# SELECTION TYPE OF WRAPPING SYSTEM AND OPTIMIZATION ON DIMENSIONS OF SUSPENSION TRACTION STEEL ROPES IN PASSANGER ELEVATOR

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NOMENCLATURE

Q = Load capacity in planning (kg)
P = KerNOMENCLATURE weight
Q = Load capacity in planning (kg)
P = Car weight (kg)
Z = Weight of counterweight (kg)
OB = Overbalance
Qtotal = Total elevator load
f = Coefficient of friction = 0.11 (dry)
k = Coefficient of groove shape or surface condition of rubbing objects
α = Contact angle of the rope with the pulley wheel (radians)
e = Base number of natural logarithm (Napiere) = 2.718
a = Acceleration / acceleration
g = Earth's gravity = 9.80 m/s2
T1 = Force on the side of the rope when it is tense
T2 = Force on the side of the rope when it is slack
n= Number of rope sheets (rounded up)
Bp= Fracture limit (kgf or N)
i= roping system 1:1; i = 1; roping system 2:1; i = 2
δ= Elongation (mm)
W = Applied load (N)
L = Length of steel rope (mm)
A = Metallic area of steel rope (mm2)
E = Elastic modulus (N/mm2)
W/Ar = Tensile Tension of the rope.
A=D/d ratio
m= f(z), Wear factor due to repeated curvature
C=Construction/braiding factors
C1=Steel rope diameter factor
C2=Factors of wire material type, rope production and operation.
z= Number of bend repetitions until failure
nd=Average number of working days per week
nw = Average number of working days per year
U=Average number of cycles used per day
Q= Cargo capacity load in planning (kg¬)
P= Weight of empty train (kg¬)
T= Weight of rope (can be ignored)
fk= Safety factor
N=Age of rope, years
Steel Rope A = 8x19S-CGFS DUAL TENSILE 1570/1770 MPa - 1620/1770 MPa
Steel Rope B = 8x19S-CGFS SINGLE TENSILE 1770 MPa

***Abstract—Based on the calculation results, the choice of wrapping system specifications uses a winding angle of 175 degree with Wrapping type Single Wrape Traction Machine Above with U105 degree or to guarantee a high level of security, a winding angle of 340 degree is chosen with Wrapping type Double Wrape Traction Machine Above with U round and for lifting speed The elevator according to specifications is met by the construction of steel ropes 8x19S-CGFS DUAL TENSILE 1570/1770 MPa-1620/1770 MPa, namely steel ropes with a diameter of 12 mm and 12.7 and the one that best meets the requirements is the one with a diameter of 12 mm, which is the smallest diameter.***

***Keywords: Steel rope, diameter, elevator, wrapping, traction.***

## I. INTRODUCTION

The larger the diameter of the steel rope, the larger the diameter of the pulley that will be used, which of course will have implications for construction and operating costs. On the other hand, the smaller the diameter of the rope, the smaller the pulley diameter required, causing a large number of steel ropes. This dilemma can only be resolved by involving other factors that influence operational safety and fatigue of steel rope materials, namely safety factors, age, number of steel ropes and elongation which are respectively the priority levels for selecting the optimum steel rope diameter. for each parameter that has been previously determined (planned).

**I.**

## II. LITERATURE REVIEW

### A. Roping System

A 1:1 roping system occurs when the rope shifts 1 m, which will cause the train to move 1 meter. The use of double Wrap provides a significant increase in the traction surface area of the rope against the sheave and is desirable in heavy load elevators.

