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To whom it may concern

'Model' test of quasi-steady
ship powering trials and monitoring

Ref: The basic 'model' test and this 'model' trial are directly accessible via the following links:
http://www.m-schmiechen.homepage.t-online.de/HomepageClassic01/mod_evaf.pdf
http://www.m-schmiechen.homepage.t-online.de/HomepageClassic01/mod_trial.pdf

Preamble
The latter file replaces the unsatisfactory, subsequently found to be flawed preliminary
version documented in the 'Festschrift' published on this website and distributed at the 108th
Annual Meeting of STG at Berlin in 2013 to commemorate the quasisteady propulsion tests
with the research vessel METEOR in the Greenland Sea in November 1988.

Preface
The following 'model' test of quasi-steady ship powering trials and monitoring is
intended to demonstrate, that quasi-steady trials full scale, nota bene without thrust
measurements!, of about one hour duration, at service conditions without anybody
noticing that such tests are being performed, permit to monitor the resistance and the
propulsive efficiency in the range of interest at the conditions prevailing during the
trials.

This paradigmatic test is based on the data of the 'model' test of only two minutes duration
with models VWS 2491/1340 performed on 09.09.1986 to demonstrate the feasibility of the
more ambitious quasi-steady tests including thrust measurements performed with the
research vessel METEOR in the Greenland Sea in November 1988. The same data have
since extensively been used further to develop the rational technique proposed, details to be
found in the file directly accessible via the link quoted in the Reference.

Exposition improved by plots of data
Text and layout marginally changed
Evaluation corrected following the detection of an error in
data transmission and subsequently rigorously rationalised

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Preliminaries

Mathcad permits to handle physical quantities, but all data are being used without their SI units in view of further use in mathematical subroutines, which by definition cannot handle arguments with units.

Constants

Field strength
\[ g := 9.81 \cdot m \cdot sec^{-2} \]
\[ g := g \cdot m^{-1} \cdot sec^{2} \]

Units

Force
\[ N := \text{newton} \]
\[ kp := g \cdot N \]

Torque
\[ Nm := \text{newton} \cdot m \]

Power
\[ W := \text{watt} \]

Model data VWS 2491/1340

Test identification
TID := "VWS 2491 /1340"

Date of test
Date := 860909

Test No.
Test := 8

Basic data

Ship model VWS Mod. 2491.0

Barge Carrier, which has not been built, body plan and contours of stem and stern to be found in the first appendix.

Model scale
\[ \lambda := 37.23 \]

Length
\[ L := 6.5 \cdot m \]
\[ L := L \cdot m^{-1} \]

Breadth
\[ B := 1.00 \cdot m \]
\[ B := B \cdot m^{-1} \]

Draught
\[ Tg := 0.255 \cdot m \]
\[ Tg := Tg \cdot m^{-1} \]

Displacement
\[ V := 1.431 \cdot m^{3} \]
\[ V := V \cdot m^{3} \]

Block coefficient
\[ \phi := \frac{V}{L \cdot B \cdot Tg} \]
\[ \phi = 0.8633 \]

Density of tank water
\[ \rho := 1.00 \cdot 10^{3} \cdot kg \cdot m^{-3} \]
\[ \rho := \rho \cdot kg^{-1} \cdot m^{3} \]

Mass, model
\[ m_{mod} := \rho \cdot V \]
\[ m_{mod} = 1431.0000 \]

Added inertia
\[ m_{x} := 0.024 \]

Total inertia
\[ M_{x} := m_{mod} \left( 1 + m_{x} \right) \]
\[ M_{x} = 1465.3440 \]

Surface
\[ S := 8.967 \cdot m^{2} \]
\[ S := S \cdot m^{-2} \]
Propeller model VWS Prop. 1340
CP propeller, right handed

Diameter of propeller
D := 0.195·m
D := D·m⁻¹

Disc area
A_D := \pi \cdot D^2
A_D = 0.0299

Pitch ratio, design
P_{D,des} := 0.825

Pitch ratio, actual
P_{D,act} := 0.813

Number of blades
Z := 4

Rate of revolutions
n_{open} := 12·Hz

Model test conditions

Carriage velocity
F_n := 0.168
v_{carr} := F_n \sqrt{\frac{g \cdot L}{v_{carr}}} \quad v_{carr} = 1.3415

Frictional deduction
C_F := 0.183
F_F := C_F \cdot \rho \cdot D^2 \cdot v_{carr}^2 \quad F_F = 12.5234

Tank dimensions
h := 4.2
l := 240

Data input

Digitized .jpg files

Fig's 6, 7, 8, 9 in VWS Report No. 1100/87
to found in the first appendix.

