{aligned}
 W &= 0,75 \times 2,4 \times (2,31)^2 \times 29,2 \times 1 \\
 &= 218 \text{ cm}^3
 \end{aligned}$$

Profil yang direncanakan T 280 x 15 FP 110 x 15

Tebal plat = 7,5

Koreksi modulus (40 ~ 50)  $t = 50 \times 7,5 = 375$

$$F = 50 \times 0,75 = 37,5$$

$$f_s = 28 \times 1,5 = 4,2$$

$$f = 15 \times 1,5 = 22,5$$

$$f_s/F = 0,11$$

$$f/F = 0,60$$

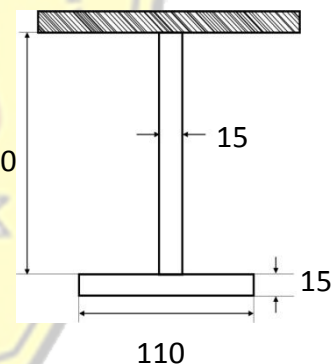
$$w = 0,51$$

maka

$$W = w \times F \times h$$

$$= 0,51 \times 37,5 \times 15 = 286,875 \text{ cm}^3$$

W rencana > W perhitungan (memenuhi)



#### 4.2 Modulus penampang strong beam untuk daerah 0,1L dari FP (haluan)

$$P_D = 16,595 \text{ kN/m}^2$$

Jadi

$$\begin{aligned}
 W &= 0,75 \times 2,4 \times (2,31)^2 \times 16,595 \times 1 \\
 &= 159,395 \text{ cm}^3
 \end{aligned}$$

Profil yang direncanakan T 430 x 19 FP 150 x 19

Tebal plat = 7,5

Koreksi modulus (40 ~ 50)  $t = 40 \times 7,5 = 375$

$$F = 50 \times 0,75 = 37,5$$

$$f_s = 43 \times 1,9 = 4,2$$

$$f = 15 \times 1,9 = 22,5$$

$$f/F = 0,11$$

$$f_s/F = 0,60$$

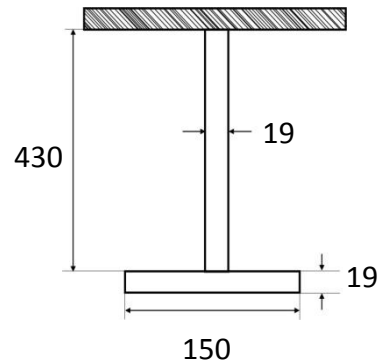
$$w = 0,51$$

maka

$$W = w \times F \times h$$

$$= 0,51 \times 37,5 \times 19 = 286 \text{ cm}^3$$

W rencana > W perhitungan (memenuhi)



4.3 Modulus penampang strong beam untuk daerah 0,6 L tengah kapal (midship) tidak boleh kurang dari :

Dimana;

$$P_D = 29,22 \text{ kN/m}^2$$

Jadi

$$W = 0,75 \times 2,4 \times (2,31)^2 \times 29,22 \times 1$$

$$= 218,9 \text{ cm}^3$$

Profil yang direncanakan T 430 x 19 FP 110 x 19

Tebal plat = 7,5

Koreksi modulus (40 ~ 50)  $t = 50 \times 7,5 = 375$

$$F = 50 \times 0,75 = 37,5$$

$$f_s = 43 \times 1,9 = 4,2$$

$$f = 11 \times 1,9 = 16,5$$

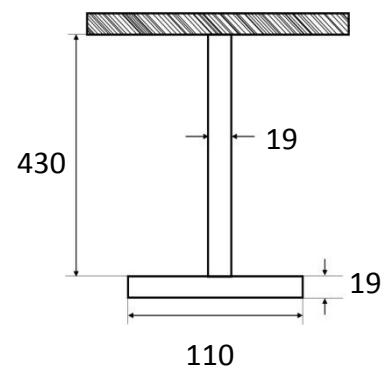
$$f_s/F = 0,11$$

$$f/F = 0,44$$

$$w = 0,45$$

maka

$$W = w \times F \times h$$





$$= 0,45 \times 37,5 \times 15 = 253,12 \text{ cm}^3$$

W rencana > W perhitungan (memenuhi)

#### 5. Strong Beam Untuk Bangunan Atas

Perhitungan strong beam pada bangunan atas sesuai dengan ketentuan

Modulus gading bangunan atas tidak boleh kurang dari:

$$W = 0,75 \cdot e \cdot l^2 \cdot P \cdot k \quad (\text{cm}^3)$$

Dimana :

$$k = 1$$

$$c = 0,75 \text{ untuk beam}$$

$$e = \text{jarak gading besar} = 2,4 \text{ m}$$

$$l = \text{Panjang tak ditumpu} = 2,31 \text{ m}$$

##### 5.1 Poop Deck

$$W = 0,75 \cdot e \cdot l^2 \cdot P \cdot k \quad (\text{cm}^3)$$

dimana :

$$P_{DA} = 25,71 \text{ KN/m}^2$$

Jadi

$$\begin{aligned} W &= 0,75 \times 2,4 \times 25,71 \times (2,31)^2 \times 1,0 \\ &= 192,63 \text{ cm}^3 \end{aligned}$$

Profil yang direncanakan T 200 x 15 FP 100 x 15

Tebal plat = 7,5

Koreksi modulus (40 ~ 50)  $t = 50 \times 7,5 = 375$

$$F = 50 \times 0,75 = 37,5$$

$$f_s = 20 \times 1,5 = 37,5$$

$$f = 10 \times 1,5 = 15$$

$$f_s/F = 0,80$$

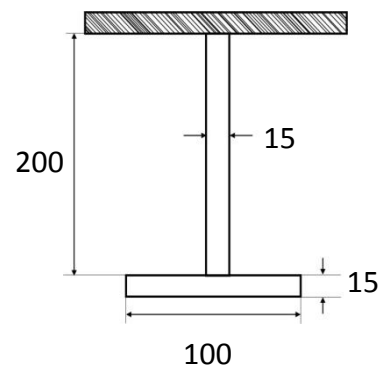
$$f/F = 0,40$$

$$w = 0,59$$

maka

$$W = w \times F \times h$$

$$= 0,59 \times 37,5 \times 16 = 331 \text{ cm}^3$$



W rencana > W perhitungan (memenuhi)

### 5.2 Boat Deck

$$W = 0,75 \cdot e \cdot l^2 \cdot P \cdot k \quad (\text{cm}^3)$$

dimana :

$$P_{DA} = 18,70 \text{ KN/m}^2$$

Jadi

$$\begin{aligned} W &= 0,75 \times 2,4 \times 18,70 \times (2,31)^2 \times 1,0 \\ &= 140,09 \text{ cm}^3 \end{aligned}$$

Profil yang direncanakan T 180x 13 FP 100 x 13

Tebal plat = 7,5

Koreksi modulus (40 ~ 50)  $t = 5 \times 7,5 = 37,5$

$$F = 50 \times 0,75 = 37,5$$

$$f_s = 18 \times 1,3 = 0,35$$

$$f = 10 \times 0,13 = 0,42$$

$$f_s/F = 0,62$$

$$f/F = 0,35$$

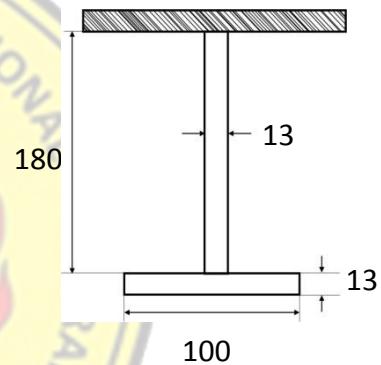
$$w = 0,42$$

maka

$$W = w \times F \times h$$

$$= 0,42 \times 37,5 \times 15 = 236,25 \text{ cm}^3$$

W rencana > W perhitungan (memenuhi)



### 5.3 Geladak Navigasi, dan Compass Deck

$$W = 0,75 \cdot e \cdot l^2 \cdot P \cdot k \quad (\text{cm}^3)$$

dimana :

$$P_{DA} = 14,6 \text{ KN/m}^2$$

Jadi

$$\begin{aligned} W &= 0,75 \times 2,4 \times 14,6 \times (2,31)^2 \times 1,0 \\ &= 109,45 \text{ cm}^3 \end{aligned}$$

Profil yang direncanakan T 160 x 8 FP 100 x 8

Tebal plat = 7,5

Koreksi modulus (40 ~ 50 ) t = 50 x 7,5 = 375

$$F = 50 \times 0,75 = 37,5$$

$$f_s = 16 \times 0,7 = 12,8$$

$$f = 10 \times 0,7 = 8$$

$$f_s/F = 0,34$$

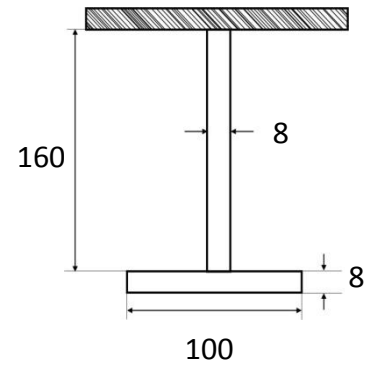
$$f/F = 0,21$$

$$w = 0,24$$

maka

$$W = w \times F \times h \\ = 0,24 \times 37,5 \times 15 = 135 \text{ cm}^3$$

W rencana > W perhitungan (memenuhi)



#### 5.4 Fore Castle Deck

$$W = 0,75 \cdot e \cdot l^2 \cdot P \cdot k \quad (\text{cm}^3)$$

dimana :

$$P_{DA} = 16,595 \text{ KN/m}^2$$

jadi

$$W = 0,75 \times 2,4 \times 16,595 \times (2,31)^2 \times 1,0 \\ = 159,395 \text{ cm}^3$$

Profil yang direncanakan T 220 x 18 FP 120 x 18

Tebal plat = 7,5

Koreksi modulus (40 ~ 50 ) t = 50 x 7,5 = 375

$$F = 50 \times 0,75 = 37,5$$

$$f_s = 22 \times 1,8 = 16,2$$

$$f = 120 \times 1,8 = 4,5$$

$$f/F = 0,11$$

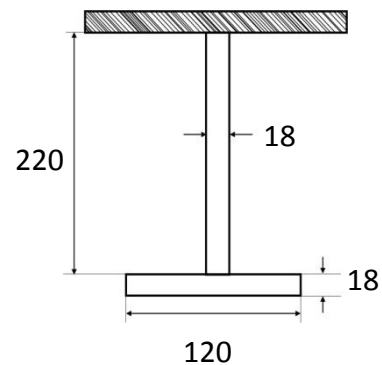
$$f_s/F = 0,62$$

$$w = 0,52$$

maka

$$W = w \times F \times h \\ = 0,52 \times 37,5 \times 22 = 200 \text{ cm}^3$$

W rencana > W perhitungan (memenuhi)



### V.7.6 Penumpu Geladak (*Deck Girder*)

Tinggi penumpu tidak boleh kurang dari  $1/25$  panjang tak ditumpu tinggi plat bilah hadap, penumpu yang dilubangi (lubang las) untuk balok geladak yang menerus minimal  $1,5$  x tinggi geladak.

1. Penumpu Tengah (*Centre Deck Girder*) dan Penumpu samping (*Side Deck girder*)

Perhitungan center deck girder dan side deck girder sesuai dengan ketentuan (*BKI 2001 Vol II sec.10 B.4.1*)

Modulus gading utama tidak boleh kurang dari:

$$W = c \cdot e \cdot l^2 \cdot P_D \cdot k \quad (\text{cm}^3)$$

Dimana :

$e$  = lebar pembebanan

$$= 2,31 \text{ m}$$

$c$  = 0,75

$l$  = 2,4 m

$k$  = 1 (Faktor bahan,)

- 1.1 Modulus penampang tengah dan penumpu samping geladak pada daerah  $0,05 L$  dari AP tidak boleh kurang dari :

$$W = c \cdot e \cdot l^2 \cdot P_D \cdot k \quad (\text{cm}^3)$$

Dimana :

$P_D$  = beban geladak =  $23,3 \text{ KN/m}^2$  430

Jadi :

$$W = 0,75 \times 2,31 \times (2,4)^2 \times 23,3 \times 1 \\ = 224,5 \text{ cm}^3$$

Profil yang direncanakan T 430 x 19 FP 110 x 19

Tebal plat = 11

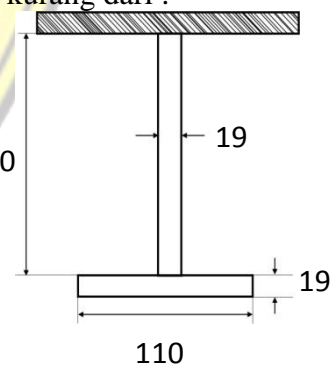
Koreksi modulus ( $40 \sim 50$ )  $t = 40 \times 7,5 = 300$

$$F = 40 \times 0,75 = 30$$

$$f_s = 16 \times 0,9 = 14,4$$

$$f = 5 \times 0,9 = 4,5$$

$$f_s/F = 0,48$$



$$f/F = 0,12$$

$$w = 0,25$$

maka

$$\begin{aligned} W &= w \times F \times h \\ &= 0,25 \times 30 \times 16 = 250 \text{ cm}^3 \end{aligned}$$

W rencana > W perhitungan (memenuhi)

1.2 Modulus penampang penumpu tengah geladak daerah midship tidak boleh kurang dari :

Dimana;

$$P_D = \text{beban geladak} = 10,621 \text{ kN/m}^2$$

Jadi :

$$\begin{aligned} W &= 0,75 \times 2,31 \times (2,4)^2 \times 10,621 \times 1 \\ &= 200,5 \text{ cm}^3 \end{aligned}$$

Profil yang direncanakan T 430 x 19 FP 110 x 19

Tebal plat = 7,5

Koreksi modulus (40 ~ 50) t = 40 x 75 = 300

$$F = 40 \times 0,75 = 30$$

$$f_s = 43 \times 0,19 = 4,2$$

$$f = 5 \times 0,19 = 16,5$$

$$f_s/F = 0,76$$

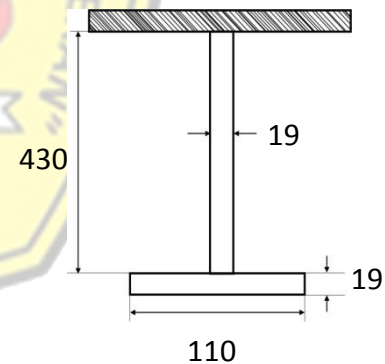
$$f/F = 0,30$$

$$w = 0,45$$

maka

$$\begin{aligned} W &= w \times F \times h \\ &= 0,24 \times 30 \times 16 = 321,25 \text{ cm}^3 \end{aligned}$$

W rencana > W perhitungan (memenuhi)



1.3 Modulus penampang penumpu tengah geladak pada daerah haluan kapal tidak boleh kurang dari :

Dimana;

$$P_D = \text{beban geladak} = 28,66 \text{ kN/m}^2$$

Jadi :

$$W = 0,75 \times 2,31 \times (2,4)^2 \times 13,276 \times 1$$

$$= 275,368 \text{ cm}^3$$

Profil yang direncanakan T 220 x 18 FP 120 x 18

Tebal plat = 7,5

Koreksi modulus (40 ~ 50)  $t = 40 \times 7,5 = 300$

$$F = 40 \times 0,75 = 30$$

$$f_s = 18 \times 0,8 = 3,96$$

$$f = 5 \times 0,8 = 21,6$$

$$f_s/F = 0,07$$

$$f/F = 0,39$$

$$w = 0,25$$

maka

$$W = w \times F \times h$$

$$= 0,25 \times 30 \times 18 = 302,5 \text{ cm}^3$$

$W_{\text{rencana}} > W_{\text{perhitungan}}$  (memenuhi)

## 2. Modulus Penumpu Bangunan Atas

Perhitungan center deck girder dan side deck girder pada bangunan atas sesuai dengan ketentuan BKI 2001:

$$W = c \cdot e \cdot l^2 \cdot P \cdot k \quad (\text{cm}^3)$$

Dimana :

$$k = 1$$

$$c = 0,75$$

$$l = \text{jarak gading besar} = 2,4 \text{ m}$$

$$e = \text{Panjang tak ditumpu} = 2,31 \text{ m}$$

### 2.1 Poop Deck

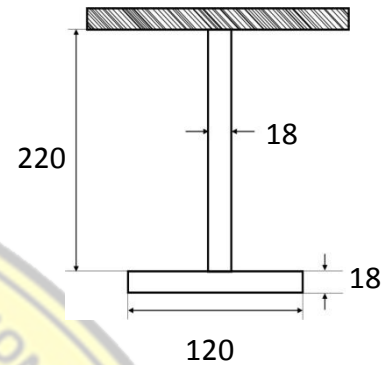
Dimana :

$$P_D = \text{beban geladak} = 20,5 \text{ kN/m}^2$$

Jadi :

$$W = 0,75 \times 2,31 \times (2,4)^2 \times 20,5 \times 1$$

$$= 197,6 \text{ cm}^3$$



Profil yang direncanakan T 200 x 15 FP 110 x 15

Tebal plat = 7,5

Koreksi modulus (40 ~ 50)  $t = 40 \times 7,5 = 300$

$$F = 40 \times 0,75 = 55$$

$$f_s = 16 \times 0,7 = 4,2$$

$$f = 5 \times 0,7 = 16,5$$

$$f_s/F = 0,08$$

$$f/F = 0,30$$

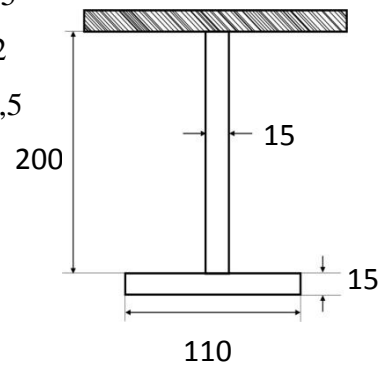
$$w = 0,44$$

maka

$$W = w \times F \times h$$

$$= 0,22 \times 30 \times 16 = 363 \text{ cm}^3$$

W rencana > W perhitungan (memenuhi)



## 2.2 Boat Deck

Dimana :

$$P_D = \text{beban geladak} = 14,9 \text{ cm}^2$$

Jadi :

$$W = 0,75 \times 2,31 \times (2,4)^2 \times 14,9 \times 1$$

$$= 143,71 \text{ cm}^3$$

Profil yang direncanakan T 180 x 13 FP 110 x 13

Tebal plat = 8

Koreksi modulus (40 ~ 50)  $t = 40 \times 7,5 = 400$

$$F = 40 \times 0,8 = 40$$

$$f_s = 18 \times 1,3 = 2,34$$

$$f = 11 \times 1,3 = 14,3$$

$$f_s/F = 0,06$$

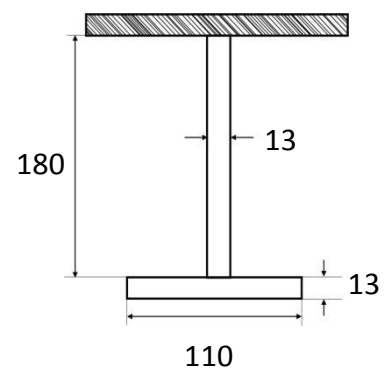
$$f/F = 0,36$$

$$w = 0,32$$

maka

$$W = w \times F \times h$$

$$= 0,32 \times 30 \times 14 = 192 \text{ cm}^3$$



W rencana > W perhitungan (memenuhi)

### 2.3 Navigation Deck dan Compass Deck

Dimana :

$$P_D = \text{beban geladak} = 11,689 \text{ kN/m}^2$$

Jadi :

$$\begin{aligned} W &= 0,75 \times 2,31 \times (2,4)^2 \times 11,689 \times 1 \\ &= 112,273 \text{ cm}^3 \end{aligned}$$

Profil yang direncanakan 160 x 13 FP 110 x 13

Tebal plat = 8

Koreksi modulus (40 ~ 50 ) t = 40 x 7,5 = 400

$$F = 50 \times 0,8 = 40$$

$$f_s = 16 \times 1,3 = 0,36$$

$$f = 4,5 \times 1,3 = 14,3$$

$$f_s/F = 0,06$$

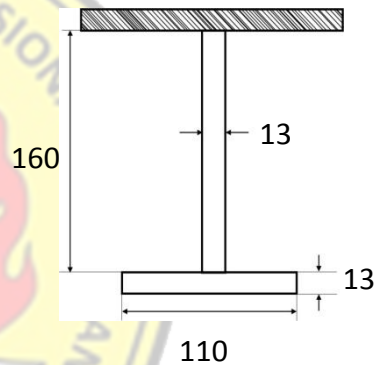
$$f/F = 0,6$$

$$w = 0,32$$

maka

$$\begin{aligned} W &= w \times F \times h \\ &= 0,32 \times 30 \times 12 = 192,2 \text{ cm}^3 \end{aligned}$$

W rencana > W perhitungan (memenuhi)



### 3.4 Fore Castle Deck

Dimana :

$$P_D = \text{beban geladak} = 28,66 \text{ KN/m}^2$$

Jadi :

$$\begin{aligned} W &= 0,75 \times 2,31 \times (2,4)^2 \times 28,66 \times 1 \\ &= 275,36 \text{ cm}^3 \end{aligned}$$

Profil yang direncanakan T 220 x 17 FP 150 x 17

Tebal plat = 7

Koreksi modulus (40 ~ 50 ) t = 40 x 7,5 = 350

$$F = 40 \times 0,75 = 35$$



$$f_s = 18 \times 0,8 = 3,74$$

$$f = 5 \times 0,8 = 25,5$$

$$f_s/F = 0,11$$

$$f/F = 0,73$$

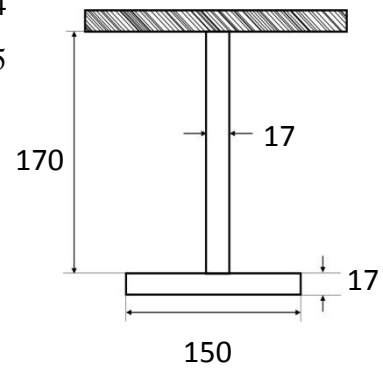
$$w = 0,53$$

maka

$$W = w \times F \times h$$

$$= 0,53 \times 30 \times 18 = 278,25 \text{ cm}^3$$

W rencana > W perhitungan (memenuhi)



### V.7.7 Pembujur Alas (*Bottom Longitudinal*)

Perhitungan pembujur alas sesuai ketentuan ( *BKI 2001 VOL II sec 9* )

Modulus penampang balok geladak tidak boleh kurang :

$$W = c \cdot m \cdot a \cdot l^2 \cdot P \quad (\text{cm}^3)$$

Dimana :

$$c = 1$$

$$m = k \times n$$

$$= 1 \times 0,7$$

$$= 0,7$$

$$a = \text{jarak gading bujur geladak} = 0,7 \text{ m}$$

$$l = \text{panjang tak ditumpu} = 2,4 \text{ m}$$

$$P = \text{untuk pembujur alas}$$

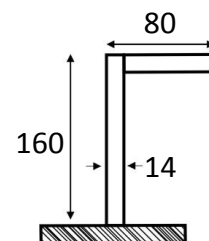
$$= 92,12 \text{ kN/m}^2$$

Modulus pembujur alas pada tengah kapal

$$W = 1 \times 0,7 \times 0,7 \times (2,4)^2 \times 92,12$$

$$W = 260,022 \text{ cm}^3$$

Profil yang di ambil L 160 x 80 x 14



### V.7.8 Bulkhead (Sekat Kedap Air)

#### 1. Sekat kedap air

Sebuah kapal harus mempunyai sekat tubrukan pada haluan, sekat buritan, sekat ruang mesin dan sekat antar ruang muat.

