UJI EKSPERIMENTAL PENGUKURAN *VELOCITY* KAPAL MODEL DENGAN METODE *LOW-COST FREE RUNNING MODEL TEST*

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ABSTRAK

Pengujian kapal model memerlukan pengukuran *Velocity* akurat dalam skema Free Running Model Test (FRMT), namun instrumen konvensional seperti GPS presisi tinggi berbiaya mahal. Penelitian ini menguji skema pengukuran low-cost menggunakan tiga metode: stopwatch, *Video Tracker* Analysis, dan sensor Inertial Measurement Unit (IMU) WitMotion, pada kapal model monohull dengan variasi RPM (19000 dan 23000) dan pembebanan (lightship 2.5 kg, 3.5 kg, dan 5 kg). Validasi silang menetapkan *Video Tracker* sebagai metode acuan karena mengukur jarak-waktu secara langsung tanpa integrasi, dengan ketidakpastian Tipe A rata-rata terendah (0,2014 m/s) dibanding IMU (0,2398 m/s) dan Stopwatch (0,2279 m/s). IMU menunjukkan deviasi kecil pada kecepatan tinggi (-13,55% hingga +20,13%), namun meningkat tajam pada beban penuh hingga +104,55% akibat galat drift integrasi, sementara Stopwatch menunjukkan deviasi rata-rata 18,95% akibat perbedaan konsep kecepatan rata-rata dan sesaat. Analisis sensitivitas menunjukkan penambahan beban menurunkan kecepatan hingga 85,2% (19000 RPM) dan 79,6% (23000 RPM), sedangkan peningkatan RPM berpengaruh marginal pada beban ringan (2,8%-0,6%) namun signifikan pada beban penuh (41,8%). Hasil menunjukkan kombinasi *Video Tracker* dan IMU low-cost dapat menjadi alternatif valid instrumentasi FRMT konvensional, dengan catatan diperlukan koreksi drift tambahan pada IMU untuk kecepatan rendah.

Kata Kunci : *Free Running Model Test*, instrumen ukur kecepatan, validasi silang dan ketidakpastian pengukuran

EXPERIMENTAL TESTING OF VELOCITY MEASUREMENT ON SHIP MODEL USING LOW-COST FREE RUNNING MODEL TEST METHOD

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ABSTRACT

Free Running Model Test (FRMT) in ship modeling demands accurate Velocity measurements, but standard tools like high-precision GPS are costly. This research assesses an affordable measurement framework utilizing three techniques: a stopwatch, Video Tracker Analysis, and a WitMotion Inertial Measurement Unit (IMU). These were tested on a monohull ship model across distinct RPMs (19,000 and 23,000) and varied loads (lightship 2.5 kg, 3.5 kg, and 5 kg). Cross-validation confirmed the Video Tracker as the definitive reference because it directly captures distance-time without integration, yielding the lowest average Type A uncertainty (0.2014 m/s) against the IMU (0.2398 m/s) and stopwatch (0.2279 m/s). While the IMU displayed minor high-speed deviations (-13.55% to +20.13%), errors spiked at full capacity to +104.55% due to integration drift. Meanwhile, stopwatch deviations averaged 18.95% owing to average versus instantaneous speed discrepancies. Sensitivity analysis revealed that higher loads severely drop speeds by 85.2% (19,000 RPM) and 79.6% (23,000 RPM). Conversely, RPM increases marginally affect the light loads (2.8% to 0.6%) but significantly impact full loads (41.8%). Ultimately, combining Video Tracker with a cheap IMU forms a viable FRMT alternative, assuming low-speed IMU drift correction applies.

Keywords : *Free-Running Model Test, Velocity measurement instrument, cross-validation, and measurement uncertainty*