**B. Train Weight Against Elevator Carrying Capacity**

To avoid slipping, the pulley wheel is made with a V or U-shaped groove (Shi, Pan and Ma, 2017). So the weight of the train can be calculated using the following equation (1):

$$P = 2,0 \, x \, Q \qquad (1)$$

**C. Draw Weight (Counterweight)**

The overbalance value is obtained from the average load in the train that is transported up and down throughout the day, so the elevator is expected to work more in a balanced state, with savings on electrical energy to overcome resistance and friction that will arise between the sliding space and the guide rail and resistance in pulley wheel bearings, train wheels, guide wheels and due to rope bending (Ma, Pan and Shi, 2018). So the weight of the counterweight can be determined based on the following equation (2):

$$Z = P + O_B x Q \qquad (2)$$

**D. Total Elevator Load**

The total load on the elevator is the maximum total load that will be carried by the wire rope based on the carrying capacity, train weight and counterweight weight which can be determined based on the following equation (3):

$$Q_{total} = Q + P + Z \qquad (.3)$$

**E. Traction system**

Traction strength depends on the specific pressure between the rope and the sheave (or pulley/drum), namely the frictional properties of the rope and sheave material, with a certain groove angle and shape and the amount of rope used to pass through the groove of the sheave wrapped around it (Vogel, 2016 ).

**F. Pull and Friction (Traction and Slip)**

The permitted traction value (TR) must be smaller than the traction that occurs (Ta). To calculate traction availability, use the following equation (4):

$$T_a = e^{fk\alpha} \qquad (4)$$

The allowable traction can be calculated using the following equation (5):

$$T_R = \frac{T_1}{T_2} C_d \qquad (5)$$

Static traction is when an object stops or is in constant motion without acceleration or deceleration which can be calculated using the following equation (6):

$$T_{R(s)} = \frac{T_1}{T_2} = \frac{P+Q}{P+OBxQ} \qquad (6)$$

Make sure $T_1/T_2$ is 20% smaller than the static slip limit ($e^{fk\alpha}$).

In planning $T_1/T_2$ must be at least equal to 0.8 times $e^{fk\alpha}$ because the dynamic force when decelerating accelerates, so when acceleration occurs and deceleration there will be no slip occurs. If the magnitude of acceleration or deceleration occurs, then the magnitude of the traction relation changes to dynamic traction with the following equation (7):

$$T_{R(d)} = T_{R(s)} \, x \, C_d \qquad (7)$$

$C_d$ is a dynamic factor which can be calculated using the following equation (8):

$$C_d = \frac{1+\frac{a}{g}}{1-\frac{a}{g}} \qquad (8)$$

**G. Number of Rope Sheets**

The safety of elevator passengers is very dependent on the traction steel rope so that the safety factor is the main thing. In determining the number of rope sheets, dynamic forces are ignored so that only static forces are considered with a safety factor that includes the possibility of additional stress arising during acceleration and deceleration (Zayadi and HP, 2016). Determining the number of rope sheets can be done using the following equation (9):

$$n = \frac{(P+Q+T_b)f_k}{B_p \, x \, i} \qquad (9)$$

Determining the weight of the rope can be done by calculating the following equation (10):

$$T_b = n \text{ x track height x approximate weight} \qquad (10)$$

**G. Elongation**

The main proportion of the elongation of the steel rope construction appearsafter installation of the elevator rope and gradually disappears with the number of use cycles, the lighter the load the longer the time required for stabilization (Akhmadi and Usman, 2019). A reasonable estimate of elastic strain can be made using the following equation (11):

$$\delta = \frac{W \times L}{E \times Ar} \quad (11)$$

(Khurmi and Gupta, 2005)

### H. Rope life

The factors that determine the life of a steel rope depend on the number of bends, level of wear, ratio of sheave/pulley diameter to steel rope diameter, number of wires, type of construction, quality of manufacturing and operating conditions as well as environmental conditions for corrosion, etc. (Ashbah, Mangalla and Aksar, 2023).

From the results of fatigue experiments on steel ropes for diameters 3 mm to 28 mm, a relationship was obtained as in equation (12), where: z=Number of bend repetitions.

$$z = f_1(\sigma) = f_2\left(\frac{D}{d}\right) \quad (12)$$

The experimental results based on the factors above, then obtained the relationship,

$$A = \frac{D}{d} = m\sigma C C_1 C_2 + 12 \quad (13)$$

The life of a steel rope will last as long as the number of bends that the steel rope passes through, besides that it is also very dependent on the ratio of the diameter of the pulley to the diameter of the rope. steel (Senjaya and Suyitno, 2022).