(BKI' 2001 Vol II Sec. 11 B 2.1)

Sekat Tubrukan

Tebal sekat kedap air pada double bottom

$$t_s = C_p \cdot a \cdot \sqrt{P} + t_k \quad (\text{mm})$$

Dimana:

$$C_p = 1,1 \sqrt{f}$$

Dimana

$$f = \frac{235}{Re \cdot h}$$

$$Re \cdot H = 265 \text{ N/mm}^2$$

$$f = \frac{235}{265 \text{ N/mm}^2}$$

$$= 0,887 \text{ N/mm}^2$$

$$C_p = 1,1 \times \sqrt{0,887} = 1,036$$

$$a = 0, \quad (\text{Frame spacing})$$

$$P = 9,81 \times h'$$

$$h' = \frac{2}{3}(H + 1)$$

$$= \frac{2}{3}(8,26 + 1)$$

$$= 6,17 \text{ m}$$

$$P = 9,1 \times 6,17 = 60,56 \text{ kN/m}^2$$

$$t_k = 1,5 \quad (\text{Corrosion Factor})$$

Maka :

$$t_s = 1,036 \times 0,6 \times \sqrt{84,90} + 1,5 \quad (\text{mm})$$

$$= 7,143 \text{ mm, diambil } 7 \text{ mm}$$

$$t_{smin} = 6,0 \times \sqrt{k}$$

$$= 6,0 \text{ mm}$$

## 2. Modulus penampang penegar sekat kedap air

### 2.1 Modulus penampang penegar sekat tubrukan tidak boleh

kurang dari :(BKI Vol II 2001, Sec 11. B. 3. 1)

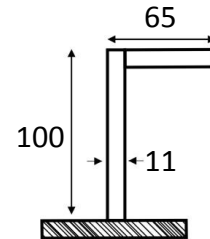
$$W = C_s \cdot a \cdot l^2 \cdot P \quad (\text{cm}^3)$$

Dimana :

$$\begin{aligned} C_s &= 0,45 \cdot f \\ &= 0,45 \times 0,887 \\ &= 0,399 \end{aligned}$$

$$l = 2,31 \text{ m}$$

$$P = 90,291 \text{ kN/m}^2$$



Maka :

$$\begin{aligned} W &= 0,399 \times 0,6 \times (2,31)^2 \times 90,291 \\ &= 90,29 \text{ cm}^3 \end{aligned}$$

Profil yang di ambil L 100 x 65 x 11

### 2.2 Stiffener Bangunan Atas : (BKI 2001. Vol II sec.16. C.3.1)

$$W = 0,35 \cdot a \cdot l^2 \cdot P_A \cdot k$$

Dimana :

$$l = 2,4 \text{ m}$$

$$a = 0,6 \text{ m (jarak stiffener)}$$

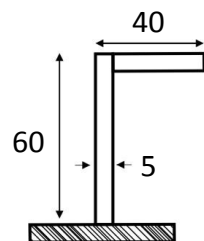
$$k = 1,0$$

#### a. Poop Deck

$$P_{A1} = 12,267 \text{ kN/m}^2$$

$$\begin{aligned} W &= 0,35 \times 0,6 \times (2,4)^2 \times 12,267 \times 1 \\ &= 14,838 \text{ cm}^3 \end{aligned}$$

Profil yang di ambil L 60 x 40 x 5

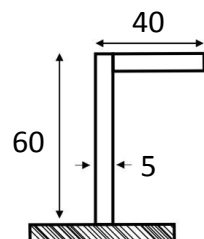


#### b. Boat Deck

$$P_{A2} = 8,922 \text{ kN/m}^2$$

$$\begin{aligned} W &= 0,35 \times 0,6 \times (2,4)^2 \times 8,922 \times 1 \\ &= 10,792 \text{ cm}^3 \end{aligned}$$

Profil yang di ambil L 60 x 40x 5

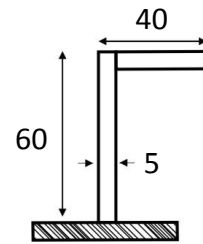


## c. Navigation Deck

$$P_{A3} = 7,869 \text{ kN/m}^2$$

$$W = 0,35 \times 0,6 \times (2,4)^2 \times 7,869 \times 1 \\ = 9,790 \text{ cm}^3$$

Profil yang di ambil L 60 x 40 x 5

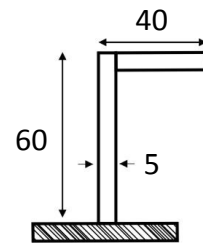


## d. Compas Deck

$$P_{A4} = 7,869 \text{ kN/m}^2$$

$$W = 0,35 \times 0,6 \times (2,4)^2 \times 7,869 \times 1 \\ = 9,518 \text{ cm}^3$$

Profil yang di ambil L 60 x 40 x 5



### V.7.9 Web Stiffener

#### 1. WEB STIFFENER

a. Modulus web stiffener sekat tubrukan tidak boleh kurang dari

$$W = C_s \cdot e \cdot l^2 \cdot P \cdot k \quad (\text{cm}^3)$$

Dimana

$$C_s = 0,399$$

e = lebar pembebanan = 2,4

l = panjang tak ditumpu

$$= 13 - 1,3 / 5 = 2,34 \text{ m}$$

$$P = 9,81 \times h \quad h = \left( \frac{H - h_{DB}}{2} \right) + 1$$

$$P = 9,81 \times 6,85 \quad h = \left( \frac{8,62 - 1,3}{2} \right) + 1$$

$$P = 60,56 \text{ kN/m}^3 \quad h = 6,17$$

jadi

$$W = 0,399 \times 2,4 \times (2,34)^2 \times 60,56 \times 1 \\ = 269,79 \text{ cm}^3$$

Profil yang direncanakan T 200 x 19 FP 80 x 19

Tebal plat = 9

Koreksi modulus (40 ~ 50 ) t = 50 x 8,0 = 450

$$F = 50 \times 0,9 = 45$$

$$f_s = 20 \times 1,9 = 38$$

$$f = 8 \times 1,9 = 15,2$$

$$f/F = 0,84$$

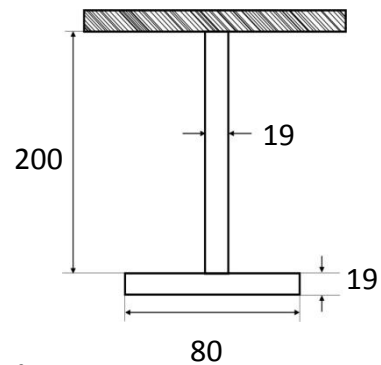
$$f_s/F = 0,34$$

$$w = 0,24$$

maka

$$W = w \times F \times h \\ = 0,50 \times 32 \times 24 = 345 \text{ cm}^3$$

W rencana > W perhitungan (memenuhi)



b. Modulus web stiffener sekat kamar mesin dan sekat lain pada tengah kapal tidak boleh kurang dari

$$W = C_s \cdot e \cdot l^2 \cdot p \cdot k \quad (\text{cm}^3)$$

Dimana:

$$C_s = 0,399$$

$$e = \text{lebar pembebanan} = 2,4 \text{ m}$$

$$l = \text{panjang tak ditumpu} = 2,34 \text{ m}$$

$$p = 48,069 / \text{m}^2$$

$$k = 1$$

jadi

$$W = 0,399 \times 2,4 \times (2,34)^2 \times 48,069 \times 1 \\ = 252,047 \text{ cm}^3$$

Profil yang direncanakan T 220 x 10 FP 70 x 10

Tebal plat = 8,0

Koreksi modulus (40 ~ 50 ) t = 40 x 8,0 = 320

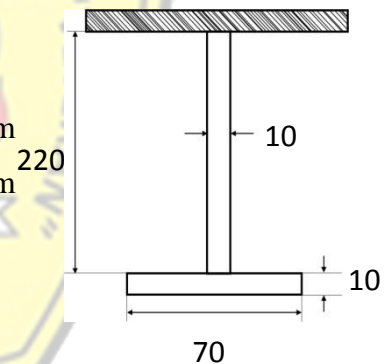
$$F = 40 \times 0,8 = 32$$

$$f_s = 22 \times 1,0 = 22$$

$$f = 7 \times 1,0 = 7$$

$$f/F = 0,22$$

$$f_s/F = 0,687$$



$$w = 0,39$$

maka

$$W = w \times F \times h$$

$$= 0,39 \times 32 \times 22 = 274,56 \text{ cm}^3$$

$$W \text{ rencana} > W \text{ perhitungan} \quad (\text{memenuhi})$$

### c. Web Stiffener Bangunan Atas

#### ♦ Poop Deck

$$W = C_s \cdot e \cdot l^2 \cdot P \cdot k \quad (\text{cm}^3)$$

Di mana :

$$C_s = 0,399$$

$$e = \text{lebar pembebanan}$$

$$= 2,4 \text{ m}$$

$$l = \text{panjang tak ditumpu} = 2 \text{ m}$$

$$p = 31,855 \text{ kN/m}^2$$

$$k = 1$$

jadi

$$W = 0,399 \times 2,4 \times (2,34)^2 \times 31,855 \times 1$$

$$= 167,030 \text{ cm}^3$$

Profil yang direncanakan T 180 x 9 FP 60 x 9

Tebal plat = 8,0

Koreksi modulus (40 ~ 50)  $t = 40 \times 8,0 = 320$

$$F = 40 \times 0,8 = 32$$

$$f_s = 18 \times 0,9 = 16,2$$

$$f = 6 \times 0,9 = 5,4$$

$$f/F = 0,168 \quad 180$$

$$f_s/F = 0,506$$

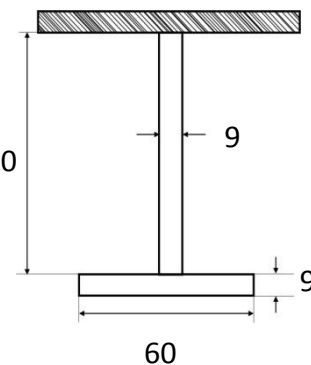
$$w = 0,31$$

maka

$$W = w \times F \times h$$

$$= 0,31 \times 32 \times 18 = 178,56 \text{ cm}^3$$

$$W \text{ rencana} > W \text{ perhitungan} \quad (\text{memenuhi})$$



- ◆ Boat Deck

Dimana:

$$p = 28,051 \text{ KN/m}^2$$

jadi

$$W = 0,399 \times 2,4 \times (2,34)^2 \times 28,051 \times 1$$

$$= 147,083 \text{ cm}^3$$

Profil yang direncanakan T 180 x 9 FP 50 x 9

Tebal plat = 8,0

Koreksi modulus (40 ~ 50 ) t = 40 x 8,0 = 320

$$F = 40 \times 0,8 = 32$$

$$f_s = 18 \times 0,9 = 16,2$$

$$f = 5 \times 0,9 = 4,5$$

$$f/F = 0,14$$

$$f_s/F = 0,506$$

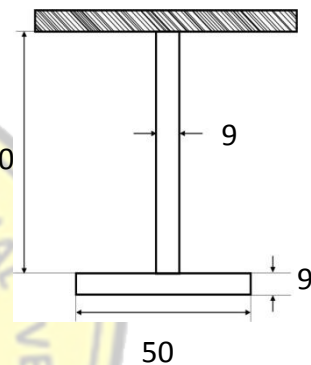
$$w = 0,26$$

maka

$$W = w \times F \times h$$

$$= 0,26 \times 32 \times 18 = 149,76 \text{ cm}^3$$

W rencana > W perhitungan (memenuhi)



- ◆ Navigation Deck dan Compass Deck

Dimana:

$$p = 25,059 \text{ KN/m}^2$$

jadi

$$W = 0,399 \times 2,4 \times (2,34)^2 \times 25,059 \times 1$$

$$= 131,395 \text{ cm}^3$$

Profil yang direncanakan T 180 x 8 FP 45 x 8

Tebal plat = 8,0

Koreksi modulus (40 ~ 50 ) t = 40 x 8,0 = 320

$$F = 40 \times 0,8 = 32$$

$$f_s = 18 \times 0,8 = 14,4$$

$$f = 4,5 \times 0,8 = 3,6$$

$$f/F = 0,1125$$

$$f_s/F = 0,45$$

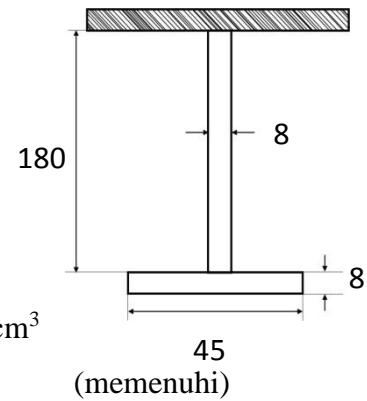
$$w = 0,25$$

maka

$$W = w \times F \times h$$

$$= 0,25 \times 32 \times 18 = 144 \text{ cm}^3$$

W rencana > W perhitungan



◆ Fore Castle Deck

Dimana:

$$p = 38,322 \text{ KN/m}^2$$

jadi

$$W = 0,399 \times 2,4 \times (2,34)^2 \times 38,322 \times 1$$

$$= 200,939 \text{ cm}^3$$

Profil yang direncanakan T 200 x 9 FP 70 x 9

Tebal plat = 8,0

Koreksi modulus (40 ~ 50)  $t = 40 \times 8,0 = 320$

$$F = 40 \times 0,8 = 32$$

$$f_s = 20 \times 0,9 = 18$$

$$f = 7 \times 0,9 = 6,3$$

$$f/F = 0,197$$

$$f_s/F = 0,562$$

$$w = 0,34$$

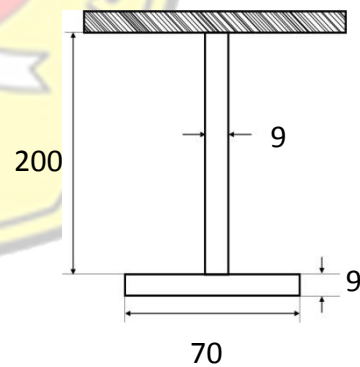
maka

$$W = w \times F \times h$$

$$= 0,34 \times 32 \times 20 = 217,6 \text{ cm}^3$$

W rencana > W perhitungan

(memenuhi)





### V.7.10 Senta Sisi (Stringers)

Perhitungan senta sisi sesuai dengan ketentuan (*BKI 2001 Sec.9A..5.3B*)

Modulus penampang balok geladak tidak boleh kurang :

$$W = 0,6 \cdot e \cdot l^2 \cdot P \cdot k \quad (\text{cm}^3)$$

a. Modulus senta sisi pada tengah kapal

$$W = 0,6 \cdot e \cdot l^2 \cdot P \cdot k \quad (\text{cm}^3)$$

Dimana :

$$e = \text{jarak web frame} \\ = 2,8 \text{ m}$$

$$l = \text{Panjang tak ditumpu} \\ = 2,4 \text{ m}$$

$$p = 64,662 \text{ kN/m}^2$$

$$k = 1$$

jadi

$$W = 0,6 \cdot 2,4 \cdot (2,8)^2 \cdot 64,662 \cdot 1 \\ = 625,72 \text{ cm}^3$$

Profil yang direncanakan T 320 x 20 FP 150 x 20

Tebal plat samping = 9

Koreksi modulus (40 ~ 50)  $t = 50 \times 11,0 = 450$

$$F = 50 \times 0,9 = 45$$

$$f_s = 32 \times 2 = 6,4$$

$$f = 15 \times 2 = 30$$

$$f/F = 1,42$$

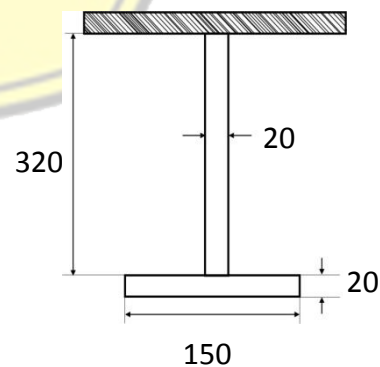
$$f_s/F = 0,67$$

$$w = 0,54$$

maka

$$W = w \times F \times h \\ = 0,54 \times 55 \times 28 = 777,6 \text{ cm}^3$$

$W \text{ rencana} > W \text{ perhitungan}$  (memenuhi)



b. Modulus senta sisi pada kamar mesin

$$W = 0,6 \cdot e \cdot l^2 \cdot P \cdot k \quad (\text{cm}^3)$$

Dimana :

$$e = \text{jarak web frame} = 2,4 \text{ m}$$

$$l = \text{Panjang tak ditumpu} = 2,34 \text{ m}$$

$$p = 75,133 \text{ kN/m}^2$$

$$k = 1$$

jadi

$$\begin{aligned} W &= 0,6 \times 2,4 \times (2,34)^2 \times 75,133 \times 1 \\ &= 592,413 \text{ cm}^3 \end{aligned}$$

Profil yang direncanakan T 280 x 13 FP 100 x 13

Tebal plat samping = 11,0

Koreksi modulus (40 ~ 50 ) t = 50 x 11 = 550

$$F = 55 \times 1,1 = 55$$

$$f_s = 28 \times 1,3 = 36,4$$

$$f = 10 \times 1,3 = 13$$

$$f/F = 0,236$$

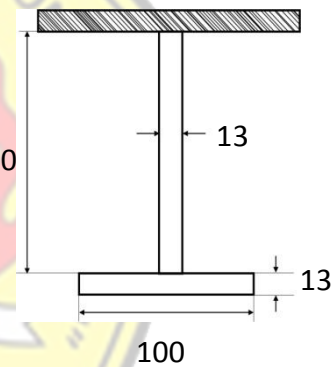
$$f_s/F = 0,662$$

$$w = 0,41$$

maka

$$\begin{aligned} W &= w \times F \times h \\ &= 0,41 \times 55 \times 28 = 631,4 \text{ cm}^3 \end{aligned}$$

W rencana > W perhitungan (memenuhi)



b. Modulus senta sisi pada kamar haluan kapal

$$W = 0,6 \cdot e \cdot l^2 \cdot P \cdot k \quad (\text{cm}^3)$$

Dimana :

$$e = \text{jarak web frame} = 2,4 \text{ m}$$

$$l = \text{Panjang tak ditumpu} = 2,34 \text{ m}$$

$$p = 89,45 \text{ kN/m}^2$$

$$k = 1$$

jadi

$$W = 0,6 \cdot 2,4 \cdot (2,34)^2 \cdot 89,45 \cdot 1$$

$$= 865,6 \text{ cm}^3$$

Profil yang direncanakan T 320 x 25 FP 150 x 25

Tebal plat samping = 9

Koreksi modulus (40 ~ 50)  $t = 50 \times 12 = 450$

$$F = 50 \times 2,5 = 45$$

$$f_s = 32 \times 2,5 = 80$$

$$f = 15 \times 2,5 = 37,5$$

$$f/F = 1,78$$

$$f_s/F = 0,83$$

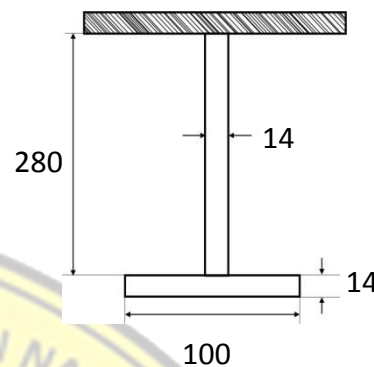
$$w = 0,61$$

maka

$$W = w \times F \times h$$

$$= 0,61 \times 45 \times 32 = 878,4 \text{ cm}^3$$

$W_{\text{rencana}} > W_{\text{perhitungan}}$  (memenuhi)



## V.8 Perhitungan Kekuatan

Pada seluruh bangunan konstruksi terapung yang dipengaruhi oleh gelombang akan menerima momen lentur (*bending momen*). Hal ini diakibatkan oleh adanya perbedaan antara distribusi berat kapal dengan daya apung yang dialami pada seluruh bagian konstruksi tersebut.