In the fundamental 'model' test mod_eval.mcd the raw
data have been scrutinized, faired and recorded for ready
reference.

Dat_fair := READPRN("dat_fair.dat")

\begin{align*}
\text{t} & := \text{Dat_fair}^{<0>} \\
\text{ni} & := \text{last(t)} \\
\text{i} & := 0..\text{ni} \\
\text{t} & := \frac{\text{t \cdot sec}}{\text{min}} \\
\text{t_m} & := \text{mean(t)} \\
\Delta \text{t} & := \text{t} - \text{t_m} \\
\text{N_S} & := \text{Dat_fair}^{<1>} \\
\text{V_G} & := \text{Dat_fair}^{<2>} \\
\text{A} & := \text{Dat_fair}^{<3>} \\
\text{Q} & := \text{Dat_fair}^{<4>} \\
\end{align*}
Shaft frequency

![Shaft frequency vs time graph]

Hull speed over ground

![Hull speed over ground vs time graph]

Hull acceleration

![Hull acceleration vs time graph]
Shaft torque

\[ Q \cdot P := Q \cdot S \]

### Parameters identified

**Hull speed**

\[ V_{C_i} := 0.0 \]

\[ V_H := V_G - V_C \]

\[ V_{H,\text{mean}} := \text{mean}(V_H) \quad V_{H,\text{mean}} = 1.3417 \]

\[ \Delta V_{H_i} := V_{H_i} - V_{H,\text{mean}} \]

**Hull advance ratio**

\[ J_{H_i} := \frac{V_{H_i}}{D \cdot N \cdot S_i} \]

\[ J_{H,\text{mean}} := \text{mean}(J_H) \quad J_{H,\text{mean}} = 0.6984 \]

\[ \Delta J_{H_i} := J_{H_i} - J_{H,\text{mean}} \]

**Shaft power**

\[ P_{P_i} := 2 \cdot \pi \cdot N \cdot S_i \cdot Q \cdot P_i \]

\[ P_{P,\text{mean}} := \text{mean}(P_P) \quad \Delta P_{P_i} := P_{P_i} - P_{P,\text{mean}} \]

\[ P_{P,\text{mean}} = 46.4870 \]
Set up energy balance

\[ A_{P_{i,0}} := -V_{H_i} \]
\[ A_{P_{i,1}} := A_{P_{i,0}} \cdot \Delta V_{H_i} \]
\[ A_{P_{i,2}} := P_{i} \]
\[ A_{P_{i,3}} := A_{P_{i,2}} \cdot \Delta J_{H_i} \]
\[ B_{P_{i}} := (M_X \cdot A_i - F_F) \cdot V_{H_i} \]

Partial linearised towing power with unknown total resistance parameters

Partial linearised propulsive power with unknown propulsive efficiency parameters

Towing power due to known 'forces'

Solve equations

\[ X_P := \text{geninv}(A_P) \cdot B_P \]
\[ X_P = \begin{bmatrix} 29.2225 \\ 59.2086 \\ 0.4821 \\ -0.0603 \end{bmatrix} \]

\[ E_P := B_P - A_P \cdot X_P \]

Power residua vs time

The power residua are exhibiting a pronounced linear tendency.
Results of evaluations including measured thrust values

\[
\begin{bmatrix}
V_H & R_{\text{rat.T.incl}} & R_{\text{trad.T.incl}} \\
J_H & \eta_{\text{TEP.rat.T.incl}} & \eta_{\text{TEP.trad.T.incl}}
\end{bmatrix} := \text{READPRN("Res_mod_eval")}
\]

Resistance values identified excluding measured thrust values

\[j := 0..\text{last}(V_H)\]

\[\Delta V_{H,\text{plt}} := V_{H_j} - V_{H,\text{mean}}\]

\[R_{\text{rat.T.excl}} := X_{P_0} + X_{P_1} \cdot \Delta V_{H,\text{plt}}\]
Propulsive efficiency values identified excluding measured thrust values

\[ j := 0 \ldots \text{last} \left( J_H \right) \]

\[ \Delta J_{H,\text{plt}} := J_{H,j} - J_{H,\text{mean}} \]

\[ \eta_{\text{TEP}\cdot\text{rat}\cdot\text{T}\cdot\text{excl}} := X_{P_2} + X_{P_3} \cdot \Delta J_{H,\text{plt}} j \]