The life of a steel rope is a function of the moving pulley, the height of the lifting load (as a ratio between the full load and the average load) (Wiratama and Soeharsono, 2017), so different Hoistings but with the same steel rope will produce different lives.

Once the operating conditions are known through age determination, the relationship with the number of bend repetitions until failure (z) is:

$$z = n_w n_d U N \quad (14)$$

## III. METHODS

For safety considerations, the minimum breaking stress of the steel rope material chosen is the one with the largest number, followed by the age of the rope, the number of ropes and the elongation of the rope.

Ratings; The rating is determined based on 3 levels of priority numbers with the highest significant level being 3 followed by 2 and 1 respectively. Meanwhile, the interval categorization uses the interval method of the minimum number, middle number and highest number from the calculation results for each criterion being rated. The weighting is carried out based on the category of risk level that will be faced, in this case the safety factor, age, number of steel ropes and elongation respectively have weights of 4, 3, 2 and 1.

## IV DISCUSSION

### A. Total Load on Passenger Elevators

***Car Weight;*** If the load capacity is 1600 kg, with the weight of the empty train, the weight of the train can be calculated using equation 1 to obtain, P = 2 x 1600 kg = 3200 kg

***Counterweight Weight***; Overbalance (OB) with a carrying capacity (Q) of 1600 kg can be found. For carrying capacities above 1160 kg, the overbalance on the counterweight is 42.5%. An overbalance of 42.5% means that the counterweight is heavier than the empty carriage by 42.5% of the carrying capacity. By using equation (2), we get: Z = 3880 kg

***Total Load on Elevator***; After getting the values from several plans above, we can determine the total load on the elevator which can be calculated using equation 3 with the result: $Q_{total} = 8680\ kg$

### B. Static and Dynamic Traction

Just before the elevator starts to move up and just before it stops or is called a static condition, the maximum static traction value can be calculated using equation (6), namely: TR(s)=1,237

To determine the acceleration that occurs, it is determined based on the set speed, then determine the dynamic traction value due to acceleration or deceleration. Where for a speed of 210 m/minute, an acceleration of 1.2 m/s$^2$ is obtained. Next, referring to equation (8), a dynamic factor of, Cd=1,279.

Based on equation (7), the dynamic traction obtained is, $T_{R(d)} = T_{R(s)} x C_d$=1,582

The dynamic traction of 1.582 is the maximum value in the condition of the train rising at full load ($T_1$=P+Q and $T_2$=Z), then the minimum to maximum value when the train is rising, namely starting from the condition of the train boarding/alighting without passengers, 1 passengers, 2 passengers and so on up to 21 passengers (assuming the weight per person is 1600 Kg/ 21 people). Meanwhile, when the train descends when the load is empty ($T_1$=P and $T_2$=Z) it will experience a maximum dynamic traction of (3880/3200) x 1.279 =1.550 less than the maximum dynamic traction.

***Sheave (main pulley) and Wrapping system selection;*** The permitted traction value or TR(d) is 1.582, which is the largest dynamic traction between up and down train movements, so the traction value that occurs or Ta must be greater (Ta > $TR_{(d)}$.).

If a contact angle of $180^0$ is selected, this means using a single wrap with a contact angle of $180^0$, namely Single Wrape Traction Machine Above (SWT M/A). Meanwhile, the shape of the main pulley groove (sheave). The $T_a$ value for a contact angle of $180^0$ and a U-shaped groove with an undercut of $105^0$ is 1.62 with a shape factor of 1.4 or using equation (4) is obtained,Ta= 1.62 which meets the requirements for a Ta > TR(d) value, meaning the traction value is safe when using a single wrap with the above machine.