Ketentuan besar kecilnya momen lentur diperoleh karena keadaan gelombang yang melalui kapal tersebut. Keadaan kritis terjadi apabila kapal mengalami gelombang "Trochoid", yaitu gelombang laut yang panjangnya dari puncak ke puncak sama dengan panjang kapal. Sehingga dengan demikian kapal mengalami dua keadaan, yaitu :

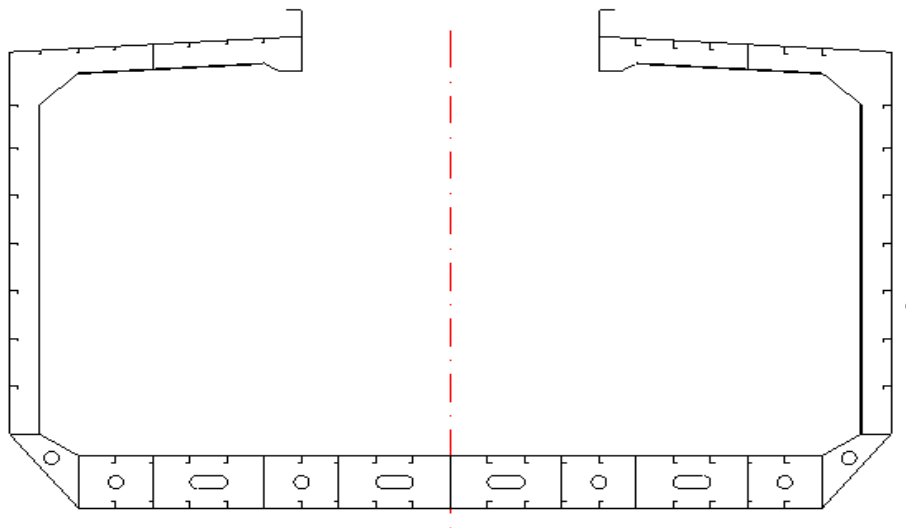
### a. Kondisi *Hogging/Wellenberg*

Kondisi ini memiliki ciri puncak berada ditengah kapal dan lembah gelombang berada pada haluan dan buritan. Kondisi ini umumnya terjadi apabila kapal memiliki ruang mesin dibagian tengah kapal.

### b. Kondisi *Sagging/Wallental*

Kondisi ini memiliki ciri-ciri puncak gelombang berada pada bagian ujung haluan dan buritan, kemudian lembah gelombang berada pada bagian tengah kapal. Kondisi ini umumnya terjadi apabila kapal memiliki ruang mesin dibagian buritan kapal.

Perhitungan kekuatan memanjang adalah tahap untuk menghitung kekuatan konstruksi kapal dalam kondisi air tenang dan dalam kondisi bergelombang (*sagging & hogging*). Perhitungan kekuatan memanjang dimulai dengan penyebaran beban dan penyebaran gaya angkat, kemudian dilakukan koreksi terhadap berat dan titik berat. Setelah itu dilakukan perhitungan gaya lintang dan momen pada air tenang serta dilakukan koreksi (linier dan non linier), kemudian dilanjutkan dengan perhitungan *sagging hogging* sesuai dengan BKI Vol. II Sec. 5.B.3.1. dan menghasilkan total *bending momen sagging* ( $M_{sagging}$ ) dan total *bending momen hogging* ( $M_{hogging}$ ). Disamping itu dari gambar penampang melintang dilakukan perhitungan modulus penampang untuk menentukan modulus pada geladak ( $W_{deck}$ ) dan modulus pada alas ( $W_{bottom}$ ), kemudian dilakukan cek kekuatan dengan membandingkan besarnya tegangan, modulus dan momen inersia kapal dengan nilai minimum yang disyaratkan BKI. Besarnya tegangan, modulus dan momen inersia kapal tidak boleh kurang dari nilai yang disyaratkan BKI.



**Gambar 36. Komponen *Midship***

Tabel 96. Komponen Penampang *Midship*


| No | Item                          | n | Hor   | Ver   | Luas (A) | Lengan Ver ( $\ell_v$ ) | Lengan Hor ( $\ell_h$ ) | $A\ell_v$ | $A\ell_h$ | $A\ell_v^2$ | $A\ell_h^2$ | $I_{ov}$  | $I_{oh}$  |
|----|-------------------------------|---|-------|-------|----------|-------------------------|-------------------------|-----------|-----------|-------------|-------------|-----------|-----------|
| 1  | Keel plate                    | 1 | 1,300 | 0,011 | 0,014    | 0,006                   | 0,000                   | 7,9E-05   | 0         | 4,33E-07    | 0           | 2,014E-03 | 1,442E-07 |
| 2  | Bottom plate                  | 2 | 5,478 | 0,009 | 0,047    | 0,004                   | 3,389                   | 0,0002    | 0,1578    | 8,41E-07    | 0,53479     | 2,329E-01 | 5,607E-07 |
| 3  | Bilge Plate                   | 2 | 2,200 | 0,013 | 0,029    | 1,700                   | 8,200                   | 0,04862   | 0,23452   | 8,27E-02    | 1,92306     | 3,84E-02  | 8,056E-07 |
| 4  | Inner Bottom Plate            | 2 | 8,160 | 0,009 | 0,069    |                         | 0,000                   | 0         | 0         | 0,00E+00    | 0           | 7,697E-01 | 8,352E-07 |
| 5  | Side plate di bawah garis air | 2 | 0,009 | 4,750 | 0,043    | 4,407                   | 8,155                   | 0,1884    | 0,34863   | 8,30E-01    | 2,84305     | 5,771E-07 | 1,608E-01 |
| 6  | Side plate di atas garis air  | 2 | 0,007 | 1,750 | 0,012    | 7,657                   | 8,156                   | 0,0938    | 0,09991   | 7,18E-01    | 0,81487     | 1,000E-07 | 6,253E-03 |
| 7  | Deck plate                    | 2 | 8,160 | 0,007 | 0,057    | 8,644                   | 4,079                   | 0,49375   | 0,23299   | 4,27E+00    | 0,95038     | 3,975E-02 | 4,665E-07 |
| 8  | 1. Bottom Longt. L160x80x14   | 2 | 0,014 | 0,160 | 0,002    | 0,080                   | 0,707                   | 0,00018   | 0,00158   | 1,43E-05    | 0,00112     | 7,317E-08 | 9,557E-06 |
|    |                               | 2 | 0,066 | 0,014 | 0,001    | 0,153                   | 0,747                   | 0,00014   | 0,00069   | 2,16E-05    | 0,00052     | 6,708E-07 | 3,018E-08 |
| 9  | 2. Bottom Longt. L160x80x14   | 2 | 0,014 | 0,160 | 0,002    | 0,080                   | 1,407                   | 0,00018   | 0,00315   | 1,43E-05    | 0,00443     | 7,317E-08 | 9,557E-06 |
|    |                               | 2 | 0,066 | 0,014 | 0,001    | 0,153                   | 1,447                   | 0,00014   | 0,00134   | 2,16E-05    | 0,00193     | 6,708E-07 | 3,018E-08 |
| 10 | 3. Bottom Longt. L160x80x14   | 2 | 0,014 | 0,160 | 0,002    | 0,080                   | 2,107                   | 0,00018   | 0,00472   | 1,43E-05    | 0,00994     | 7,317E-08 | 9,557E-06 |
|    |                               | 2 | 0,066 | 0,014 | 0,001    | 0,153                   | 2,147                   | 0,00014   | 0,00198   | 2,16E-05    | 0,00426     | 6,708E-07 | 3,018E-08 |
| 11 | 4. Bottom Longt. L160x80x14   | 2 | 0,014 | 0,160 | 0,002    | 0,080                   | 3,387                   | 0,00018   | 0,00759   | 1,43E-05    | 0,0257      | 7,317E-08 | 9,557E-06 |
|    |                               | 2 | 0,066 | 0,014 | 0,001    | 0,153                   | 3,427                   | 0,00014   | 0,00317   | 2,16E-05    | 0,01085     | 6,708E-07 | 3,018E-08 |
| 12 | 5. Bottom Longt. L160x80x14   | 2 | 0,014 | 0,160 | 0,002    | 0,080                   | 4,807                   | 0,00018   | 0,01077   | 1,43E-05    | 0,05176     | 7,317E-08 | 9,557E-06 |
|    |                               | 2 | 0,066 | 0,014 | 0,001    | 0,153                   | 4,127                   | 0,00014   | 0,00381   | 2,16E-05    | 0,01574     | 6,708E-07 | 3,018E-08 |
| 13 | 6. Bottom Longt. L160x80x14   | 2 | 0,014 | 0,160 | 0,002    | 0,080                   | 4,787                   | 0,00018   | 0,01072   | 1,43E-05    | 0,05133     | 7,317E-08 | 9,557E-06 |
|    |                               | 2 | 0,066 | 0,014 | 0,001    | 0,153                   | 4,827                   | 0,00014   | 0,00446   | 2,16E-05    | 0,02153     | 6,708E-07 | 3,018E-08 |
| 14 | 7. Bottom Longt. L160x80x14   | 2 | 0,014 | 0,160 | 0,002    | 0,080                   | 6,070                   | 0,00018   | 0,0136    | 1,43E-05    | 0,08253     | 7,317E-08 | 9,557E-06 |
|    |                               | 2 | 0,066 | 0,014 | 0,001    | 0,153                   | 6,110                   | 0,00014   | 0,00565   | 2,16E-05    | 0,03449     | 6,708E-07 | 3,018E-08 |

Tabel 97. Komponen Penampang *Midship*

|    |                                    |   |       |       |       |       |       |         |         |          |         |           |           |
|----|------------------------------------|---|-------|-------|-------|-------|-------|---------|---------|----------|---------|-----------|-----------|
| 15 | 1. Inner Bottom Longt. L160x80x14  | 2 | 0,014 | 0,160 | 0,002 | 1,004 | 0,707 | 0,00225 | 0,00158 | 2,26E-03 | 0,00112 | 7,317E-08 | 9,557E-06 |
|    |                                    | 2 | 0,066 | 0,014 | 0,001 | 0,931 | 0,747 | 0,00086 | 0,00069 | 8,01E-04 | 0,00052 | 6,708E-07 | 3,018E-08 |
| 16 | 2. Inner Bottom Longt. L160x80x14  | 2 | 0,014 | 0,160 | 0,002 | 1,004 | 1,407 | 0,00225 | 0,00158 | 2,26E-03 | 0,00112 | 7,317E-08 | 9,557E-06 |
|    |                                    | 2 | 0,066 | 0,014 | 0,001 | 0,931 | 1,447 | 0,00086 | 0,00069 | 8,01E-04 | 0,00052 | 6,708E-07 | 3,018E-08 |
| 17 | 3. Inner Bottom Longt. L160x80x14  | 2 | 0,014 | 0,160 | 0,002 | 1,004 | 2,107 | 0,00225 | 0,00315 | 2,26E-03 | 0,00443 | 7,317E-08 | 9,557E-06 |
|    |                                    | 2 | 0,066 | 0,014 | 0,001 | 0,931 | 2,147 | 0,00086 | 0,00134 | 8,01E-04 | 0,00193 | 6,708E-07 | 3,018E-08 |
| 18 | 4. Inner Bottom Longt. L160x80x14  | 2 | 0,014 | 0,160 | 0,002 | 1,004 | 3,387 | 0,00225 | 0,00472 | 2,26E-03 | 0,00994 | 7,317E-08 | 9,557E-06 |
|    |                                    | 2 | 0,066 | 0,014 | 0,001 | 0,931 | 3,427 | 0,00086 | 0,00198 | 8,01E-04 | 0,00426 | 6,708E-07 | 3,018E-08 |
| 19 | 5. Inner Bottom Longt. L160x80x14  | 2 | 0,014 | 0,160 | 0,002 | 1,004 | 4,807 | 0,00225 | 0,00759 | 2,26E-03 | 0,0257  | 7,317E-08 | 9,557E-06 |
|    |                                    | 2 | 0,066 | 0,014 | 0,001 | 0,931 | 4,127 | 0,00086 | 0,00317 | 8,01E-04 | 0,01085 | 6,708E-07 | 3,018E-08 |
| 20 | 6. Inner Bottom Longt. L160x80x14  | 2 | 0,014 | 0,160 | 0,002 | 1,004 | 4,787 | 0,00225 | 0,01077 | 2,26E-03 | 0,05176 | 7,317E-08 | 9,557E-06 |
|    |                                    | 2 | 0,066 | 0,014 | 0,001 | 0,931 | 4,827 | 0,00086 | 0,00381 | 8,01E-04 | 0,01574 | 6,708E-07 | 3,018E-08 |
| 21 | 7. Inner Bottom Longt. L160x80x14  | 2 | 0,014 | 0,160 | 0,002 | 1,004 | 6,070 | 0,00225 | 0,01072 | 2,26E-03 | 0,05133 | 7,317E-08 | 9,557E-06 |
|    |                                    | 2 | 0,066 | 0,014 | 0,001 | 0,931 | 6,110 | 0,00086 | 0,00446 | 8,01E-04 | 0,02153 | 6,708E-07 | 3,018E-08 |
| 22 | 8. Inner Bottom Longt. L180x100x10 | 2 | 0,014 | 0,160 | 0,002 | 1,004 | 6,773 | 0,00225 | 0,0136  | 2,26E-03 | 0,08253 | 7,317E-08 | 9,557E-06 |
|    |                                    | 2 | 0,066 | 0,014 | 0,001 | 0,931 | 6,818 | 0,00086 | 0,00565 | 8,01E-04 | 0,03449 | 6,708E-07 | 3,018E-08 |
|    | Center girder                      | 1 | 0,011 | 1,084 | 0,012 | 0,542 | 0,000 | 0,00646 | 0       | 3,50E-03 | 0       | 1,202E-07 | 1,168E-03 |
| 23 | 1.Side girder                      | 2 | 0,009 | 1,084 | 0,010 | 0,542 | 2,680 | 0,00529 | 0,02615 | 2,87E-03 | 0,07007 | 1,317E-07 | 1,911E-03 |
| 24 | 2.Side girder                      | 2 | 0,009 | 1,084 | 0,010 | 0,542 | 5,363 | 0,00529 | 0,05232 | 2,87E-03 | 0,2806  | 1,317E-07 | 1,911E-03 |

Tabel 98. Komponen Penampang *Midship*

|    |                                 |   |       |       |       |       |       |         |         |          |         |           |           |
|----|---------------------------------|---|-------|-------|-------|-------|-------|---------|---------|----------|---------|-----------|-----------|
| 25 | 1. Side Longt. Frame L130x65x12 | 2 | 0,130 | 0,012 | 0,002 | 1,778 | 8,087 | 0,00277 | 0,01262 | 4,93E-03 | 0,10202 | 4,394E-06 | 3,744E-08 |
|    |                                 | 2 | 0,012 | 0,053 | 0,001 | 1,745 | 8,028 | 0,00111 | 0,00511 | 1,94E-03 | 0,04099 | 1,526E-08 | 2,978E-07 |
| 26 | 2. Side Longt. Frame 130x65x12  | 2 | 0,130 | 0,012 | 0,002 | 2,478 | 8,095 | 0,00387 | 0,01263 | 9,58E-03 | 0,10223 | 4,394E-06 | 3,744E-08 |
|    |                                 | 2 | 0,012 | 0,053 | 0,001 | 2,445 | 8,036 | 0,00156 | 0,00511 | 3,80E-03 | 0,04107 | 1,526E-08 | 2,978E-07 |
| 27 | 3. Side Longt. Frame 130x65x12  | 2 | 0,130 | 0,012 | 0,002 | 3,117 | 8,095 | 0,00486 | 0,01263 | 1,52E-02 | 0,10223 | 4,394E-06 | 3,744E-08 |
|    |                                 | 2 | 0,012 | 0,053 | 0,001 | 3,145 | 8,036 | 0,002   | 0,00511 | 6,29E-03 | 0,04107 | 1,526E-08 | 2,978E-07 |
| 28 | 4. Side Longt. Frame L130x65x12 | 2 | 0,130 | 0,012 | 0,002 | 3,877 | 8,095 | 0,00605 | 0,01263 | 2,34E-02 | 0,10223 | 4,394E-06 | 3,744E-08 |
|    |                                 | 2 | 0,012 | 0,053 | 0,001 | 3,835 | 8,036 | 0,00244 | 0,00511 | 9,35E-03 | 0,04107 | 1,526E-08 | 2,978E-07 |
| 29 | 5. Side Longt. Frame L130x65x12 | 2 | 0,130 | 0,012 | 0,002 | 4,577 | 8,095 | 0,00714 | 0,01263 | 3,27E-02 | 0,10223 | 4,394E-06 | 3,744E-08 |
|    |                                 | 2 | 0,012 | 0,053 | 0,001 | 4,545 | 8,036 | 0,00289 | 0,00511 | 1,31E-02 | 0,04107 | 1,526E-08 | 2,978E-07 |
| 30 | 6. Side Longt. Frame L130x65x12 | 2 | 0,130 | 0,012 | 0,002 | 5,977 | 8,095 | 0,00932 | 0,01263 | 5,57E-02 | 0,10223 | 4,394E-06 | 3,744E-08 |
|    |                                 | 2 | 0,012 | 0,053 | 0,001 | 5,945 | 8,036 | 0,00378 | 0,00511 | 2,25E-02 | 0,04107 | 1,526E-08 | 2,978E-07 |
| 31 | 7. Side Longt. Frame L130x65x12 | 2 | 0,130 | 0,012 | 0,002 | 6,677 | 8,095 | 0,01042 | 0,01263 | 6,95E-02 | 0,10223 | 4,394E-06 | 3,744E-08 |
|    |                                 | 2 | 0,012 | 0,053 | 0,001 | 6,645 | 8,036 | 0,00423 | 0,00511 | 2,81E-02 | 0,04107 | 1,526E-08 | 2,978E-07 |


 JAKARTA

**Tabel 99. Komponen Penampang *Midship***

|    |                                |   |       |       |       |       |       |         |         |          |         |           |           |
|----|--------------------------------|---|-------|-------|-------|-------|-------|---------|---------|----------|---------|-----------|-----------|
| 32 | 1. Deck Long. L 90x60x8        | 2 | 0,008 | 0,090 | 0,001 | 8,642 | 0,704 | 0,00622 | 0,00051 | 5,38E-02 | 0,00036 | 7,680E-09 | 9,720E-07 |
|    |                                | 2 | 0,052 | 0,008 | 0,000 | 8,601 | 0,734 | 0,00358 | 0,00031 | 3,08E-02 | 0,00022 | 1,875E-07 | 4,437E-09 |
| 33 | 2. Deck Long. L 90x60x8        | 2 | 0,008 | 0,090 | 0,001 | 8,636 | 1,404 | 0,00622 | 0,00101 | 5,37E-02 | 0,00142 | 7,680E-09 | 9,720E-07 |
|    |                                | 2 | 0,052 | 0,008 | 0,000 | 8,595 | 1,434 | 0,00358 | 0,0006  | 3,07E-02 | 0,00086 | 1,875E-07 | 4,437E-09 |
| 34 | 3. Deck Long. L 90x60x8        | 2 | 0,008 | 0,090 | 0,001 | 8,630 | 2,104 | 0,00621 | 0,00151 | 5,36E-02 | 0,00319 | 7,680E-09 | 9,720E-07 |
|    |                                | 2 | 0,052 | 0,008 | 0,000 | 8,589 | 2,134 | 0,00357 | 0,00089 | 3,07E-02 | 0,00189 | 1,875E-07 | 4,437E-09 |
| 35 | 4. Deck Long. L 90x60x8        | 2 | 0,008 | 0,090 | 0,001 | 8,615 | 3,384 | 0,0062  | 0,00244 | 5,34E-02 | 0,00825 | 7,680E-09 | 9,720E-07 |
|    |                                | 2 | 0,052 | 0,008 | 0,000 | 8,574 | 3,414 | 0,00357 | 0,00142 | 3,06E-02 | 0,00485 | 1,875E-07 | 4,437E-09 |
| 36 | 5. Deck Long. L 90x60x8        | 2 | 0,008 | 0,090 | 0,001 | 8,606 | 4,070 | 0,0062  | 0,00293 | 5,33E-02 | 0,01193 | 7,680E-09 | 9,720E-07 |
|    |                                | 2 | 0,052 | 0,008 | 0,000 | 8,565 | 4,100 | 0,00356 | 0,00171 | 3,05E-02 | 0,00699 | 1,875E-07 | 4,437E-09 |
| 37 | 6. Deck Long. L 90x60x8        | 2 | 0,008 | 0,090 | 0,001 | 8,595 | 4,784 | 0,00619 | 0,00344 | 5,32E-02 | 0,01648 | 7,680E-09 | 9,720E-07 |
|    |                                | 2 | 0,052 | 0,008 | 0,000 | 8,554 | 4,814 | 0,00356 | 0,002   | 3,04E-02 | 0,00964 | 1,875E-07 | 4,437E-09 |
| 38 | 7. Deck Long. L 90x60x8        | 2 | 0,008 | 0,090 | 0,001 | 8,571 | 6,067 | 0,00617 | 0,00437 | 5,29E-02 | 0,0265  | 7,680E-09 | 9,720E-07 |
|    |                                | 2 | 0,052 | 0,008 | 0,000 | 8,530 | 6,097 | 0,00355 | 0,00254 | 3,03E-02 | 0,01546 | 1,875E-07 | 4,437E-09 |
| 39 | 8. Deck Long. L 90x60x8        | 2 | 0,008 | 0,090 | 0,001 | 8,552 | 6,770 | 0,00616 | 0,00487 | 5,27E-02 | 0,033   | 7,680E-09 | 9,720E-07 |
|    |                                | 2 | 0,052 | 0,008 | 0,000 | 8,511 | 6,800 | 0,00354 | 0,00283 | 3,01E-02 | 0,01924 | 1,875E-07 | 4,437E-09 |
| 40 | 1. Deck girder T430x110x19     | 2 | 0,019 | 0,430 | 0,008 | 8,462 | 2,683 | 0,06913 | 0,02192 | 5,85E-01 | 0,05881 | 4,916E-07 | 2,518E-04 |
|    |                                | 2 | 0,110 | 0,019 | 0,002 | 8,229 | 2,683 | 0,0172  | 0,00561 | 1,42E-01 | 0,01504 | 4,215E-06 | 1,257E-07 |
| 41 | 2. Deck girder T430x110x19     | 2 | 0,019 | 0,430 | 0,008 | 8,416 | 5,362 | 0,06876 | 0,04381 | 5,79E-01 | 0,2349  | 4,916E-07 | 2,518E-04 |
|    |                                | 2 | 0,110 | 0,019 | 0,002 | 8,192 | 5,362 | 0,01712 | 0,01121 | 1,40E-01 | 0,06009 | 4,215E-06 | 1,257E-07 |
| 42 | Center Deck girder T430x110x19 | 2 | 0,019 | 0,430 | 0,008 | 8,453 | 0,000 | 0,06906 | 0       | 5,84E-01 | 0       | 4,916E-07 | 2,518E-04 |
|    |                                | 2 | 0,110 | 0,019 | 0,002 | 8,254 | 0,000 | 0,01725 | 0       | 1,42E-01 | 0       | 4,215E-06 | 1,257E-07 |