Evidently the results are quite unsatisfactory, the energy balance not accounting for unknown effects of the towing tank environment, e.g. drift due to previous tests and tidal waves.
Identify trend of power residua

\[ t_m := \text{mean}(t) \quad \Delta t := t - t_m \]

\[ A_E_{i,0} := 1 \]

\[ A_E_{i,1} := \Delta t \]

\[ A_E_{i,2} := (\Delta t)^2 \]

\[ X_E := \text{geninv}(A_E) \cdot E_p \]

\[ X_E = \begin{bmatrix} -0.004483 \\ 1.192338 \\ 0.010865 \end{bmatrix} \]

The analysis shows that the trend is in fact linear.

\[ P_{P,\text{Res}} := A_E \cdot X_E \]
Modify power balance

\[ A_{P_{i,2}} := P_{i} + P_{i} \cdot Res_{i} \]

Solve modified equations

\[ X_{P} := \text{geninv}(A_{P}) \cdot B_{P} \]

\[ X_{P} = \begin{bmatrix} 32.4629 \\ 66.7494 \\ 0.5800 \\ 0.4202 \end{bmatrix} \]

\[ E_{P} := B_{P} - A_{P} \cdot X_{P} \]

Power residua vs time

- Time in min
- Power residua in W

\[ \Delta t \]

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**Resistance values**

**identified excluding measured thrust values**

\[ j := 0 \ldots \text{last} \left( V_H \right) \]

\[ \Delta V_{H,plt}^j := V_{H,j} - V_{H,\text{mean}} \]

\[ R_{\text{rat.T.excl}}^j := X_{P_0} + X_{P_1} \cdot \Delta V_{H,plt}^j \]

---

**The model resistance identified excluding the measured thrust values is thus nearly identical to the towing resistance.**

\[
V_H = \begin{bmatrix}
1.3100 \\
1.3200 \\
1.3300 \\
1.3400 \\
1.3500 \\
1.3600
\end{bmatrix}
\]

\[
R_{\text{rat.T.excl}} = \begin{bmatrix}
30.3466 \\
31.0141 \\
31.6816 \\
32.3491 \\
33.0166 \\
33.6841
\end{bmatrix}
\]

\[
R_{\text{trad.T.incl}} = \begin{bmatrix}
30.9400 \\
31.5000 \\
32.0600 \\
32.6300 \\
33.2100 \\
33.7900
\end{bmatrix}
\]

---

**Similarly the values of the model propulsive efficiency identified excluding the measured thrust values are nearly identical to the values based on the model propeller open water performance.**
Propulsive efficiency values  
identified excluding measured thrust values  

\[ j := 0 \ldots \text{last}(J_H) \]

\[ \Delta J_{H,\text{plt}_j} := J_{H_j} - J_{H,\text{mean}} \]

\[ \eta_{\text{TEP.rat.T.excl}} := X_{P_2} + X_{P_3} \cdot \Delta J_{H,\text{plt}} \]

Propulsive eff's vs hull advance ratio
Conclusions

After correction of the mistake in the data transmission from the preceding basic programme mod_eval.mcd to the present programme all the earlier subsequent speculations concerning the reasons of the discrepancies observed in the propulsive efficiencies are obsolete.

Accounting for the trend of the observed power residua, without caring for their possible reasons, results in perfect agreement with the traditional results not only in case of the resistance, but also in case of the propulsive efficiency.

Thus, from the preceding basic exercise, the evaluation of data acquired at a quasi-steady 'model' test of only two minutes duration, ignoring the thrust data (!), it is concluded that quasi-steady trials of about an hour full scale will be possible for detailed monitoring of the powering performance of ships at the conditions prevailing during the test.

Towing tanks can easily test this procedure, as they did in 1936/37 with Horn's proposal, and can ask for such tests at the next trials they are involved in. Of course in evaluating full scale data others of my procedures developed to identify current and environmental parameters have to be accounted for. The pertinent development may be subject of a master's or even a doctoral thesis.

'Unnecessary' to mention that in routine applications the programming will be quite different, typically in terms of subroutines, which have been used only occasionally in this document. But in view of the sensitivity of the problem at hand colleagues are warned: there may be 'no plug and play' program. In any case careful scrutiny of data and intermediate results is absolutely mandatory.

And to repeat: The method proposed offers dramatic technological and commercial advantages. No hull towing tests and propeller open water are necessary and the extremely short propulsion tests provide a wealth of consistent data and results.

END
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