In the middle of a train with a certain area, a deflector pulley is needed that follows the standard winding angles, namely $160^o$, $165^o$, $170^o$ and $175^o$.

The use of deflectors will be fulfilled by deflector pulleys with a winding angle in the sheave groove of $175^o$ for the U$105^o$ groove shape. And the choice of winding angles of $160^o$, $165^o$ and $170^o$ is fulfilled by the U$60^o$ groove shape. To prevent too much grip when releasing between the rope and the sheave groove when considering passengers far below 21 persons, based on the provisions, a winding angle of $175^o$ is selected, namely with Wrapping type Single Wrape Traction Machine Above with U$105^o$ or to guarantee a high level of security a winding angle of $340^o$ is chosen. with Wrapping type Double Wrape Traction Machine Above with U$0^o$ (U round) as well as Ta of 1.60 and 1.92.

**Criteria for Selection of Steel Rope Specifications**

In the process of selecting steel ropes, adjustments to the elevator lifting speed of 210 m/minute or 3.5 m/s are met by steel ropes of group 8x19S-CGFS and group 8x19S-IWRC, 8x19S-CSC, 8x19W-IWRC, 8x19W- CSC, 8x25F-IWRC and 8x25F-CSC, however, for lifting height applications approaching below 100 meters, 8x19S-CGFS is fulfilled, namely with variations in the smallest diameter of 8 mm to the largest 16 mm by taking the two types of highest rope strength, namely minimum dual tensile 1570/1770 MPa; 1620/1770 MPa (Steel Rope A) and minimum single tensile 1770 MPa (Steel Rope B)

**Steel rope Safety Factor**

The safety factor that is the standard for steel ropes can be determined based on an elevator speed of 210 mpm, which refers to SNI 03-6573-2001, namely $f_k$=11. This safety factor is the maximum safety factor so of course, taking a safety factor above that figure is considered overdesign. Safety factor inspection includes all diameter variations that will be optimized starting from the smallest diameter (in mm) to the largest size.

**Number of steel ropes**

Referring to equation 9, as a representation of the calculation, namely a single tensile strength of 1770 MPa for a steel rope diameter of 8 mm having a minimum breaking load of 38.2 kN, then the number of steel ropes required is, where i=2 (roping system 2:1. where for now the weight of the steel rope is ignored, so the number of steel ropes is $n = 6.772775, then\ n = 7\ sheets$.

The estimated unit weight of steel rope is 21.8 kg per 100 m, so with a hoistway height L= 92.325 m, the weight of steel rope (Tb) can be calculated using

equation 10: Tb=281.7759 kg per 7 sheets.
Checking the safety factor that occurs after calculating the weight of the rope n:= 6.78, then n = 7 sheets $f_k = 10{,}74$
The value above is less than the permitted safety factor, namely 11. Thus, to be safe, the number of ropes must be increased again to n=8 and Tb will be 322.03 kg. The result is $f_k = 12{,}18$
The value above is greater than 11 (safe), so the number of steel ropes that meet the specifications above is 8.

Calculation of representation of Elongation of variation in diameter of Steel Rope, namely diameter 8 mm for 8x19S-CGFS DUAL TENSILE 1570/1770 MPa -1620/1770 MPa is: $\delta$= 73,536 mm

**Steel rope life**

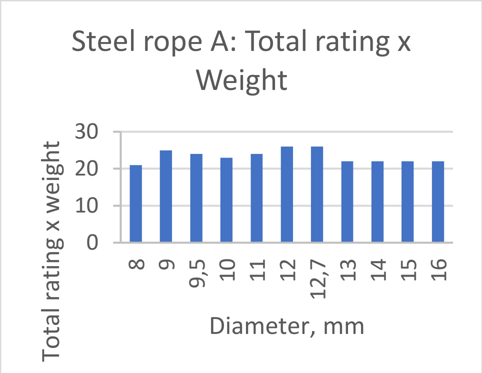
The number of curves of the steel rope for the 2:1 roping system is 4.