Tabel 100. Komponen Penampang *Midship*

|    |                                |   |       |       |       |       |       |         |         |          |          |           |           |           |
|----|--------------------------------|---|-------|-------|-------|-------|-------|---------|---------|----------|----------|-----------|-----------|-----------|
| 43 | 1. Second Deck Long. L 90x60x8 | 2 | 0,008 | 0,090 | 0,001 | 5,237 | 0,704 | 0,00377 | 0,00051 | 1,97E-02 | 0,00036  | 7,680E-09 | 9,720E-07 |           |
|    |                                | 2 | 0,052 | 0,008 | 0,000 | 5,196 | 0,734 | 0,00216 | 0,00031 | 1,12E-02 | 0,00022  | 1,875E-07 | 4,437E-09 |           |
| 44 | 2. Second Deck Long. L 90x60x8 | 2 | 0,008 | 0,090 | 0,001 | 5,237 | 1,404 | 0,00377 | 0,00101 | 1,97E-02 | 0,00142  | 7,680E-09 | 9,720E-07 |           |
|    |                                | 2 | 0,052 | 0,008 | 0,000 | 5,196 | 1,434 | 0,00216 | 0,0006  | 1,12E-02 | 0,00086  | 1,875E-07 | 4,437E-09 |           |
| 45 | 3. Second Deck Long. L 90x60x8 | 2 | 0,008 | 0,090 | 0,001 | 5,237 | 2,104 | 0,00377 | 0,00151 | 1,97E-02 | 0,00319  | 7,680E-09 | 9,720E-07 |           |
|    |                                | 2 | 0,052 | 0,008 | 0,000 | 5,196 | 2,134 | 0,00216 | 0,00089 | 1,12E-02 | 0,00189  | 1,875E-07 | 4,437E-09 |           |
| 46 | 4. Second Deck Long. L 90x60x8 | 2 | 0,008 | 0,090 | 0,001 | 5,237 | 3,384 | 0,00377 | 0,00244 | 1,97E-02 | 0,00825  | 7,680E-09 | 9,720E-07 |           |
|    |                                | 2 | 0,052 | 0,008 | 0,000 | 5,196 | 3,414 | 0,00216 | 0,00142 | 1,12E-02 | 0,00485  | 1,875E-07 | 4,437E-09 |           |
| 47 | 5. Second Deck Long. L 90x60x8 | 2 | 0,008 | 0,090 | 0,001 | 5,237 | 4,070 | 0,00377 | 0,00293 | 1,97E-02 | 0,01193  | 7,680E-09 | 9,720E-07 |           |
|    |                                | 2 | 0,052 | 0,008 | 0,000 | 5,196 | 4,100 | 0,00216 | 0,00171 | 1,12E-02 | 0,00699  | 1,875E-07 | 4,437E-09 |           |
| 48 | 6. Second Deck Long. L 90x60x8 | 2 | 0,008 | 0,090 | 0,001 | 5,237 | 4,784 | 0,00377 | 0,00344 | 1,97E-02 | 0,01648  | 7,680E-09 | 9,720E-07 |           |
|    |                                | 2 | 0,052 | 0,008 | 0,000 | 5,196 | 4,814 | 0,00216 | 0,002   | 1,12E-02 | 0,00964  | 1,875E-07 | 4,437E-09 |           |
| 49 | 7. Second Deck Long. L 90x60x8 | 2 | 0,008 | 0,090 | 0,001 | 5,237 | 6,067 | 0,00377 | 0,00437 | 1,97E-02 | 0,0265   | 7,680E-09 | 9,720E-07 |           |
|    |                                | 2 | 0,052 | 0,008 | 0,000 | 5,196 | 6,097 | 0,00216 | 0,00254 | 1,12E-02 | 0,01546  | 1,875E-07 | 4,437E-09 |           |
| 50 | 8. Second Deck Long. L 90x60x8 | 2 | 0,008 | 0,090 | 0,001 | 5,237 | 6,770 | 0,00377 | 0,00487 | 1,97E-02 | 0,033    | 7,680E-09 | 9,720E-07 |           |
|    |                                | 2 | 0,052 | 0,008 | 0,000 | 5,196 | 6,800 | 0,00216 | 0,00283 | 1,12E-02 | 0,01924  | 1,875E-07 | 4,437E-09 |           |
| 51 | Second Deck plate              | 2 | 8,160 | 0,007 | 0,057 | 5,279 | 4,079 | 0,30154 | 0,23299 | 1,59E+00 | 0,95038  | 2,200E-01 | 4,665E-07 |           |
|    |                                |   |       |       |       |       |       |         |         |          |          |           |           |           |
|    |                                |   |       |       |       |       |       |         |         |          |          |           |           |           |
|    |                                |   |       |       |       |       |       |         |         |          |          |           |           |           |
|    |                                |   |       |       | Σ     | 0,471 |       | Σ       | 1,61702 | 1,80748  | 1,09E+01 | 10,6933   | 1,303E+00 | 1,729E-01 |

$$\text{Neutral Axis (z) / KG} = \sum \ell V / \sum A$$

$$= 1,61702/0,471$$

$$= 3,43 \text{ m}$$

$$Y_G = \sum A \ell H / \sum A$$

$$= 1,80748/0,471$$

$$= 3,84 \text{ m}$$

$$I_x = \sum I_{ov} / \sum A \ell v^2$$

$$= 12,21 \text{ m}^4$$

$$I_{xNA} = I_x - (KG^2) \sum A$$

$$= 6,67 \text{ m}^4$$

$$I_Y = \sum I_{oH} / \sum A \ell H^2$$

$$= 10,87 \text{ m}^4$$

$$I_Y = I_y - (YG^2) \cdot \sum A$$

$$= 3,93 \text{ m}^4$$

$$W_{\text{deck}} = I_{xNA} / Y_{\text{deck}}$$

$$= 6,67/5,09$$

$$= 1,31 \text{ m}^3$$

$$W_{\text{bottom}} = I_{xNA} / Y_{\text{bottom}}$$

$$= 6,67/3,43$$

$$= 1,94 \text{ m}^3$$

$$W_{\text{inner}} = I_{xNA} / Y_{\text{bottom}}$$

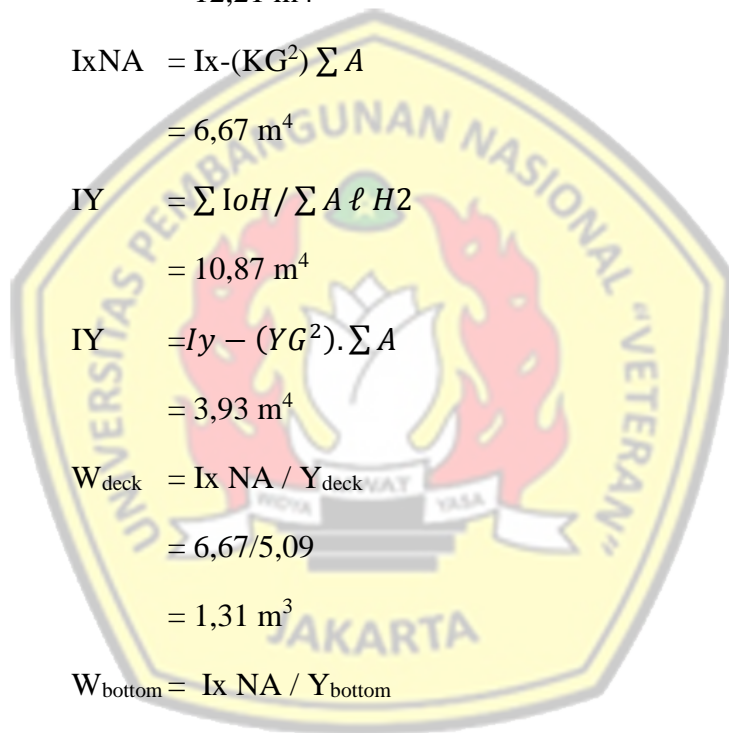
$$= 6,67/3,22$$

$$= 2,07 \text{ m}^3$$

$$W_{\text{sisi}} = I_{xNA} / Y_{\text{sisi}} \text{ (di bawah garis air)}$$

$$= 6,67/2,53$$

$$= 2,63 \text{ m}^3$$



$$\begin{aligned}
 W_{\text{sisi}} &= I_x NA / Y_{\text{sisi}} \text{ (di atas garis air)} \\
 &= 6,67/4,03 \\
 &= 1,65\text{m}^3
 \end{aligned}$$

Momen *inertia- Deck Plate*

$$I_x = t \times (1/3L^3 \sin^2 a)$$

Dimana :

$$L = 5910,73 \text{ mm}$$

$$= 5,91073 \text{ m}$$

$$a = 3$$

$$\sin a = 0,14112$$

$$I_x = t \times (1/3L^3 \sin^2 a)$$

$$= 1,99\text{E-}02$$

Momen *inertia – Bilge Plate*

$$I_x = t \times (1/3L^3 \sin^2 a)$$

Dimana :

$$L = 2202,27 \text{ mm}$$

$$= 2,20227 \text{ m}$$

$$a = 51$$

$$\sin a = 0,67023$$

$$I_x = t \times (1/3L^3 \sin^2 a)$$

$$= 1,923\text{E-}02$$

### V.8.1 Kekuatan kapal *buckling sagging*

Total *Bending Moment*

BKI Vol II : *Section V-B. 3.1*

$$M_{\text{tot}} = MSW + MWV$$

MSW = permissible vertical still water bending moment (kNm)

MWV = vertical wave bending moment (kNm)

$C_{WV} = L^2 \times B \times C_0 \times C_1 \times C_L \times C_m$  (kNm)

$C_0 C_L =$  see Section 4.A.2.2

$C_1 =$  hogging/sagging condition as follows :

$C_{IH} = 0,19 CB$  for hogging condition

$C_{IH} = 0,18$  for hogging condition

$C_{IS} = -0,11 (CB + 0,7)$  sagging condition

$C_{IS} = -0,18$  sagging condition

$C_M =$  distribution, see also fig. 5.3

$C_{MS} =$  sagging condition

$$= C_v \times 2,5 \times \frac{x}{L} \text{ for } 0 \leq \frac{x}{L} < 0,4$$

$$= C_v \times 2,5 \times \frac{x}{L} \text{ for } 0,4 \leq \frac{x}{L} < 0,65 \times C_v$$

$$= C_v \times \frac{\frac{x}{L} - 0,65 \times C_v}{1 - 0,65 \times C_v} \text{ for } 0,65 \times C_v < \frac{x}{L} \leq 1$$

$C_{MS} =$  influence with regard to speed  $v_0$  of the vessel

$$= \sqrt[3]{\frac{v_0}{1,4 \times \sqrt{L}}} \geq 1,0$$

For  $L$  the value need not be less than 1,00

= 1,0 for damaged condition

$C_0 =$  wave coefficient = 1,0

$$= \left[ \frac{L}{25} + 4,1 \right]_{CRW} \text{ for } L < 90\text{m}$$

$$= \left[ 10,75 - \left[ \frac{300-L}{100} \right]^{1,5} \right]_{CRW} = 8,59$$

= for  $90 \leq L \leq 300\text{m}$

$C_L =$  Length coefficient

$$= \sqrt{\frac{L}{90}} \text{ For } L < 90\text{m}$$

$$= 1,0 \text{ for } L \geq 90\text{m} = 1,00$$

*Sagging condition*

$$M_{wv} = L^2 \times B \times C_0 \times C_1 \times C_L \times C_m \text{ (kNm)}$$

Dimana :

$$C_0 = 8,59$$

$$C_{1s} = -0,18$$

$$C_L = 1$$

$$C_{MS} = 1$$

$$M_{wv} = L^2 \times B \times C_0 \times C_1 \times C_L \times C_m \text{ (kNm)}$$

$$= -256702 \text{ kNm}$$

$$M_{wv} = 1/3 \times M_{wv} \text{ kNm}$$

$$= -85567 \text{ kNm}$$

$$M_{tot} = M_{sw} + M_{wv}$$

$$= -342269 \text{ kNm}$$

*Sagging condition*

*Elastic buckling*

Untuk pelat Geladak

Diketahui :

$$t = 14,50 \text{ mm}$$

$$= 0,0145$$

$$W_{deck} = I_{xNA} / Y_{deck}$$

$$= 6,67 / 5,09 = 1,31 \text{ m}^3$$

$$M_{tot} = M_{sw} + M_{wv} = -342269 \text{ kNm}$$

$$\sigma = M_{tot} + M_{deck}$$

$$= -342269/1,31 = 261352,58 \text{ KN/m}^2$$

$$N = \sigma \times \text{tebal}$$

$$= 3789,61 \text{ kN/m}$$

Untuk pelat bottom

Diketahui :

$$t = 14,50 \text{ mm}$$



$$= 0,0145$$

$$\begin{aligned} W_{\text{bottom}} &= I_{xNA}/Y_{\text{bottom}} \\ &= 6,67/3,43 = 1,94 \text{ m}^3 \end{aligned}$$

$$M_{\text{tot}} = M_{\text{sw}} + M_{\text{wv}} = -342269 \text{ kNm}$$

$$\begin{aligned} \sigma &= M_{\text{tot}} + M_{\text{bottom}} \\ &= -342269/1,94 = 176172,86 \text{ KN/m}^2 \end{aligned}$$

$$\begin{aligned} N &= \sigma \times \text{tebal} \\ &= 2642,59 \text{ kN/m} \end{aligned}$$

Untuk pelat inner bottom

Diketahui :

$$\begin{aligned} t &= 14\text{mm} \\ &= 0,014 \end{aligned}$$

$$\begin{aligned} W_{\text{inner bottom}} &= I_{xNA}/Y_{\text{inner bottom}} \\ &= 6,67/3,22 = 2,07 \text{ m}^3 \end{aligned}$$

$$M_{\text{tot}} = M_{\text{sw}} + M_{\text{wv}} = -342269 \text{ kNm}$$

$$\begin{aligned} \sigma &= M_{\text{tot}} + M_{\text{inner bottom}} \\ &= -342269/2,07 = 165335,03 \text{ KN/m}^2 \end{aligned}$$

$$\begin{aligned} N &= \sigma \times \text{tebal} \\ &= 2314,69 \text{ kN/m} \end{aligned}$$

Untuk pelat sisi di bawah garis air

Diketahui :

$$\begin{aligned} t &= 14\text{mm} \\ &= 0,014 \end{aligned}$$

$$\begin{aligned} W_{\text{sisi}} &= I_{xNA}/Y_{\text{sisi}} \\ &= 6,67/2,53 = 2,63 \text{ m}^3 \end{aligned}$$

$$\sigma = M_{\text{tot}} + M_{\text{sisi}}$$

$$= -342269/2,63 = 129906,10 \text{ KN/m}^2$$

$$\begin{aligned} N &= \sigma \times \text{tebal} \\ &= 18181,69 \text{ kN/m} \end{aligned}$$

Untuk pelat sisi di atas garis air

Diketahui :

$$\begin{aligned} t &= 13\text{mm} \\ &= 0,013 \end{aligned}$$

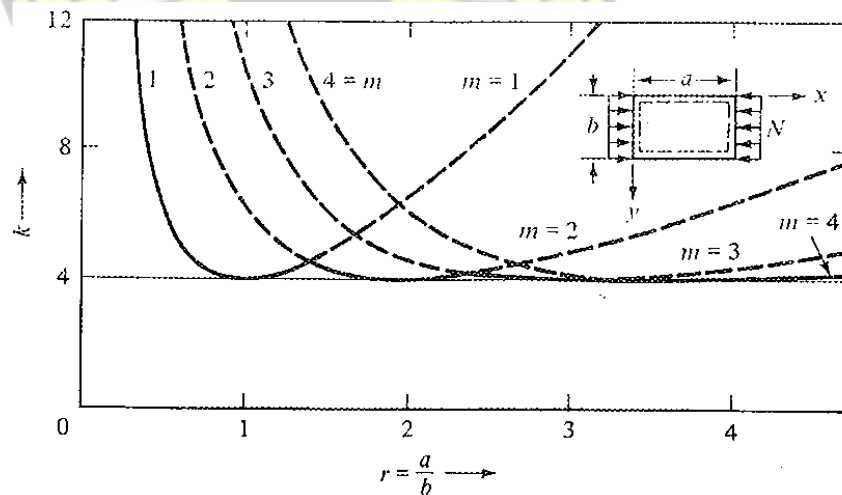
$$\begin{aligned} W_{\text{sisi}} &= I_{XNA}/Y_{\text{sisi}} \\ &= 6,67/4,03 = 1,65 \text{ m}^3 \end{aligned}$$

$$\begin{aligned} \sigma &= M_{\text{tot}} + M_{\text{sisi}} \\ &= -342269/1,65 = 206925,52 \text{ KN/m}^2 \end{aligned}$$

$$\begin{aligned} N &= \sigma \times \text{tebal} \\ &= 2690,03 \text{ kN/m} \end{aligned}$$

Dari persamaan

$$N_{\text{cr}} = \frac{\pi^2 D}{b^2} \left( \frac{m}{r} + \frac{r}{m} \right)^2 = k^2 \frac{\pi^2 D}{b^2}$$



$$\begin{aligned} r &= a/b \\ &= 4,0 \end{aligned}$$



$$K = (m/r + r/m)^2 \quad m=3$$

$$= 4,00$$

Untuk pelat geladak

$$D = \frac{E h^3}{12(1-\nu^2)} \quad \text{dimana : } E = 206 \text{ Gpa, } \nu = 0,3$$

$$= 57511$$

$$N_{cr} = \frac{\pi^2 D}{b^2} \left( \frac{m}{r} + \frac{r}{m} \right)^2 = k^2 \frac{\pi^2 D}{b^2}$$

$$= 4036321,94 \text{ N/m} = 4036,32 \text{ kN/m} > 3789,61 \text{ kN/m}$$

memenuhi

Untuk pelat bottom

$$D = \frac{E h^3}{12(1-\nu^2)}$$

$$= 63668$$

$$N_{cr} = \frac{\pi^2 D}{b^2} \left( \frac{m}{r} + \frac{r}{m} \right)^2 = k^2 \frac{\pi^2 D}{b^2}$$

$$= 4468436,28 \text{ N/m} = 4468,44 \text{ kN/m} > 2642,59 \text{ kN/m}$$

memenuhi

Untuk pelat inner bottom

$$D = \frac{E h^3}{12(1-\nu^2)}$$

$$= 51764$$

$$N_{cr} = \frac{\pi^2 D}{b^2} \left( \frac{m}{r} + \frac{r}{m} \right)^2 = k^2 \frac{\pi^2 D}{b^2}$$

$$= 363304,19 \text{ N/m} = 3633,00 \text{ kN/m} > 2314,69 \text{ kN/m}$$

memenuhi

Untuk pelat sisi di bawah garis air

$$D = \frac{E h^3}{12(1-\nu^2)}$$

$$= 51764$$

$$N_{cr} = \frac{\pi^2 D}{b^2} \left( \frac{m}{r} + \frac{r}{m} \right)^2 = k^2 \frac{\pi^2 D}{b^2}$$

$$= 363304,19 \text{ N/m} = 3633,00 \text{ kN/m} > 1818,69$$

Untuk pelat sisi di air garis air

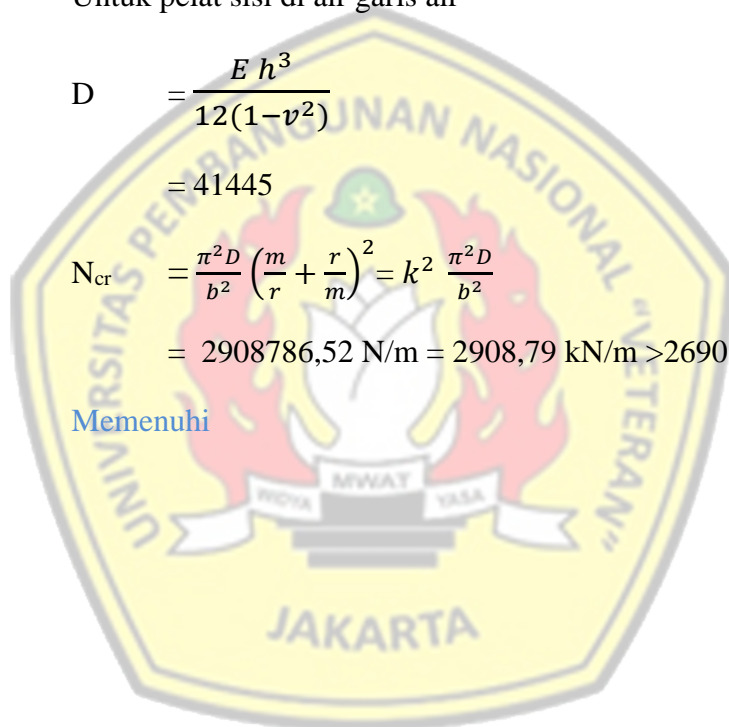
$$D = \frac{E h^3}{12(1-\nu^2)}$$

$$= 41445$$

$$N_{cr} = \frac{\pi^2 D}{b^2} \left( \frac{m}{r} + \frac{r}{m} \right)^2 = k^2 \frac{\pi^2 D}{b^2}$$

$$= 2908786,52 \text{ N/m} = 2908,79 \text{ kN/m} > 2690,03 \text{ kN/m}$$

Memenuhi



Tabel 101. Komponen Penampang *Midship*

| No | Item                          | n | Hor   | Ver   | Luas (A) | Lengan Ver ( $e_V$ ) | Lengan Hor ( $e_H$ ) | $Ae_V$  | $Ae_H$  | $Ae_V^2$ | $Ae_H^2$ | $I_{OV}$ | $I_{OH}$ |
|----|-------------------------------|---|-------|-------|----------|----------------------|----------------------|---------|---------|----------|----------|----------|----------|
| 1  | Keel plate                    | 1 | 1,300 | 0,011 | 0,014    | 0,006                | 0,000                | 7,9E-05 | 0       | 0,00000  | 0        | 0,00201  | 0,00000  |
| 2  | Bottom plate                  | 2 | 5,478 | 0,009 | 0,051    | 0,005                | 3,389                | 0,00024 | 0,17451 | 0,00000  | 0,59142  | 0,25754  | 0,00000  |
| 3  | Bilge Plate                   | 2 | 3,260 | 0,011 | 0,036    | 0,558                | 7,613                | 0,02001 | 0,27297 | 0,01116  | 2,0781   | 0,09109  | 0,00000  |
| 4  | Inner Bottom Plate            | 2 | 8,160 | 0,009 | 0,077    | 1,089                | 4,012                | 0,08351 | 0,30774 | 0,09091  | 1,23464  | 0,85123  | 0,00000  |
| 5  | Side plate di bawah garis air | 2 | 0,009 | 4,750 | 0,043    | 4,407                | 8,155                | 0,1884  | 0,34863 | 0,83028  | 2,84305  | 0,00000  | 0,16076  |
| 6  | Side plate di atas garis air  | 2 | 0,007 | 1,750 | 0,012    | 7,657                | 8,156                | 0,0938  | 0,09991 | 0,71821  | 0,81487  | 0,00000  | 0,00625  |
| 7  | Deck plate                    | 2 | 8,160 | 0,008 | 0,061    | 8,644                | 4,079                | 0,52901 | 0,24963 | 4,57279  | 1,01826  | 0,10460  | 0,00000  |
| 8  | 1. Bottom Longt. L160x80x14   | 2 | 0,014 | 0,160 | 0,002    | 0,080                | 0,707                | 0,00018 | 0,00158 | 0,00001  | 0,00112  | 0,00000  | 0,00001  |
|    |                               | 2 | 0,066 | 0,014 | 0,001    | 0,153                | 0,747                | 0,00014 | 0,00069 | 0,00002  | 0,00052  | 0,00000  | 0,00000  |
| 9  | 2. Bottom Longt. L160x80x14   | 2 | 0,014 | 0,160 | 0,002    | 0,080                | 1,407                | 0,00018 | 0,00315 | 0,00001  | 0,00443  | 0,00000  | 0,00001  |
|    |                               | 2 | 0,066 | 0,014 | 0,001    | 0,153                | 1,447                | 0,00014 | 0,00134 | 0,00002  | 0,00193  | 0,00000  | 0,00000  |
| 10 | 3. Bottom Longt. L160x80x14   | 2 | 0,014 | 0,160 | 0,002    | 0,080                | 2,107                | 0,00018 | 0,00472 | 0,00001  | 0,00994  | 0,00000  | 0,00001  |
|    |                               | 2 | 0,066 | 0,014 | 0,001    | 0,153                | 2,147                | 0,00014 | 0,00198 | 0,00002  | 0,00426  | 0,00000  | 0,00000  |
| 11 | 4. Bottom Longt. L160x80x14   | 2 | 0,014 | 0,160 | 0,002    | 0,080                | 3,387                | 0,00018 | 0,00759 | 0,00001  | 0,0257   | 0,00000  | 0,00001  |
|    |                               | 2 | 0,066 | 0,014 | 0,001    | 0,153                | 3,427                | 0,00014 | 0,00317 | 0,00002  | 0,01085  | 0,00000  | 0,00000  |
| 12 | 5. Bottom Longt. L160x80x14   | 2 | 0,014 | 0,160 | 0,002    | 0,080                | 4,807                | 0,00018 | 0,01077 | 0,00001  | 0,05176  | 0,00000  | 0,00001  |
|    |                               | 2 | 0,066 | 0,014 | 0,001    | 0,153                | 4,127                | 0,00014 | 0,00381 | 0,00002  | 0,01574  | 0,00000  | 0,00000  |
| 13 | 6. Bottom Longt. L160x80x14   | 2 | 0,014 | 0,160 | 0,002    | 0,080                | 4,787                | 0,00018 | 0,01072 | 0,00001  | 0,05133  | 0,00000  | 0,00001  |
|    |                               | 2 | 0,066 | 0,014 | 0,001    | 0,153                | 4,827                | 0,00014 | 0,00446 | 0,00002  | 0,02153  | 0,00000  | 0,00000  |
| 14 | 7. Bottom Longt. L160x80x14   | 2 | 0,014 | 0,160 | 0,002    | 0,080                | 6,070                | 0,00018 | 0,0136  | 0,00001  | 0,08253  | 0,00000  | 0,00001  |
|    |                               | 2 | 0,066 | 0,014 | 0,001    | 0,153                | 6,110                | 0,00014 | 0,00565 | 0,00002  | 0,03449  | 0,00000  | 0,00000  |

Tabel 102. Komponen Penampang *Midship*

|    |                                    |   |       |       |       |       |       |         |         |         |         |         |         |
|----|------------------------------------|---|-------|-------|-------|-------|-------|---------|---------|---------|---------|---------|---------|
| 15 | 1. Inner Bottom Longt. L160x80x14  | 2 | 0,014 | 0,160 | 0,002 | 1,004 | 0,707 | 0,00225 | 0,00158 | 0,00226 | 0,00112 | 0,00000 | 0,00001 |
|    |                                    | 2 | 0,066 | 0,014 | 0,001 | 0,931 | 0,747 | 0,00086 | 0,00069 | 0,00080 | 0,00052 | 0,00000 | 0,00000 |
| 16 | 2. Inner Bottom Longt. L160x80x14  | 2 | 0,014 | 0,160 | 0,002 | 1,004 | 1,407 | 0,00225 | 0,00158 | 0,00226 | 0,00112 | 0,00000 | 0,00001 |
|    |                                    | 2 | 0,066 | 0,014 | 0,001 | 0,931 | 1,447 | 0,00086 | 0,00069 | 0,00080 | 0,00052 | 0,00000 | 0,00000 |
| 17 | 3. Inner Bottom Longt. L160x80x14  | 2 | 0,014 | 0,160 | 0,002 | 1,004 | 2,107 | 0,00225 | 0,00315 | 0,00226 | 0,00443 | 0,00000 | 0,00001 |
|    |                                    | 2 | 0,066 | 0,014 | 0,001 | 0,931 | 2,147 | 0,00086 | 0,00134 | 0,00080 | 0,00193 | 0,00000 | 0,00000 |
| 18 | 4. Inner Bottom Longt. L160x80x14  | 2 | 0,014 | 0,160 | 0,002 | 1,004 | 3,387 | 0,00225 | 0,00472 | 0,00226 | 0,00994 | 0,00000 | 0,00001 |
|    |                                    | 2 | 0,066 | 0,014 | 0,001 | 0,931 | 3,427 | 0,00086 | 0,00198 | 0,00080 | 0,00426 | 0,00000 | 0,00000 |
| 19 | 5. Inner Bottom Longt. L160x80x14  | 2 | 0,014 | 0,160 | 0,002 | 1,004 | 4,807 | 0,00225 | 0,00759 | 0,00226 | 0,0257  | 0,00000 | 0,00001 |
|    |                                    | 2 | 0,066 | 0,014 | 0,001 | 0,931 | 4,127 | 0,00086 | 0,00317 | 0,00080 | 0,01085 | 0,00000 | 0,00000 |
| 20 | 6. Inner Bottom Longt. L160x80x14  | 2 | 0,014 | 0,160 | 0,002 | 1,004 | 4,787 | 0,00225 | 0,01077 | 0,00226 | 0,05176 | 0,00000 | 0,00001 |
|    |                                    | 2 | 0,066 | 0,014 | 0,001 | 0,931 | 4,827 | 0,00086 | 0,00381 | 0,00080 | 0,01574 | 0,00000 | 0,00000 |
| 21 | 7. Inner Bottom Longt. L160x80x14  | 2 | 0,014 | 0,160 | 0,002 | 1,004 | 6,070 | 0,00225 | 0,01072 | 0,00226 | 0,05133 | 0,00000 | 0,00001 |
|    |                                    | 2 | 0,066 | 0,014 | 0,001 | 0,931 | 6,110 | 0,00086 | 0,00446 | 0,00080 | 0,02153 | 0,00000 | 0,00000 |
| 22 | 8. Inner Bottom Longt. L180x100x10 | 2 | 0,014 | 0,160 | 0,002 | 1,004 | 6,773 | 0,00225 | 0,0136  | 0,00226 | 0,08253 | 0,00000 | 0,00001 |
|    |                                    | 2 | 0,066 | 0,014 | 0,001 | 0,931 | 6,818 | 0,00086 | 0,00565 | 0,00080 | 0,03449 | 0,00000 | 0,00000 |
|    | Center girder                      | 1 | 0,011 | 1,084 | 0,012 | 0,542 | 0,000 | 0,00646 | 0       | 0,00350 | 0       | 0,00000 | 0,00117 |
| 23 | 1.Side girder                      | 2 | 0,009 | 1,084 | 0,010 | 0,542 | 2,680 | 0,00529 | 0,02615 | 0,00287 | 0,07007 | 0,00000 | 0,00191 |
| 24 | 2.Side girder                      | 2 | 0,009 | 1,084 | 0,010 | 0,542 | 5,363 | 0,00529 | 0,05232 | 0,00287 | 0,2806  | 0,00000 | 0,00191 |

**Tabel 103. Komponen Penampang *Midship***

|    |                                 |   |       |       |       |       |       |         |         |         |         |         |         |
|----|---------------------------------|---|-------|-------|-------|-------|-------|---------|---------|---------|---------|---------|---------|
| 25 | 1. Side Longt. Frame L130x65x12 | 2 | 0,130 | 0,012 | 0,002 | 1,778 | 8,087 | 0,00277 | 0,01262 | 0,00493 | 0,10202 | 0,00000 | 0,00000 |
|    |                                 | 2 | 0,012 | 0,053 | 0,001 | 1,745 | 8,028 | 0,00111 | 0,00511 | 0,00194 | 0,04099 | 0,00000 | 0,00000 |
| 26 | 2. Side Longt. Frame 130x65x12  | 2 | 0,130 | 0,012 | 0,002 | 2,478 | 8,095 | 0,00387 | 0,01263 | 0,00958 | 0,10223 | 0,00000 | 0,00000 |
|    |                                 | 2 | 0,012 | 0,053 | 0,001 | 2,445 | 8,036 | 0,00156 | 0,00511 | 0,00380 | 0,04107 | 0,00000 | 0,00000 |
| 27 | 3. Side Longt. Frame 130x65x12  | 2 | 0,130 | 0,012 | 0,002 | 3,117 | 8,095 | 0,00486 | 0,01263 | 0,01516 | 0,10223 | 0,00000 | 0,00000 |
|    |                                 | 2 | 0,012 | 0,053 | 0,001 | 3,145 | 8,036 | 0,002   | 0,00511 | 0,00629 | 0,04107 | 0,00000 | 0,00000 |
| 28 | 4. Side Longt. Frame L130x65x12 | 2 | 0,130 | 0,012 | 0,002 | 3,877 | 8,095 | 0,00605 | 0,01263 | 0,02345 | 0,10223 | 0,00000 | 0,00000 |
|    |                                 | 2 | 0,012 | 0,053 | 0,001 | 3,835 | 8,036 | 0,00244 | 0,00511 | 0,00935 | 0,04107 | 0,00000 | 0,00000 |
| 29 | 5. Side Longt. Frame L130x65x12 | 2 | 0,130 | 0,012 | 0,002 | 4,577 | 8,095 | 0,00714 | 0,01263 | 0,03268 | 0,10223 | 0,00000 | 0,00000 |
|    |                                 | 2 | 0,012 | 0,053 | 0,001 | 4,545 | 8,036 | 0,00289 | 0,00511 | 0,01314 | 0,04107 | 0,00000 | 0,00000 |
| 30 | 6. Side Longt. Frame L130x65x12 | 2 | 0,130 | 0,012 | 0,002 | 5,977 | 8,095 | 0,00932 | 0,01263 | 0,05573 | 0,10223 | 0,00000 | 0,00000 |
|    |                                 | 2 | 0,012 | 0,053 | 0,001 | 5,945 | 8,036 | 0,00378 | 0,00511 | 0,02248 | 0,04107 | 0,00000 | 0,00000 |
| 31 | 7. Side Longt. Frame L130x65x12 | 2 | 0,130 | 0,012 | 0,002 | 6,677 | 8,095 | 0,01042 | 0,01263 | 0,06955 | 0,10223 | 0,00000 | 0,00000 |
|    |                                 | 2 | 0,012 | 0,053 | 0,001 | 6,645 | 8,036 | 0,00423 | 0,00511 | 0,02808 | 0,04107 | 0,00000 | 0,00000 |
| 32 | 1. Deck Long. L 90x60x8         | 2 | 0,008 | 0,090 | 0,001 | 8,642 | 0,704 | 0,00622 | 0,00051 | 0,05377 | 0,00036 | 0,00000 | 0,00000 |
|    |                                 | 2 | 0,052 | 0,008 | 0,000 | 8,601 | 0,734 | 0,00358 | 0,00031 | 0,03077 | 0,00022 | 0,00000 | 0,00000 |
| 33 | 2. Deck Long. L 90x60x8         | 2 | 0,008 | 0,090 | 0,001 | 8,636 | 1,404 | 0,00622 | 0,00101 | 0,05370 | 0,00142 | 0,00000 | 0,00000 |
|    |                                 | 2 | 0,052 | 0,008 | 0,000 | 8,595 | 1,434 | 0,00358 | 0,00006 | 0,03073 | 0,00086 | 0,00000 | 0,00000 |
| 34 | 3. Deck Long. L 90x60x8         | 2 | 0,008 | 0,090 | 0,001 | 8,630 | 2,104 | 0,00621 | 0,00151 | 0,05362 | 0,00319 | 0,00000 | 0,00000 |
|    |                                 | 2 | 0,052 | 0,008 | 0,000 | 8,589 | 2,134 | 0,00357 | 0,00089 | 0,03069 | 0,00189 | 0,00000 | 0,00000 |
| 35 | 4. Deck Long. L 90x60x8         | 2 | 0,008 | 0,090 | 0,001 | 8,615 | 3,384 | 0,0062  | 0,00244 | 0,05344 | 0,00825 | 0,00000 | 0,00000 |
|    |                                 | 2 | 0,052 | 0,008 | 0,000 | 8,574 | 3,414 | 0,00357 | 0,00142 | 0,03058 | 0,00485 | 0,00000 | 0,00000 |
| 36 | 5. Deck Long. L 90x60x8         | 2 | 0,008 | 0,090 | 0,001 | 8,606 | 4,070 | 0,0062  | 0,00293 | 0,05333 | 0,01193 | 0,00000 | 0,00000 |
|    |                                 | 2 | 0,052 | 0,008 | 0,000 | 8,565 | 4,100 | 0,00356 | 0,00171 | 0,03052 | 0,00699 | 0,00000 | 0,00000 |
| 37 | 6. Deck Long. L 90x60x8         | 2 | 0,008 | 0,090 | 0,001 | 8,595 | 4,784 | 0,00619 | 0,00344 | 0,05319 | 0,01648 | 0,00000 | 0,00000 |
|    |                                 | 2 | 0,052 | 0,008 | 0,000 | 8,554 | 4,814 | 0,00356 | 0,002   | 0,03044 | 0,00964 | 0,00000 | 0,00000 |
| 38 | 7. Deck Long. L 90x60x8         | 2 | 0,008 | 0,090 | 0,001 | 8,571 | 6,067 | 0,00617 | 0,00437 | 0,05289 | 0,0265  | 0,00000 | 0,00000 |
|    |                                 | 2 | 0,052 | 0,008 | 0,000 | 8,530 | 6,097 | 0,00355 | 0,00254 | 0,03027 | 0,01546 | 0,00000 | 0,00000 |
| 39 | 8. Deck Long. L 90x60x8         | 2 | 0,008 | 0,090 | 0,001 | 8,552 | 6,770 | 0,00616 | 0,00487 | 0,05266 | 0,033   | 0,00000 | 0,00000 |
|    |                                 | 2 | 0,052 | 0,008 | 0,000 | 8,511 | 6,800 | 0,00354 | 0,00283 | 0,03013 | 0,01924 | 0,00000 | 0,00000 |

Tabel 104. Komponen Penampang *Midship*

|    |                                |   |       |       |       |       |       |         |         |         |          |         |           |           |
|----|--------------------------------|---|-------|-------|-------|-------|-------|---------|---------|---------|----------|---------|-----------|-----------|
| 40 | 1.Deck girder T430x110x19      | 2 | 0,019 | 0,430 | 0,008 | 8,462 | 2,683 | 0,06913 | 0,02192 | 0,58502 | 0,05881  | 0,00000 | 0,00025   |           |
|    |                                | 2 | 0,110 | 0,019 | 0,002 | 8,229 | 2,683 | 0,0172  | 0,00561 | 0,14153 | 0,01504  | 0,00000 | 0,00000   |           |
| 41 | 2.Deck girder T430x110x19      | 2 | 0,019 | 0,430 | 0,008 | 8,416 | 5,362 | 0,06876 | 0,04381 | 0,57867 | 0,2349   | 0,00000 | 0,00025   |           |
|    |                                | 2 | 0,110 | 0,019 | 0,002 | 8,192 | 5,362 | 0,01712 | 0,01121 | 0,14026 | 0,06009  | 0,00000 | 0,00000   |           |
| 42 | Center Deck girder T430x110x19 | 2 | 0,019 | 0,430 | 0,008 | 8,453 | 0,000 | 0,06906 | 0       | 0,58377 | 0        | 0,00000 | 0,00025   |           |
|    |                                | 2 | 0,110 | 0,019 | 0,002 | 8,254 | 0,000 | 0,01725 | 0       | 0,14239 | 0        | 0,00000 | 0,00000   |           |
| 43 | 1. Second Deck Long. L 90x60x8 | 2 | 0,008 | 0,090 | 0,001 | 5,237 | 0,704 | 0,00377 | 0,00051 | 0,01975 | 0,00036  | 0,00000 | 0,00000   |           |
|    |                                | 2 | 0,052 | 0,008 | 0,000 | 5,196 | 0,734 | 0,00216 | 0,00031 | 0,01123 | 0,00022  | 0,00000 | 0,00000   |           |
| 44 | 2. Second Deck Long. L 90x60x8 | 2 | 0,008 | 0,090 | 0,001 | 5,237 | 1,404 | 0,00377 | 0,00101 | 0,01975 | 0,00142  | 0,00000 | 0,00000   |           |
|    |                                | 2 | 0,052 | 0,008 | 0,000 | 5,196 | 1,434 | 0,00216 | 0,0006  | 0,01123 | 0,00086  | 0,00000 | 0,00000   |           |
| 45 | 3. Second Deck Long. L 90x60x8 | 2 | 0,008 | 0,090 | 0,001 | 5,237 | 2,104 | 0,00377 | 0,00151 | 0,01975 | 0,00319  | 0,00000 | 0,00000   |           |
|    |                                | 2 | 0,052 | 0,008 | 0,000 | 5,196 | 2,134 | 0,00216 | 0,00089 | 0,01123 | 0,00189  | 0,00000 | 0,00000   |           |
| 46 | 4. Second Deck Long. L 90x60x8 | 2 | 0,008 | 0,090 | 0,001 | 5,237 | 3,384 | 0,00377 | 0,00244 | 0,01975 | 0,00825  | 0,00000 | 0,00000   |           |
|    |                                | 2 | 0,052 | 0,008 | 0,000 | 5,196 | 3,414 | 0,00216 | 0,00142 | 0,01123 | 0,00485  | 0,00000 | 0,00000   |           |
| 47 | 5. Second Deck Long. L 90x60x8 | 2 | 0,008 | 0,090 | 0,001 | 5,237 | 4,070 | 0,00377 | 0,00293 | 0,01975 | 0,01193  | 0,00000 | 0,00000   |           |
|    |                                | 2 | 0,052 | 0,008 | 0,000 | 5,196 | 4,100 | 0,00216 | 0,00171 | 0,01123 | 0,00699  | 0,00000 | 0,00000   |           |
| 48 | 6. Second Deck Long. L 90x60x8 | 2 | 0,008 | 0,090 | 0,001 | 5,237 | 4,784 | 0,00377 | 0,00344 | 0,01975 | 0,01648  | 0,00000 | 0,00000   |           |
|    |                                | 2 | 0,052 | 0,008 | 0,000 | 5,196 | 4,814 | 0,00216 | 0,002   | 0,01123 | 0,00964  | 0,00000 | 0,00000   |           |
| 49 | 7. Second Deck Long. L 90x60x8 | 2 | 0,008 | 0,090 | 0,001 | 5,237 | 6,067 | 0,00377 | 0,00437 | 0,01975 | 0,0265   | 0,00000 | 0,00000   |           |
|    |                                | 2 | 0,052 | 0,008 | 0,000 | 5,196 | 6,097 | 0,00216 | 0,00254 | 0,01123 | 0,01546  | 0,00000 | 0,00000   |           |
| 50 | 8. Second Deck Long. L 90x60x8 | 2 | 0,008 | 0,090 | 0,001 | 5,237 | 6,770 | 0,00377 | 0,00487 | 0,01975 | 0,033    | 0,00000 | 0,00000   |           |
|    |                                | 2 | 0,052 | 0,008 | 0,000 | 5,196 | 6,800 | 0,00216 | 0,00283 | 0,01123 | 0,01924  | 0,00000 | 0,00000   |           |
| 51 | Second Deck plate              | 2 | 8,160 | 0,007 | 0,057 | 5,279 | 4,079 | 0,30154 | 0,23299 | 1,59181 | 0,95038  | 0,22000 | 0,00000   |           |
|    |                                |   |       |       |       |       |       |         |         |         |          |         |           |           |
|    |                                |   |       |       |       |       |       |         |         |         |          |         |           |           |
|    |                                |   |       |       |       |       |       |         |         |         |          |         |           |           |
|    |                                |   |       |       | Σ     | 0,495 |       | Σ       | 1,70723 | 2,18701 | 1,12E+01 | 12,2075 | 1,527E+00 | 1,729E-01 |