Based on the rope construction, where for the number of bends $n_b$=4 the ratio of sheave diameter to steel rope diameter is obtained, namely $D_{min}$/d=25.
The actual stress acting on the steel rope.
For the diameter of the steel rope, d=8 mm
with load, W= 320.13 kg, then the stress is obtained actual, $\sigma$=6.37 kg/mm2.
The number of repetitions of accumulated curve points is closely related to the fatigue that occurs in the steel rope which is influenced by various factors contained in equation 13 where for diameter d= 8 mm and other diameters the factor C=1 (both for 8x19 construction has a value close to 1), C1 =0.85, C2=1 (carbon steel). According to equation 13. To meet D/d which is greater than the minimum, a curvature factor for the roping system of 2:1 is obtained, namely: m= 2,40
Based on the table in N Rudenko's Book (1996)-Materials Handling Equipment, the m value is between 2.27 and 2.42, so through interpolation the number of curves is obtained, z= 444726.668 curves.

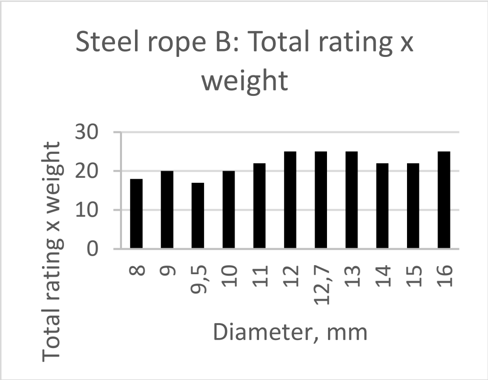
**Calculation of the Life of a Steel Rope;**Based on equation 14, the life of the steel rope can be determined. For steel rope, the price is U=200, which is assumed to be used 200 times up and down per day. Next, the number of working days in 1 week is 5 days (nd=5), and the number of weeks per year, nw=4x12=48, namely the number of weeks in each month is 4 and multiplied by 12 months in each year, then ndxnw=5x48=240. So that the life of the steel rope for rope diameter d=8 mm 8x19S-CGFS DUAL TENSILE 1570/1770 MPa - 1620/1770 MPa is as long as, N=9,27 years.

**Optimization of Traction Steel Rope Selection**

Optimizing the selection of steel ropes begins by recapitulating data from calculation results regarding safety factors, rope age, number of steel ropes and elongation using the intervalization method of ratings 1,2 and 3. The rope age where the highest calculated number has a rating of 3 is followed by higher calculation results. low for ratings 2 and 1. On the other hand, for the safety factor (overcoming overdesign), number of ropes and elongation where the lowest calculated number occupies the highest rating number, namely rating 3, followed by a larger calculated number, namely rating 2 and the largest is **rating 1 .**




[1] *Figure 16 Total rating x weight A*




[2] *Figure 17 Total rating x weight B*

Based on pictures 16 and 17 above, it can be seen that the construction of the 8x19S-CGFS DUAL TENSILE 1570/1770 MPa-1620/1770 MPa steel rope which meets the optimization requirements and is suitable for the manufacturing industry is 12 mm and 12.7 in diameter with a sheave diameter of 600 mm respectively. (D/d=50) and 635mm (D/d=52.91) and the one that best meets the requirements is a diameter of 12 mm which is the smallest diameter.

## V. CONCLUSION

1. To overcome the limited distance between the counterweight and the carriage, a single wrap 175º wrapping system with a deflector pulley is a better choice than a 180º angle with a traction value of 1.6. If consideration of the grip between the rope and the groove is eliminated, then the U0º groove shape must be used with a double wrap with a winding angle of 340º
2. Optimization results show that a steel rope with a diameter of 12 mm for the dual tensile type with the type of breaking load studied is the optimal option, however, if the consideration in choosing the diameter of the steel rope prioritizes a longer service life, then the best option must be to use the diameter of the steel rope. diameter 12.7 mm steel rope group A

**II.**

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