$$\text{Neutral Axis (z) / KG} = \sum \ell V / \sum A$$

$$= 1,70723/0,495$$

$$= 3,45 \text{ m}$$

$$Y_G = \sum A \ell H / \sum A$$

$$= 2,18701/0,495$$

$$= 4,42 \text{ m}$$

$$I_x = \sum I_{ov} / \sum A \ell v^2$$

$$= 12,76 \text{ m}^4$$

$$I_{xNA} = I_x - (KG^2) \sum A$$

$$= 6,87 \text{ m}^4$$

$$I_Y = \sum I_{oH} / \sum A \ell H^2$$

$$= 12,38 \text{ m}^4$$

$$I_Y = I_y - (YG^2) \cdot \sum A$$

$$= 2,72 \text{ m}^4$$

$$W_{\text{deck}} = I_x \text{ NA} / Y_{\text{deck}}$$

$$= 6,87/5,24$$

$$= 1,31 \text{ m}^3$$

$$W_{\text{bottom}} = I_x \text{ NA} / Y_{\text{bottom}}$$

$$= 6,87/3,45$$

$$= 1,99 \text{ m}^3$$

$$W_{\text{inner}} = I_x \text{ NA} / Y_{\text{bottom}}$$

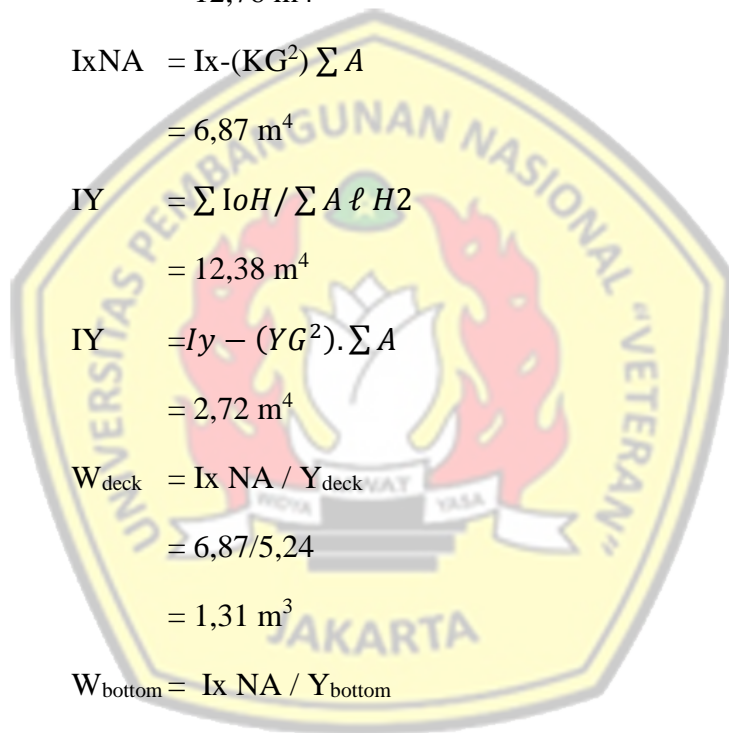
$$= 6,87/2,37$$

$$= 2,90 \text{ m}^3$$

$$W_{\text{sisi}} = I_x \text{ NA} / Y_{\text{sisi}} \text{ (di bawah garis air)}$$

$$= 6,87/0,96$$

$$= 3,20 \text{ m}^3$$



$$\begin{aligned}
 W_{\text{sisi}} &= I_x \text{ NA} / Y_{\text{sisi}} \text{ (di atas garis air)} \\
 &= 6,87/4,21 \\
 &= 1,63\text{m}^3
 \end{aligned}$$

*Momen inertia- Deck Plate*

$$I_x = t \times (1/3L^3 \sin^2 a)$$

Dimana :

$$L = 8160 \text{ mm}$$

$$= 8,16 \text{ m}$$

$$a = 3$$

$$\sin a = 0,14112$$

$$I_x = t \times (1/3L^3 \sin^2 a)$$

$$= 5,23\text{E-}02$$

*Momen inertia – Bilge Plate*

$$I_x = t \times (1/3L^3 \sin^2 a)$$

Dimana :

$$L = 3259,62 \text{ mm}$$

$$= 3,2596 \text{ m}$$

$$a = 98$$

$$\sin a = -0,5734$$

$$I_x = t \times (1/3L^3 \sin^2 a)$$

$$= 0,0455$$

**V.8.2 Kekuatan kapal *buckling hogging***

Total *Bending Moment*

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$$M_{\text{tot}} = \text{MSW} + \text{MWV}$$



MSW = permissible vertical still water bending moment (kNm)

MWV = vertical wave bending moment (kNm)

$$C_{WV} = L^2 \times B \times C_0 \times C_1 \times C_L \times C_m \text{ (kNm)}$$

$C_0 C_L$  = see Section 4.A.2.2

$C_1$  = hogging/sagging condition as follows :

$C_{IH}$  = 0,19 CB for hogging condition

$C_{IH}$  = 0,14 for hogging condition

$C_{IS}$  = -0,11 (CB + 0,7) sagging condition

$C_{IS}$  = -0,16 hogging condition

$C_M$  = distribution, see also fig. 5.3

$C_{MS}$  = hogging condition

$$= C_v \times 2,5 \times \frac{x}{L} \text{ for } 0 \leq \frac{x}{L} < 0,4 = 0,5$$

$$= C_v \times 2,5 \times \frac{x}{L} \text{ for } 0,4 \leq \frac{x}{L} < 0,65 \times C_v = 1$$

$$= C_v \times \frac{\frac{x}{L} - 0,65 \times C_v}{1 - 0,65 \times C_v} \text{ for } 0,65 \times C_v < \frac{x}{L} \leq 1 = 0,57$$

$C_{MS}$  = influence with regard to speed  $v_0$  of the vessel

$$= \sqrt[3]{\frac{v_0}{1,4 \times \sqrt{L}}} \geq 1,0$$

For L the value need not be less than 1,00

= 1,0 for damaged condition

$C_0$  = wave coefficient = 1,0

$$= \left[ \frac{L}{25} + 4,1 \right]_{CRW} \text{ for } L < 90\text{m}$$

$$= \left[ 10,75 - \left[ \frac{300-L}{100} \right]^{1,5} \right]_{CRW} = 7,96$$

= for  $90 \leq L \leq 300\text{m}$

$C_L$  = Length coefficient

$$= \sqrt{\frac{L}{90}} \text{ For } L < 90\text{m}$$

$$= 1,0 \text{ for } L \geq 90\text{m} = 1,00$$

*Hogging condition*

$$M_{wv} = L^2 \times B \times C_0 \times C_1 \times C_L \times C_m \text{ (kNm)}$$

Dimana :

$$C_0 = 7,96$$

$$C_{1s} = 0,14$$

$$C_L = 1$$

$$C_{MS} = 1$$

$$M_{wv} = L^2 \times B \times C_0 \times C_1 \times C_L \times C_m \text{ (kNm)}$$

$$= 189817 \text{ kNm}$$

$$M_{wv} = 1/3 \times M_{wv} \text{ kNm}$$

$$= 63272 \text{ kNm}$$

$$M_{tot} = M_{sw} + M_{wv}$$

$$= 253089 \text{ kNm}$$

*Hogging condition*

*Elastic buckling*

Untuk pelat Geladak

Diketahui :

$$t = 14,50 \text{ mm}$$

$$= 0,0145$$

$$W_{deck} = I_{xNA} / Y_{deck}$$

$$= 6,87 / 5,24 = 1,31 \text{ m}^3$$

$$M_{tot} = M_{sw} + M_{wv} = 253089 \text{ kNm}$$

$$\sigma = M_{tot} + M_{deck}$$

$$= 253088,89/1,31 = 193097,45 \text{ KN/m}^2$$

$$N = \sigma \times \text{tebal}$$

$$= 2799,91 \text{ kN/m}$$

Untuk *pelat bottom*

Diketahui :

$$t = 15\text{mm}$$

$$= 0,015$$

$$W_{\text{bottom}} = I_{XNA}/Y_{\text{bottom}}$$

$$= 6,87/3,45 = 1,99 \text{ m}^3$$

$$\sigma = M_{\text{tot}} / M_{\text{bottom}}$$

$$= 253088,89/1,99 = 127035,50 \text{ KN/m}^2$$

$$N = \sigma \times \text{tebal}$$

$$= 1905,53 \text{ kN/m}$$

Untuk *pelat inner bottom*

Diketahui :

$$t = 14\text{mm}$$

$$= 0,014$$

$$W_{\text{inner bottom}} = I_{XNA}/Y_{\text{inner bottom}}$$

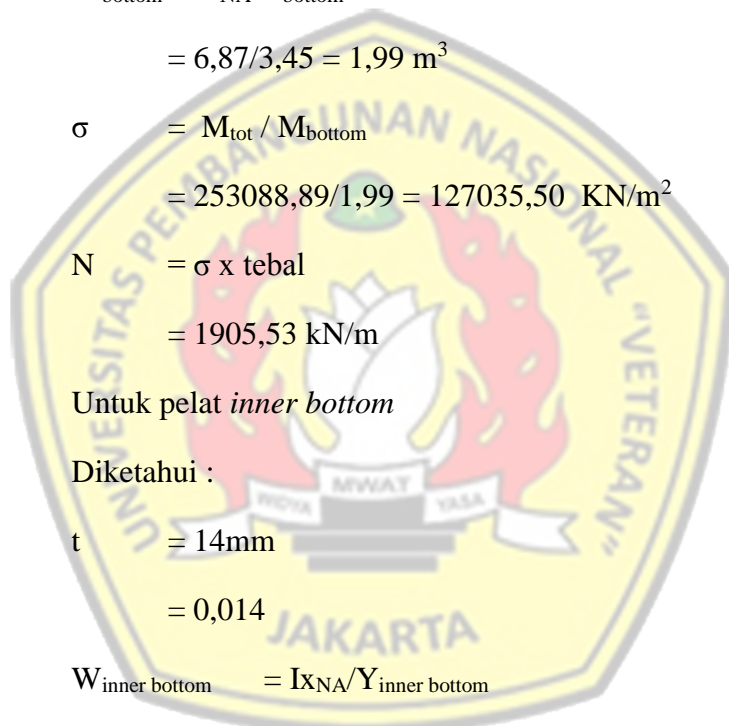
$$= 6,87/2,27 = 2,90 \text{ m}^3$$

$$\sigma = M_{\text{tot}} / M_{\text{inner bottom}}$$

$$= 253088,89/2,90 = 87129,13 \text{ KN/m}^2$$

$$N = \sigma \times \text{tebal}$$

$$= 1219,81 \text{ kN/m}$$



Untuk pelat sisi di bawah garis air

Diketahui :

$$t = 14\text{mm}$$

$$= 0,014$$

$$W_{\text{sisi}} = I_{X_{NA}}/Y_{\text{sisi}}$$

$$= 6,87/0,96 = 7,18 \text{ m}^3$$

$$\sigma = M_{\text{tot}} / M_{\text{sisi}}$$

$$= 253089/7,18 = 35251,21 \text{ KN/m}^2$$

$$N = \sigma \times \text{tebal}$$

$$= 493,52 \text{ kN/m}$$

Untuk pelat sisi di atas garis air

Diketahui :

$$t = 13\text{mm}$$

$$= 0,013$$

$$W_{\text{sisi}} = I_{X_{NA}}/Y_{\text{sisi}}$$

$$= 6,87/4,21 = 1,63 \text{ m}^3$$

$$\sigma = M_{\text{tot}} / M_{\text{sisi}}$$

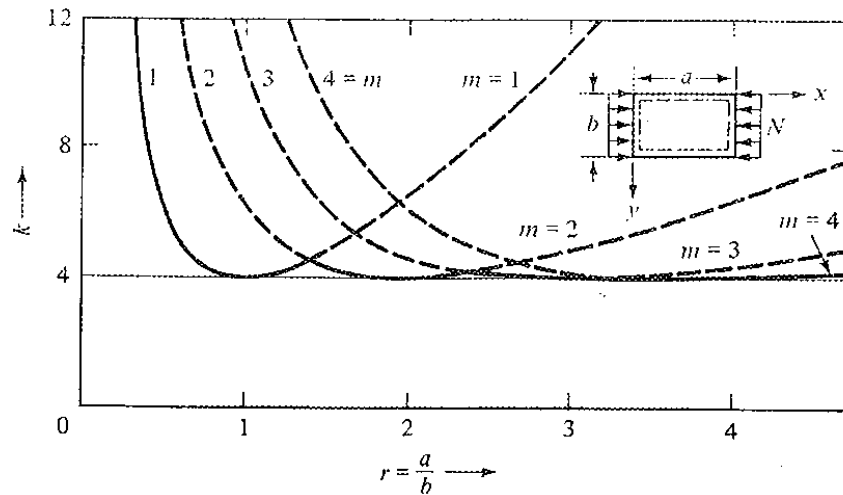
$$= 253089/1,63 = 154943,66 \text{ KN/m}^2$$

$$N = \sigma \times \text{tebal}$$

$$= 2014,27\text{kN/m}$$

Dari persamaan

$$N_{\text{cr}} = \frac{\pi^2 D}{b^2} \left( \frac{m}{r} + \frac{r}{m} \right)^2 = k^2 \frac{\pi^2 D}{b^2}$$



$$r = a/b$$

$$= 4,0$$

$$K = (m/r + r/m)^2 \quad m=3$$

$$= 4,00$$

Untuk pelat geladak

$$D = \frac{E h^3}{12(1-\nu^2)}$$

$$= 57511$$

dimana :  $E = 206 \text{ Gpa}$ ,  $\nu = 0,3$

$$N_{cr} = \frac{\pi^2 D}{b^2} \left( \frac{m}{r} + \frac{r}{m} \right)^2 = k^2 \frac{\pi^2 D}{b^2}$$

$$= 5027704,90 \text{ N/m} = 5027,70 \text{ kN/m} > 2799,91 \text{ kN/m}$$

memenuhi

Untuk pelat bottom

$$D = \frac{E h^3}{12(1-\nu^2)}$$

$$= 63668$$

$$N_{cr} = \frac{\pi^2 D}{b^2} \left( \frac{m}{r} + \frac{r}{m} \right)^2 = k^2 \frac{\pi^2 D}{b^2}$$

$$= 4848563,67 \text{ N/m} = 4848,56 \text{ kN/m} > 1905,53 \text{ kN/m}$$

memenuhi

Untuk pelat inner bottom

$$D = \frac{E h^3}{12(1-\nu^2)}$$

$$= 51764$$

$$N_{cr} = \frac{\pi^2 D}{b^2} \left( \frac{m}{r} + \frac{r}{m} \right)^2 = k^2 \frac{\pi^2 D}{b^2}$$

$$= 3942061,84 \text{ N/m} = 3942,06 \text{ kN/m} > 1219,81 \text{ kN/m}$$

memenuhi

Untuk pelat sisi di bawah garis air

$$D = \frac{E h^3}{12(1-\nu^2)}$$

$$= 51764$$

$$N_{cr} = \frac{\pi^2 D}{b^2} \left( \frac{m}{r} + \frac{r}{m} \right)^2 = k^2 \frac{\pi^2 D}{b^2}$$

$$= 3942061,84 \text{ N/m} = 3942,06 \text{ kN/m} > 493,52 \text{ kN/m}$$

memenuhi

Untuk pelat sisi di air garis air

$$D = \frac{E h^3}{12(1-\nu^2)}$$

$$= 41445$$

$$N_{cr} = \frac{\pi^2 D}{b^2} \left( \frac{m}{r} + \frac{r}{m} \right)^2 = k^2 \frac{\pi^2 D}{b^2}$$

$$= 3156235,37 \text{ N/m} = 3156,24 \text{ kN/m} > 2014,27 \text{ kN/m}$$

memenuhi

## V.9 Perhitungan *Freeboard*

Lambung timbul atau *freeboard* menurut *Load Line Convention* adalah jarak vertikal yang diukur secara vertikal ke arah bawah dari ujung atas garis dek sampai ke ujung atas garis beban pada bagian tengah kapal.

### V.9.1. Dimension *Freeboard*

#### a. Panjang (L1)

Yaitu 96 % dari total panjang garis air kapal pada ketinggian 0,85 H atau panjang kapal menurut garis tegak dipilih yang lebih besar.

**Tabel 105. Interpolasi Pada 0,85H**

| L1 pada 0,85 H    |        |             |        |     |
|-------------------|--------|-------------|--------|-----|
| Tinggi Garis Air  |        | L           |        |     |
| Pada Nilai T      | 8,61   | Nilai Bawah | 129,71 | Lwl |
| Pada Nilai 0.85 H | 9,89   | Nilai X     | 132,22 |     |
| Pada Nilai H      | 11,63  | Nilai Atas  | 135,65 | Loa |
| L <sub>1</sub>    | 132,22 | m           |        |     |

$$\text{LWL pada } 0,85H = 132,22 \text{ m}$$

$$\text{LPP} = 125,93 \text{ m}$$

$$\text{Jadi, } L_1 = 132,22 \text{ m}$$

Lebar (B1)

Adalah lebar maksimum kapal yang diukur pada *midship*

$$B_1 = 18,49 \text{ m}$$

#### b. Tinggi (Hi)

$$H_i = H + t + S_p$$

$$\text{dengan, } H = 11,63 \text{ m}$$

$$t = \text{wood cover}$$

$$= 60 \text{ mm}$$

$$S_p = 5 + 0,03L$$

$$= 5 + (0,03 \times 125,93)$$

$$= 8,78 \text{ mm}$$

$$\text{Maka : } H_i = 11,63 \text{ m} + 60 \text{ mm} + 8,78 \text{ mm}$$

$$= 11,70 \text{ m}$$

### V.9.2. *Tabular Freeboard*

Menurut “*International Load Line Convention 1966*”, maka minimum *freeboard* untuk *passenger*, *cargo*, dan *bulk ship* dengan L yang diperoleh dari basic *Freeboard Table Load Line*

**Tabel 106. Interpolasi L1 Pada 0,85H**

| L1 pada 0,85 H    |        |                   |        |
|-------------------|--------|-------------------|--------|
| Tinggi Garis Air  |        | LWL               |        |
| L bawah           | 129,71 | Freeboard Bawah : | 269,76 |
| L <sub>1</sub>    | 132,22 | Nilai X :         | 270,49 |
| L atas            | 135,65 | Freeboard Atas :  | 271,50 |
| Fb <sub>min</sub> | 270,49 | mm                |        |
|                   | 0,27   | m                 |        |

Setelah dihitung sesuai dengan tabel *freeboard* yang ada di *International Load Convention* 1966 maka didapatkan Fb min = 272,49 mm = 0,27 m.

### V.9.3. Koreksi *Freeboard*

#### a. Koreksi C<sub>b</sub>

Bila C<sub>b</sub> > 0,68 maka dikoreksi dengan faktor pengoreksi berikut ini :

$$\begin{aligned}
 C_1 &= \left( \frac{cb - 0,68}{1,36} \right) \\
 &= \left( \frac{0,76 - 0,68}{1,36} \right) \\
 &= 0,058
 \end{aligned}$$

$$\begin{aligned}
 f_{bmin} \times C_1 &= 270,49 \times 0,058 \\
 &= 15,91 \text{ mm}
 \end{aligned}$$

Sehingga,

$$\begin{aligned}
 f_{bmin} &= 270,49 + 0,095 \\
 &= 270,554 \text{ mm } (fb_2)
 \end{aligned}$$

#### b. Koreksi Tinggi Kapal

Pada rancangan kapal dengan panjang kapal lebih dari 90 meter *freeboard* yang disyaratkan adalah

$$\begin{aligned}
 f_{bmin} &= 270,49 \text{ mm} \\
 f_b &= H - T \\
 &= 11,63 - 8,61 \\
 &= 3,02 > f_{bmin} \text{ (memenuhi)}
 \end{aligned}$$



Dari perselisihan ini maka tinggi kapal (H) dapat dipakai dalam perancangan kapal. Bila  $H > \frac{L}{15}$ , maka *freeboard* ditambah faktor koreksi  $C_2$  yang besarnya :

$$\text{Rumus } C_2 = \left(H - \frac{L}{15}\right)R$$

Dimana :

$$R = 210 \text{ mm jika } L \leq 120 \text{ m}$$

$$H_i = H + t + S_p$$

Sehingga

$$\begin{aligned} C_2 &= \left(H - \frac{L}{15}\right)R \\ &= \left(11,70 - \frac{8,40}{15}\right)250 \\ &= 693,72 \text{ mm} \end{aligned}$$

Jadi *freeboard* menjadi

$$\begin{aligned} fb_3 &= fb_2 + C_2 \\ &= 270,554 + 693,72 \\ &= 964,277 \text{ mm} = 0,964 \text{ m} \end{aligned}$$

c. Koreksi Bangunan Atas

2. Untuk  $L = 24 \text{ m}$  faktor reduksi 350 mm

Untuk  $L = 85 \text{ m}$  faktor reduksi 850 mm

Kapal rancangan memiliki  $L = 100,62 \text{ m}$ , sehingga dengan interpolasi

**Tabel 107. Faktor Reduksi dan Koreksi Bangunan Atas**

|                                   |                              |                               |          |
|-----------------------------------|------------------------------|-------------------------------|----------|
| $fb_4$                            | 846,133                      | mm                            |          |
|                                   | 0,846                        | m                             |          |
| $l_{\text{kamar mesin}}$          | 13,88                        | m                             |          |
| $l_{\text{forcastle}}$            | 11,22                        | m                             | > 7% Lpp |
| $l_{\text{rata2 Superstructure}}$ | 25,1                         | m                             |          |
| $hs$                              | 2,3                          | Tinggi superstructure standar |          |
| $hsr$                             | 28,1628                      | Tinggi superstructure asli    |          |
| $hsr > hs$                        | Tidak Ada Penambahan Panjang |                               |          |
| maka                              |                              |                               |          |
| $E = S$                           | 25,1                         | m                             |          |
| $S E/L$                           | 0,20                         |                               |          |
| Faktor Reduksi                    |                              |                               |          |
| E/L                               |                              | reduksi %                     |          |
| E/L (1)                           | 0,2                          | reduksi Bawah :               | 10,00%   |
| E/L                               | 0,20                         | Nilai X :                     | 9,97%    |
| E/L (2)                           | 0,3                          | reduksi Atas :                | 15,00%   |
| Sehingga faktor reduksi didapat   |                              | 9,97%                         |          |
| Faktor Reduksi                    |                              |                               |          |
| L                                 |                              | reduksi (mm)                  |          |
| L (1)                             | 24,00                        | reduksi Bawah :               | 350      |
| L                                 | 125,93                       | Nilai X :                     | 1185,49  |
| L (2)                             | 85,00                        | reduksi Atas :                | 850      |
| Sehingga faktor reduksi didapat   |                              | 1185,492                      | mm       |
|                                   | $Fs_3$                       | 118,144                       | mm       |

Faktor reduksi yang didapat sebesar 1185,492 mm

$$\begin{aligned} \text{Faktor reduksi bangunan atas } (Fs_3) &= 9,97 \% \times 1185,492 \text{ mm} \\ &= 118,144 \text{ mm} \end{aligned}$$

Jadi *freeboardnya* menjadi

$$\begin{aligned} Fb_4 &= Fb_3 - Fs_3 \\ &= 964,277 - 118,144 \\ &= 846,133 \text{ mm} \\ &= 0,846 \text{ m} \end{aligned}$$

d. Koreksi *Chamber*

Kapal rancangan menggunakan *chamber* standart, yakni :

$$\frac{B}{50} = \frac{18,49}{50}$$

$$= 0,37$$

Sehingga tidak ada faktor koreksi

e. Koreksi *Sheer*

Untuk kapal rancangan, perencanaan sheer menggunakan *sheer standart*. Jadi tidak ada koreksi untuk sheer,  $C = 0$

**Tabel 108. *sheer standart*.**

| Posisi      | Jarak | Rumus            | (mm)    |
|-------------|-------|------------------|---------|
| AP          | 62,97 | $25(L/3 + 10)$   | 1299,42 |
| 1/3 dari AP | 41,98 | $11,1(L/3 + 10)$ | 576,94  |
| 1/6 dari AP | 20,99 | $2,8(L/3 + 10)$  | 145,53  |
| Midship     | 0,00  | 0                | 0,00    |
| 1/6 dari FP | 20,99 | $5,6(L/3 + 10)$  | 291,07  |
| 1/3 dari FP | 41,98 | $22,2(L/3 + 10)$ | 1153,88 |
| FP          | 62,97 | $50(L/3 + 10)$   | 2598,83 |

**Tabel 109. Koreksi *Sheer***

| Posisi      | Sheer Standar | Sheer Standard | FK | HK1           | HK2      |
|-------------|---------------|----------------|----|---------------|----------|
| FP          | 2598,83       | 0              | 1  | 2598,83       | 0        |
| 1/3 dari FP | 1153,88       | 0              | 3  | 3461,65       | 0        |
| 1/6 dari FP | 291,07        | 0              | 3  | 873,208       | 0        |
| Midship     | 0             | 0              | 1  | 0             | 0        |
|             |               |                |    | S1            | S2       |
|             |               |                |    | <b>6933,7</b> | <b>0</b> |
| Midship     | 0             | 0              | 1  | 0             | 0        |
| 1/6 dari AP | 145,53        | 0              | 3  | 436,604       | 0        |
| 1/3 dari AP | 576,94        | 0              | 3  | 1730,82       | 0        |
| AP          | 1299,42       | 0              | 1  | 1299,42       | 0        |
|             |               |                |    | S3            | S4       |
|             |               |                |    | <b>3466,8</b> | <b>0</b> |

$$T_{FH} = \Sigma_2 - \Sigma_1 / 8 = -866,7 \text{ mm}$$

$$T_{AH} = \Sigma_4 - \Sigma_3 / 8 = -3992,9 \text{ mm}$$

Oleh karena  $T_{FH} < 0$  dan  $T_{AH} < 0$ , maka

$$\text{Difference Sheer} = (T_{AH} - T_{FH}) / 2 = -2498,8 \text{ mm}$$

$$\text{Koreksi Sheer} = (-1 \times \text{Difference Sheer}) \times (0,75 - S / 2Li)$$

$$\begin{aligned}
 FS_4 &= 2498 \times 0,75 - \left( \frac{25,1}{2 \times 100,62} \right) \\
 &= 1,56 \text{ m}
 \end{aligned}$$

#### V.9.4. Plimsol Mark

##### *Summer Freeboard*

- a. *Basic/tabular Freeboard* = 270,495 mm
- b. Koreksi terhadap Cb ( $Fb_{min} \times C_1$ ) = 270,554 mm
- c. Koreksi terhadap L/H ( $Fb_3$ ) = 964,28 mm
- d. Koreksi terhadap bangunan atas = 118,144 mm
- e. Koreksi terhadap *sheer* = 1409,145106 mm
- f. Koreksi *chamber* = 0
- g. Tinggi *summer freeboard* ( $F_{so}$ ) = 3032,62 mm
- h. Sarat air pada *summer freeboard*  $To = Hi - F_{so}$   
 $= 11,63 - (3032,62/1000)$   
 $= 8,597 \text{ m}$

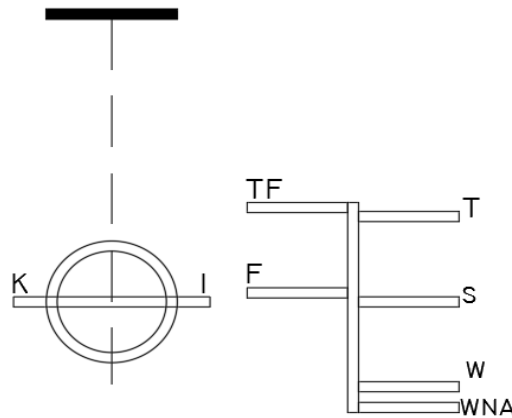
##### Tanda Lambung Timbul / *Freeboard*

- a. *Summer freeboard*  
 $S = F_{so}$   
 $= 3032,62 \text{ mm}$
- b. *Tropical freeboard* (T)  
 $T = F_{so} - 1/48 To$   
 $= 3032,62 - (1/48 \times (8,597 \times 10000))$   
 $= 2853,50 \text{ mm}$
- c. *Fresh water* (F & TF)  
 $F = F_{so} - \Delta / (40 \times TPC)$   
 $= 3032,62 - (15619,41 / (40 \times 20,58))$   
 $= 3013,64 \text{ mm}$   
 $TF = F - (1/48 \times To)$   
 $= 3013,64 - (1/48 \times 8,597)$   
 $= 2834,53 \text{ mm}$   
 $W = F_{so} + (1/48 \times To)$   
 $= 3032,62 + (1/48 \times 8,597)$

$$= 3211,73 \text{ mm}$$

$$\text{WNA} = W + 50$$

$$= 3261,73 \text{ mm}$$



**Gambar 37. Plimsol Mark**

## V.10 Perhitungan *Floodable Length Curve*

### V.10.1 *Floodable Length Curve*

*Floodable Length* atau Diagram Kebocoran adalah lengkung atau garis dari letak panjang maksimal ruangan yang dibatasi oleh sekat melintang, bila ruangan tersebut tergenang air (mengalami kebocoran) dan sarat air dari kapal tepat menyinggung garis batas tenggelam (*Margin Line*), dimana kapal masih tepat dapat terapung atau pada saat kapal akan tenggelam.

Tujuan dibuatnya *floodable length* ini untuk menjamin keamanan konstruksi kapal terutama keselamatan kapal dan penumpang saat kapal tersebut mengalami kebocoran pada salah satu ruang kompartemennya. Dari perhitungan *floodable length* ini, seorang arsitek kapal dapat menentukan jenis kompartemen kapal rancangannya berdasarkan jumlah dan letak kompartemen, yaitu :

- a. *One compartment ship*, jika kapal digenangi air laut pada satu ruangnya, maka kapal masih dapat terapung.
- b. *Two compartment ship*, jika kapal digenangi air laut pada dua ruangan sekaligus maka kapal masih dapat terapung.

### V.10.2 Pembuatan *Floodable Length*

Kapal yang mengangkut lebih dari 12 orang dapat dikategorikan sebagai kapal penumpang, dengan demikian letak sekat kedap air harus sedemikian rupa sehingga permukaan air tidak akan melampaui garis singgung batas tenggelam (*Margin Line*), sekalipun beberapa ruangan yang letaknya berurutan terisi penuh oleh air bocor. *Margin Line* ini letaknya 3 inchi (76 mm) di bawah garis geladak (*Upper Deck Side Line*).

Jarak antara dua buah sekat kedap air yang boleh terisi penuh tanpa melalui *Margin Line* disebut Panjang Isian. Pada saat menentukan panjang isian ini, maka permeabilitas dari ruangan yang dimaksud harus diperhatikan. Permeabilitas ruangan adalah perbandingan volume air yang masuk ke dalam ruangan dengan volume ruangan yang bocor. Volume air yang masuk ke dalam ruangan di sini merupakan selisih volume ruangan kosong dengan volume barang-barang, konstruksi, orang dan peralatan-peralatan lain yang ada di dalam ruangan tersebut.

Panjang isian dari kapal dengan panjang lebih dari 131 meter dan kapal penumpang lebih dari 79 meter harus diperbanyak dengan faktor untuk mendapatkan panjang isian yang diizinkan untuk menjaga keselamatan dan stabilitas kapal beserta barang dan penumpang yang dibawanya. Kalau dari tiap-tiap ruang kedap air telah dihitung panjang isian yang diizinkan maka hasil-hasil ini diukurkan secara tegak pada setiap garis tengah dari masing-masing ruangan tersebut. Dengan menggunakan titik tadi terbentuklah sebuah garis lengkung sekat kedap air (*Curve of Floodable Length*). Hasil dari *Floodable Length* dan faktor pembagian memberikan pedoman untuk menentukan panjang isian yang diizinkan. Kompartemen yang akan dibuat tidak boleh melebihi panjang isian yang diizinkan.

Secara singkat untuk menggambarkan kurva *floodable length* dengan menggunakan metode *Webster*. Metode *Webster* ini merupakan metode yang menentukan panjang genangan dengan bantuan table. Rumus yang digunakan adalah :

$$L = m (a + f)$$

Dimana :

L = dinyatakan dalam % terhadap tinggi buritan

F = perbandingan antara lambung bebas terhadap H

m dan a = didapat dari tabel yang tergantung dari perbandingan sheer terhadap H

#### Langkah-Langkah Pembuatan *Floodable Length*

##### a. Menentukan rasio lambung timbul

- Untuk koreksi tinggi kapal adalah :

$$H' = H + t - ML$$

Dimana :

H = tinggi kapal

ML = tinggi *margin line* (0,076)

t = tebal (tinggi) papan pelapis (0,009)

maka :

$$H' = H + t - ML$$

$$= 11,63 + 0,009 - 0,076$$

$$= 11,56 \text{ m}$$

- Koreksi untuk perkiraan lambung timbul

$$fb = H' - T$$

$$= 11,56 - 8,61$$

$$= 2,953 \text{ m}$$

- Rasio lambung timbul

$$f = fb / H'$$

$$= 2,953 / 11,56$$

$$= 0,25538$$

##### b. Menentukan rasio sheer depan dan belakang

- Sheer buritan

$$Za' = (Za + t - ML) - H'$$

Dimana :

Za = tinggi sheer dari base line diburitan AP

Maka :

$$\begin{aligned} Z_a' &= (Z_a + t - ML) - H' \\ &= (13,222 + 0,09 - 0,076) - 11,56 \\ &= 1,592 \text{ m} \end{aligned}$$

- Rasio sheer buritan

$$\begin{aligned} Z_a'' &= \frac{Z_a'}{H'} \\ &= \frac{1,592}{11,56} \\ &= 0,13771 \end{aligned}$$

- Sheer haluan

$$\begin{aligned} Z_f' &= (Z_f + t - ML) - H' \\ &= (15,130 + 0,009 - 0,076) - 11,56 \\ &= 3,5 \text{ m} \end{aligned}$$

- Rasio sheer haluan

$$\begin{aligned} Z_f'' &= \frac{Z_f'}{H'} \\ &= \frac{3,50}{11,56} \\ &= 0,30269 \end{aligned}$$

c. Menentukan permeabilitas

Pada kapal rancangan H adalah 8,26 m sehingga tinggi yang diizinkan untuk tergenang (sampai dengan *margin line*) adalah :  $8,26 - 0,076 = 8,184$  m. Untuk masing masing ruangan permeabilitas yang dipakai juga berbeda-beda.

Dalam rancangan dipakai :

$\mu$  untuk ruang mesin = 0,85

$\mu$  untuk ruang akomodasi = 0,63

$\mu$  untuk ruang muat = 1

d. Menentukan nilai m dan a

Untuk menentukan nilai m dan a perancangan menggunakan tabel *Webster*.

Rumusan Ekstrapolasi terdapat pada tabel 60 berikut ini :



**Tabel 110. Rumusan Ekstrapolasi**

|   |   |   |  |
|---|---|---|--|
|   | a | b | $D = (((A-B)/(C-B) \times (F-E)) + E)$ |
| 1 | A | D |  |
| 2 | B | E |  |
| 3 | C | F |  |

Dari tabel rumusan ekstrapolasi diatas akan dicari nilai m dan a dari Cb 0,81, sebagaimana pada tabel 61 dan 62 dibawah ini :

**Tabel 111. Ekstrapolasi Webster Cb = 0,76**

| Cb   | Za''    | AP      |        | 15%Lpp |        | 20%Lpp |        | 30%Lpp |        | 40%Lpp |        | 45%Lpp  |       |
|------|---------|---------|--------|--------|--------|--------|--------|--------|--------|--------|--------|---------|-------|
|      |         | m       | a      | m      | a      | m      | a      | m      | a      | m      | a      | m       | a     |
| Cb   | 0,14    | 38,971  | 0,193  | 50,700 | 0,028  | 50,543 | 0,027  | 61,643 | 0,032  | 89,186 | 0,018  | 105,271 | 0,002 |
|      | 0,15    | 39,700  | 0,203  | 51,900 | 0,040  | 51,700 | 0,038  | 62,500 | 0,044  | 90,900 | 0,020  | 105,700 | 0,002 |
|      | 0,08    | 38,000  | 0,180  | 49,100 | 0,013  | 49,000 | 0,013  | 60,500 | 0,017  | 86,900 | 0,015  | 104,700 | 0,001 |
| 0,76 | Zf''    | 50%L    |        | 60%L   |        | 70%L   |        | 80%L   |        | 85%L   |        | FP      |       |
|      |         | m       | a      | m      | a      | m      | a      | m      | a      | m      | a      | m       | a     |
|      | 0,30    | 105,429 | 0,006  | 79,779 | 0,029  | 57,214 | 0,053  | 49,736 | 0,062  | 53,421 | 0,068  | 37,929  | 0,299 |
|      | 0,30    | 105,600 | 0,006  | 81,000 | 0,029  | 58,200 | 0,056  | 51,000 | 0,064  | 54,900 | 0,070  | 38,400  | 0,303 |
| 0,16 | 104,800 | 0,004   | 75,300 | 0,028  | 53,600 | 0,042  | 45,100 | 0,054  | 48,000 | 0,062  | 36,200 | 0,283   |       |

Dari perhitungan Ekstrapolasi di atas akan didapatkan hasil nilai m dan a dari Cb = 0,81 sebagai berikut ini :

**Tabel 112. Hasil Perhitungan Webster Cb = 0,76**

|   | AP    | 15%   | 20%   | 30%   | 40%   | 45%    | 50%    | 60%   | 70%   | 80%   | 85%   | FP    |
|---|-------|-------|-------|-------|-------|--------|--------|-------|-------|-------|-------|-------|
| m | 38,97 | 50,70 | 50,54 | 61,64 | 89,19 | 105,27 | 105,43 | 79,78 | 57,21 | 49,74 | 53,42 | 37,93 |
| a | 0,193 | 0,028 | 0,027 | 0,032 | 0,018 | 0,002  | 0,006  | 0,029 | 0,053 | 0,062 | 0,068 | 0,299 |

e. Mencari panjang genangan l'

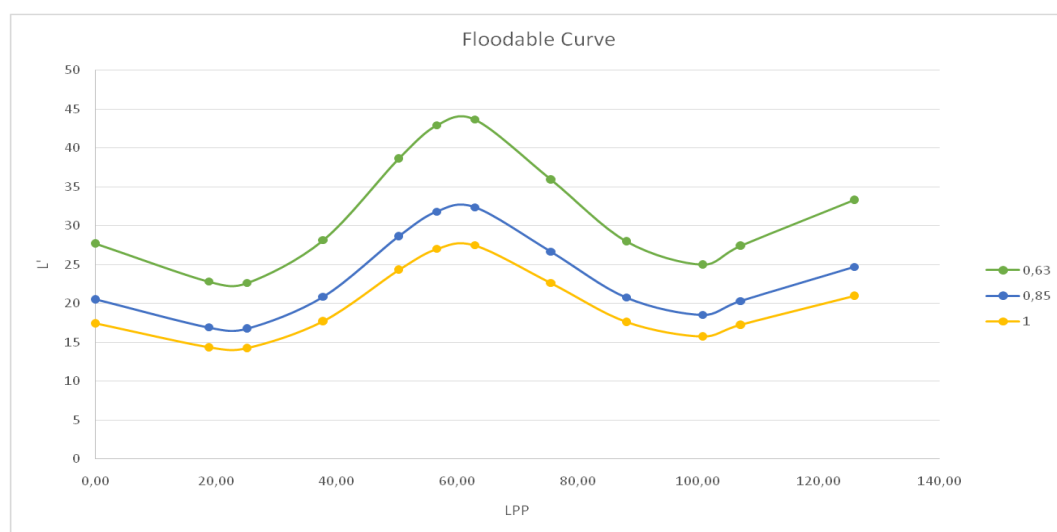
Setelah didapat nilai m dan a yang dapat dilihat pada tabel 63, selanjutnya mencari nilai l' pada masing masing jarak dalam % Lpp dan membaginya dengan factor permeabilitas seperti dibawah ini

$$l' = \frac{m \times (a + f)}{\mu}$$

Maka didapatkan nilai panjang genangan (l') dibawah ini :

**Tabel 113. Floodable Curve**

| $\mu$ | f       | AP      | 15%     | 20%     | 30%     | 40%     | 45%     | 50%     | 60%     | 70%     | 80%     | 85%     | FP      |
|-------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
|       |         | 0,00    | 18,89   | 25,19   | 37,78   | 50,37   | 56,67   | 62,97   | 75,56   | 88,15   | 100,74  | 107,04  | 125,93  |
|       |         | L'      |         |         |         |         |         |         |         |         |         |         |         |
| 0,63  | 0,25538 | 27,7456 | 22,8401 | 22,6776 | 28,1612 | 38,6812 | 42,9365 | 43,67   | 35,9851 | 28,0063 | 25,0448 | 27,4458 | 33,359  |
| 0,85  |         | 20,5644 | 16,9286 | 16,8081 | 20,8724 | 28,6696 | 31,8236 | 32,3672 | 26,6713 | 20,7576 | 18,5626 | 20,3422 | 24,7249 |
| 1     |         | 17,4797 | 14,3893 | 14,2869 | 17,7416 | 24,3692 | 27,05   | 27,5121 | 22,6706 | 17,6439 | 15,7782 | 17,2909 | 21,0161 |

**Gambar 38. Floodable Length**

## V.11 Perhitungan Peluncuran

### V.11.1 Koefisien Gesek Peluncuran

Harga rata-rata koefisien gesek selama peluncuran adalah sebagai berikut :

1.  $\mu = 0,024$ ; berlaku untuk tekanan rata-rata landasan  $30 \text{ ton/ m}^2$
2.  $\mu = 0,032$ ; berlaku untuk tekanan rata-rata landasan  $20 \text{ ton/ m}^2$
3.  $\mu = 0,040$ ; berlaku untuk tekanan rata-rata landasan  $10 \text{ ton/ m}^2$

Harga koefisien gesek pada saat berhenti untuk selama tekanan rata-rata  $\mu = 0,040$  –  $0,080$

### V.11.2 Sudut Kemiringan Peluncuran

Sudut kemiringan peluncuran dianggap sama dengan sudut kemiringan landasan terhadap permukaan air. Tangensial sudut kemiringan landasan terhadap permukaan air disebut “*afseket*”, yang besarnya adalah sebagai berikut :

1.  $\tan \beta = 0,042 - 0,056$  untuk kapal berukuran besar
2.  $\tan \beta = 0,056 - 0,063$  untuk kapal berukuran sedang
3.  $\tan \beta = 0,063 - 0,083$  untuk kapal berukuran kecil

oleh karena kapal rancangan termasuk kapal dengan ukuran besar maka direncanakan :

$$\tan \beta = 0,050$$

$$\beta = \arcsin 0,050$$

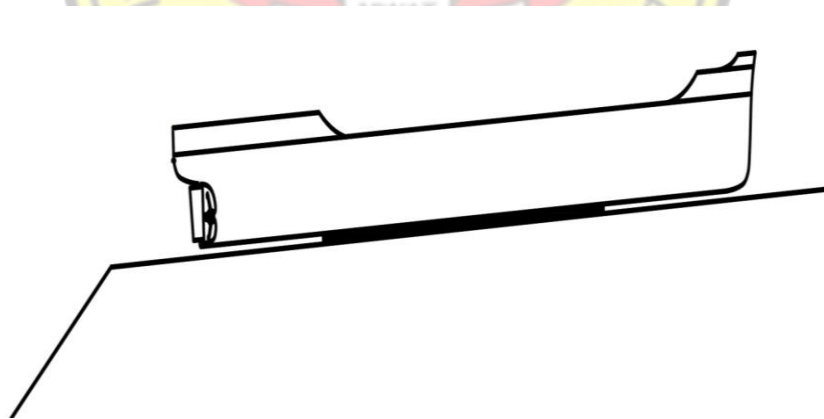
$$= 2,86^\circ$$

### V.11.3 Periode Peluncuran

Peluncuran memanjang dibagi dalam 4 fase, yaitu :

1. Periode I

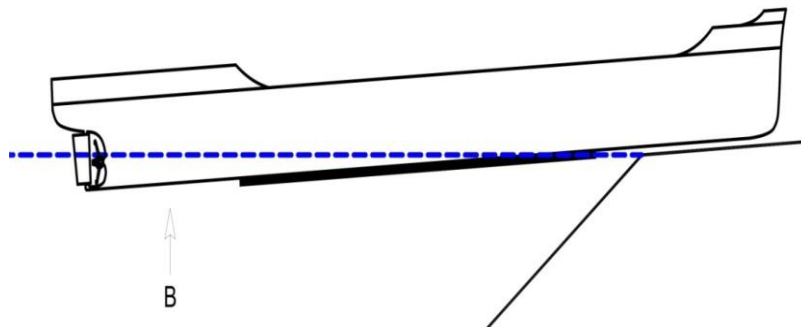
Dimulai pada saat kapal mulai bergerak dengan hingga kapal menyentuh permukaan air.



**Gambar 39. Ilustrasi Periode I**

2. Periode II

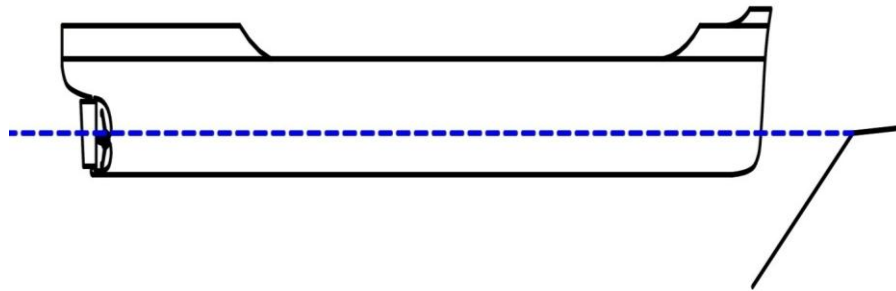
Dimulai pada saat kapal menyinggung permukaan air dan berakhir pada saat kapal mulai mendapatkan gaya apung.



**Gambar 40. Ilustrasi Periode II**

3. Periode III

Dimulai pada saat kapal mulai terapung dan berakhir pada saat kapal meninggalkan landasan.



**Gambar 41. Ilustrasi Periode III**

4. Periode IV

Dimulai pada saat kapal lepas dari landasan dan berakhir pada saat kapal terapung bebas.

#### V.11.4 Perhitungan Berat Peluncuran

berat peluncuran adalah berat kapal pada saat kapal diluncurkan ditambah dengan berat peralatan peluncuran.

1. Berat Kapal Pada Saat Diluncurkan

Umumnya pada saat diluncurkan kapal belum sepenuhnya selesai, dimana mesin-mesin banyu belum dipasang seluruhnya.

Berat kapal pada saat diluncurkan diperkirakan sebagai berikut :

$$G = C \times \text{LWT (Light Weight Tonnage)}$$

Dimana :  $C =$  koefisien peluncuran = 0,85

$$\begin{aligned} \text{LWT} &= 3242,166 \text{ ton} \\ \text{Maka } G &= 0,85 \times 3242,166 \text{ [ton]} \\ &= 2755,84 \text{ ton} \end{aligned}$$

## 2. Berat Peralatan Peluncuran

Berat peralatan peluncuran adalah 7% - 16% berat kapal pada saat diluncurkan. Diasumsikan diambil harga yang terbesar yaitu 16%. Maka :

$$\begin{aligned} M &= 16\%G \text{ [ton]} \\ &= 0,16 \times 2755,8411 \\ &= 440,9345 \text{ ton} \end{aligned}$$

Setelah didapat berat kapal dan peralatan peluncuran, maka berat peluncuran adalah :

$$\begin{aligned} W &= G + M \\ &= 2755,8411 + 440,934576 \\ &= 3196,77568 \text{ ton} \end{aligned}$$

### V.11.5 Perencanaan Sepatu Peluncuran

#### 1. Nilai $\bar{\alpha} d$ (ton/ m<sup>2</sup>)

Untuk Lpp = 100 m  $\bar{\alpha} d = 20 \text{ ton/ m}^2$

Untuk Lpp = 200 m  $\bar{\alpha} d = 30 \text{ ton/ m}^2$

Maka dengan interpolasi untuk Lpp = 110,30 m adalah :

**Tabel 114. Interpolasi Tekan Rata-Rata Pada Landasan**

| Interpolasi Tekan Rata-Rata Pada Landasan tertera pada hydrodinamika I & II hal 60 |        |                     |             |
|--|--------|---------------------|-------------|
| lpp  |        | s(t/m) <sup>2</sup> |             |
| lpp1   | 100    | radius bawah        | 20          |
| lpp  | 125,93 | nilai x             | 16,49925746 |
| lpp2   | 200    | radius atas         | 30          |

Berlaku untuk tekanan rata-rata landasan diambil nilai  $\bar{\alpha} d = 16,499 \text{ ton/ m}^2$ . Untuk koefisien gesek peluncuran didapatkan  $\mu = 0,023$  dari perhitungan interpolasi dibawah ini

**Tabel 115. Interpolasi Koefisien Gesek Peluncuran**

| Interpolasi Tekan Rata-Rata Pada Landasan tertera pada hydrodynamika I & II hal 60 |        |                      |             |
|--|--------|----------------------|-------------|
| $p(t/m)^2$   |        | fo (koefisien gesek) |             |
| lpp1   | 20     | fo bawah             | 0,032       |
| lpp  | 125,93 | mila x               | 0,023166059 |
| lpp2   | 30     | fo atas              | 0,024       |

## 2. Panjang balok peluncur (Ls)

$$\begin{aligned} Ls &= (80\% - 90\%) Lpp; \text{ diambil } 90\% \\ &= 90\% \times 125,93 \text{ m} \\ &= 113,337 \text{ m} \end{aligned}$$

## 3. Lebar minimum sepatu peluncur

$$b_{min} = \left( \frac{W}{n.Ls.ad} \right) [m]$$

Dimana :

$$W = \text{berat peluncuran} = 3196,78 \text{ ton}$$

$$n = \text{jumlah sepatu peluncuran (3 buah)}$$

$$Ls = \text{panjang sepatu peluncuran} = 113,337 \text{ m}$$

Maka :

$$b_{min} = 0,5698 \text{ m}$$

## 4. Tinggi sepatu peluncur

Tinggi sepatu peluncuran dapat dicari dengan :

$$t = \left( \frac{Ws}{n.b.s,\gamma} \right) [m]$$

Dimana :

$$Ws = \text{berat sepatu peluncur}$$

$$= 0,8 \times M$$

$$= 0,8 \times 440,934576 = 352,748 \text{ ton}$$

$$\gamma = \text{berat jenis sepatu peluncur}$$

$$= 0,85 \text{ ton/ m}^3$$

Maka :

$$t = \left( \frac{352,748}{3 \times 0,5698 \times 113,337 \times 0,85} \right)$$

$$= 2,141 \text{ m}$$

Dalam perancangan sepatu ini maka diambil tinggi dari landasan sampai lunas kapal adalah setengah dari tinggi sepatu yaitu  $t = 1,67$  m. Pada kondisi sebenarnya tinggi sepatu tidaklah harus mengikuti perhitungan yang ada karena dengan menggunakan perhitungan tersebut tinggi sepatu dapat menjadi terlalu tinggi.

### V.11.6 Perhitungan Beban Landasan

Beban rata-rata yang bekerja pada landasan per meternya adalah :

$$q = \frac{W}{s} \text{ [ton/m]}$$

Dimana :

$$W = \text{berat peluncuran} \\ = 3196,77568 \text{ ton}$$

$$s = \text{panjang sepatu peluncur} \\ = 113,337 \text{ m}$$

Maka :

$$q = \frac{3196,77568}{113,337} \text{ [ton/m]}$$

$$q = 28,2059317 \text{ ton/m}$$

### V.11.7 Perhitungan Peluncuran

Fase I

Besarnya gaya peluncuran :

$$K = W \sin \beta - \mu N \text{ [ton]}$$

$$K = W \sin \beta - \mu \cos \beta$$

Dimana

$$\beta = 2,86^\circ$$

$$N = \text{gaya normal [ton]} \\ = w \cos \beta$$

$$\mu = 0,023$$

Maka :

$$K = 2151,493 (\sin 2,86 - 0,023 \cos 2,86)$$

$$K = 107,327 \text{ ton}$$

Akibat gaya K tersebut akan timbul percepatan peluncuran sebesar :

$$a = \frac{K}{m} \text{ [m/ s}^2\text{]}$$

Dimana :

$$\begin{aligned} m &= \text{massa berat peluncuran} = W/g \\ &= 325,980399 \text{ ton s}^2/\text{m} \end{aligned}$$

Maka :

$$a = \frac{107,327}{325,980399} \text{ [m/ s}^2\text{]}$$

$$a = 0,329 \text{ m/ s}^2$$

fase ini berakhir ketika AP pada baseline menyentuh permukaan air. Jarak yang ditempuh peluncuran sampai menyentuh permukaan air (titik B tergenang air), merupakan tangen sudut  $\beta$  antar tinggi AP dari permukaan air.

$$\tan \beta = \frac{\text{tinggi AP}}{s}$$

maka :

$$\begin{aligned} s &= \frac{\text{tinggi AP}}{\tan \beta} \\ &= \frac{1,669}{0,050} = 33,39 \text{ m} \end{aligned}$$

- Fase I

Diharapkan kapal dapat langsung meluncur ketika kunci peluncuran dilepas. Syaratnya adalah  $G \sin \beta > \mu N$ ; maka :

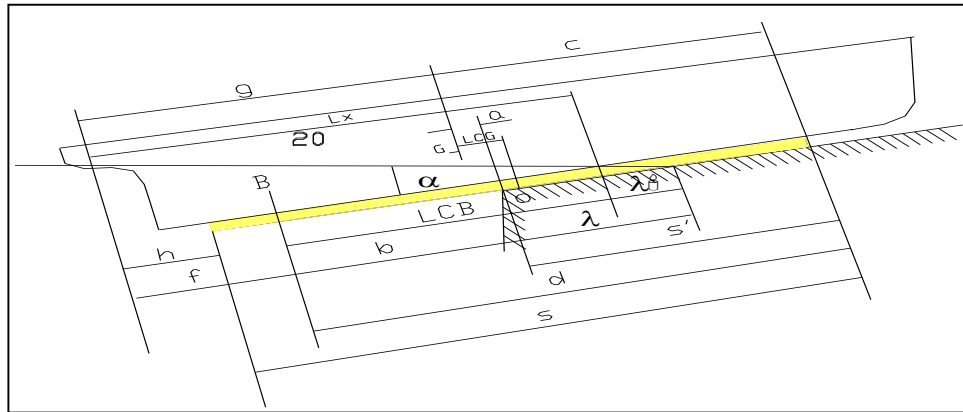
Ternyata hasil yang didapatkan  $G \sin \beta > \mu N$  sehingga kapal dapat meluncur sendiri.

- Fase II

Fase dua ini dimulai pada saat titik AP base line menyentuh permukaan air hingga kapal ulai terapung. Pada fase ini kita menganggap permukaan air tetap rata, dan karena sudut kecil, maka ada keadaan dimana titik berat G telah melewati ujung landasan, sebagian dari sepatu peluncur masih berada pada ujung landasan dan karena itu terjadi gaya gesek. Pada periode ini



kemungkinan terjadinya *tipping* pada kapal semakin besar. Tipping baru terjadi jika titik berat kapal sudah melewati ujung landasan. Untuk lebih mempermudah pemahamannya maka gambar berikutnya dijadikan acuan dalam perhitungan peluncuran



**Gambar 42. Sketsa Perhitungan Peluncuran**

Dapat dilihat dalam gambar bahwa panjang landasan :

$L_b = \overline{AB} + 0,8 L_{pp}$  ; dimana  $\overline{AB}$  = panjang sepatu peluncur

$$\begin{aligned} L_b &= 113,337 \text{ m} + (0,8 \times 125,93) \text{ m} \\ &= 113,337 + 100,744 \\ &= 214,081 \text{ m} \end{aligned}$$

Dapat diketahui bahwa panjang lintasan setelah sepatu peluncuran adalah 125,76 m dan panjang lintasan dari awal hingga kapal mulai menyentuh permukaan air seperti yang telah dijelaskan pada fase I adalah 33,39 m, maka panjang sisa lintasan yang harus ditempuh yakni

$$\begin{aligned} S_r &= 100,74 \text{ m} - 33,39 \text{ m} \\ &= 146,727 \text{ m} \end{aligned}$$

Total jarak yang dibutuhkan pada fase I adalah :

$$\begin{aligned} S \text{ fase I} &= 113,337 \text{ m} + 33,39 \text{ m} \\ &= 146,727 \text{ m} \end{aligned}$$

Dari sisi maka kapal secara bertahap mulai mendapat gaya apung akibat air mulai menggenangi lambung kapal setelah menempuh jarak 33,39. Untuk jarak gading yang tergenang air harus sebanding dengan tinggi waterline yang tergenangi air. Pada perancangan kapal ini hubungan yang akan diambil adalah setiap 5 x jarak gading sehingga

- $S_0 = 33,39 \text{ m}$
- $S_1 = 33,39 + (5 \times 7) = 68,39 \text{ m}$
- $S_2 = 68,39 + (5 \times 7) = 103,39 \text{ m}$
- $S_3 = 103,39 + (5 \times 7) = 138,39 \text{ m}$
- $S_4 = 138,39 + (5 \times 7) = 173,39 \text{ m}$
- $S_5 = 173,39 + (5 \times 7) = 208,39 \text{ m}$

Setelah dilakukan perhitungan maka diplot ke dalam suatu grafik peluncuran dan dari sini dapat menentukan fase-fase yang terjadi selama peluncuran. Fase 2 akan berakhir pada saat kapal mulai melakukan royasi karena gaya apung ke atas. Saat ini kapal telah menempuh jarak  $S_1 + S_2$  dimana besar jarak yang ditempuh diperoleh dari diagram peluncuran, tepat pada pertemuan titik grafik  $W_m$  (berat peluncuran) dan  $D_m$  (displacement).

$$S_1 + S_2 = 68,39 + 103,39 = 171,78 \text{ m}$$

1. Trim pada keadaan ini,  $t$  :

$$\begin{aligned} t &= L_{pp} \cdot \tan \alpha \\ &= 125,93 \times (1/18) \\ &= 6,9961 \text{ m} \end{aligned}$$

2. Jarak penurunan titik A,  $MA$  :

$$\begin{aligned} MA &= (S_1 + S_2) \tan \alpha \\ &= 68,39 + 103,39 \times (1/18) \\ &= 9,5433 \text{ m} \end{aligned}$$

3. Sarat air pada haluan,  $Th$  :

$$\begin{aligned} Th &= MA - f \tan \alpha - (O + e) \\ &= 9,5433 - 0,36 - (11,04 + 2,020) \\ &= 9,5433 - 0,36 - 13,06 \\ &= -387667 \text{ m} \end{aligned}$$

4. Sarat air pada buritan,  $Tb$  :

$$\begin{aligned} Tb &= Th + L_{pp} \tan \alpha \\ &= (-387667) + 5,59 \\ &= 1,7133 \text{ m} \end{aligned}$$

5. Sarat air pada titik A,  $ThA$  :

$$\begin{aligned}
 \text{ThA} &= MA - (O + e) \\
 &= 9,5433 - 13,06 \\
 &= -3,51667 \text{ m}
 \end{aligned}$$

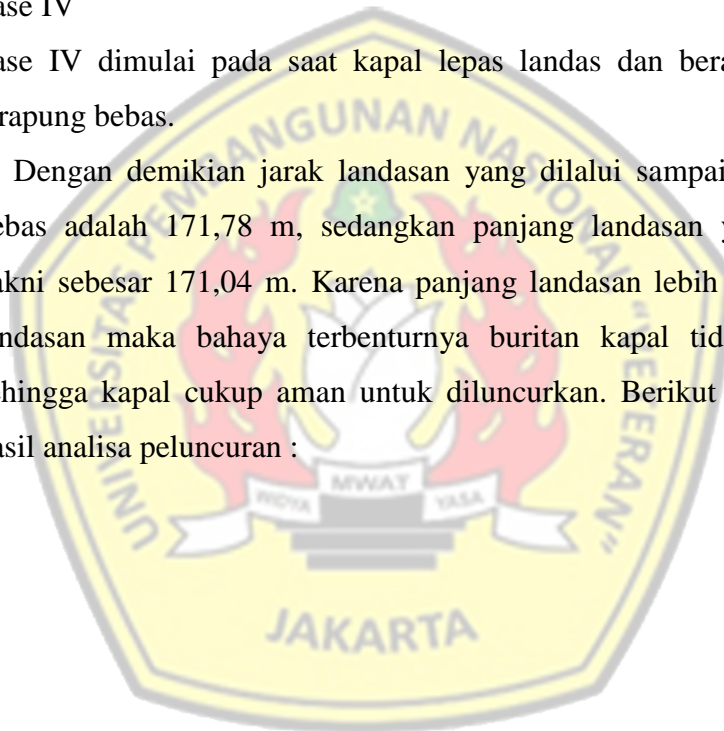
- Fase III

Fase III berlangsung pada saat kapal mulai bergerak rotasi sampai kapal meninggalkan landasannya. Selama fase ini kapal melanjutkan peluncurannya dan menggunakan ujung depan dari peluncuran sebagai sumbu putar. Pada saat kapal akan mengapung bebas displacement kapal akan sama dengan berat kapal dalam peluncuran.

- Fase IV

Fase IV dimulai pada saat kapal lepas landas dan berakhir saat kapal terapung bebas.

Dengan demikian jarak landasan yang dilalui sampai kapal terapung bebas adalah 171,78 m, sedangkan panjang landasan yang disediakan yakni sebesar 171,04 m. Karena panjang landasan lebih besar dari jarak landasan maka bahaya terbenturnya buritan kapal tidak akan terjadi sehingga kapal cukup aman untuk diluncurkan. Berikut ini adalah tabel hasil analisa peluncuran :



## BAB VI

### PENUTUP

Adapun spesifikasi perencanaan kapal *Container Vessel* 10500 DWT berdasarkan hasil perhitungan desain, sebagai berikut :

1. Ringkasan spesifikasi teknis :
  - Panjang Antara Garis Tegak (Lpp) : 125,93 m
  - Lebar (B) : 18,49 m
  - Tinggi H : 11,63 m
  - Sarat Air (T) : 8,61 m
  - Koeffisien Blok (Cb) : 0,76
  - Koeffisien Tengah Kapal (Cm) : 0,98
  - Koeffisien Prismatic (Cp) : 0,77
  - Koeffisien Garis Air (Cw) : 0,83
2. Dalam rancangan, kapal dikontrol terhadap stabilitas, trim, panjang genangan dan rencana pemuatan serta berat kapal, dimana semua hasil perhitungan harus memenuhi ketentuan yang berlaku.
3. Dalam menentukan ukuran utama yang akan diambil dalam perencanaan kapal, terlebih dahulu perlu diadakan pertimbangan-pertimbangan secara umum terutama dalam hal yang berhubungan dengan tahanan, stabilitas, *free board*, ruang muatan, kekuatan kapal, ekonomi dan teknologi pembuatannya.
4. Jumlah sekat kedap air ditentukan berdasarkan aturan dalam klasifikasi yang digunakan, yaitu sesuai dengan panjang kapal (Lpp).