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To whom it may concern

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

Ref: The basic 'model' test directly accessible via the following link:
http://www.m-schmiechen.homepage.t-online.de/HomepageClassic01/**mod_evaf.pdf**

Preface

The following 'model' test of quasi-steady ship powering trials and monitoring is intended to demonstrate that quasi-steady trials full scale without thrust measurements of only one hour duration under service conditions, without anybody noticing that such tests are being performed, permit to monitor the powering performance in great detail.

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 been extensively used further to develop the technique, details to be found in the file directly accessible via the link quoted in the Reference.

'Unneccesary' 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 sensitivty of the problem at hand colleagues are warned: there will 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.

Exposition improved by plots of data MS 201308281200

Text and layout marginally changed MS 201308311630

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

Gravity field	$g := 9.81 \cdot m \cdot sec^{-2}$	$g := g \cdot m^{-1} \cdot sec^{2}$
Units		
Force	$N := newton$	$kp := g \cdot N$
Torque	$Nm := newton \cdot m$	
Power	$W := watt$	

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.

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	$M := \rho \cdot V$	$M = 1431.0000$
Model scale	$\lambda := 37.23$	
Added inertia	$m_x := 0.024$	
Surface	$S := 8.967 \cdot m^{2}$	$S := S \cdot m^{-2}$

Propeller model VWS Prop. 1340

CP propeller, right handed

Diameter of propeller $D := 0.195 \cdot m$ $D := D \cdot m^{-1}$

Disc area $A_D := \frac{\pi}{4} \cdot D^2$ $A_D = 0.0299$

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

Pich ratio, actual $P_{D.act} := 0.813$

Number of blades $Z := 4$

Rate of revolutions at open water test $n_{open} := 12 \cdot Hz$

Model test conditions

Carriage velocity $F_n := 0.168$

$v_{carr} := F_n \cdot \sqrt{g \cdot L}$ $v_{carr} = 1.3415$

Frictional deduction $C_F := 0.183$

$F_F := C_F \cdot \rho \cdot D^2 \cdot v_{carr}^2$ $F_F = 12.5234$

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.

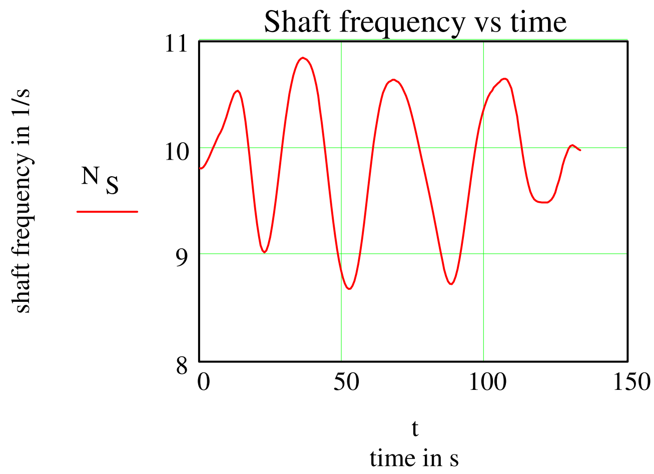
In the fundamental 'model' test mod_eval.mcd the raw data have been scutinzed, faired and recorded for ready reference..

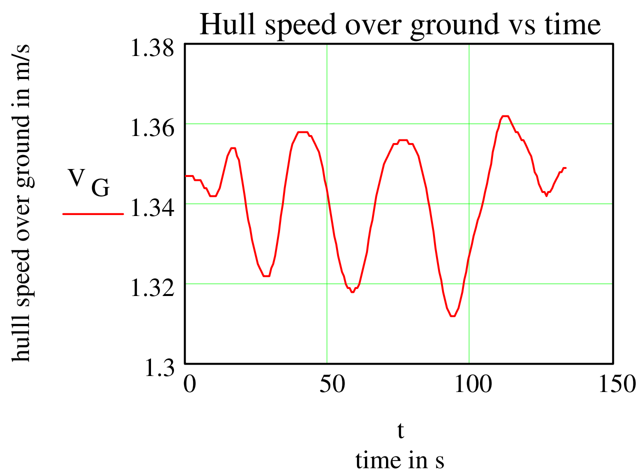
$Dat_{fair} := READPRN("dat\_fair.dat")$

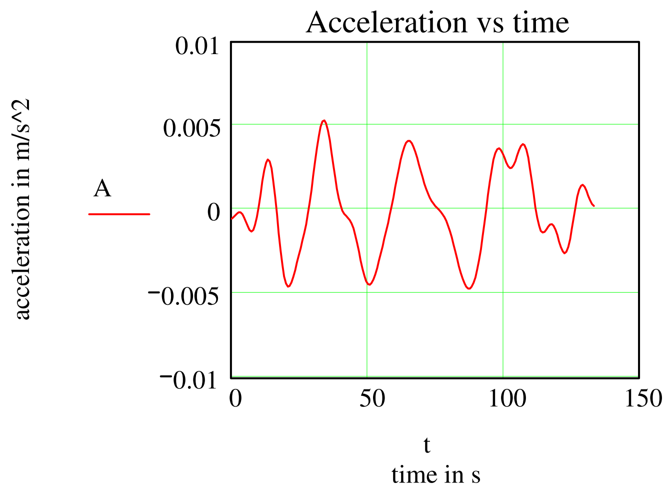
$t := Dat_{fair}^{\langle 0 \rangle}$ $ni := last(t)$ $i := 0..ni$

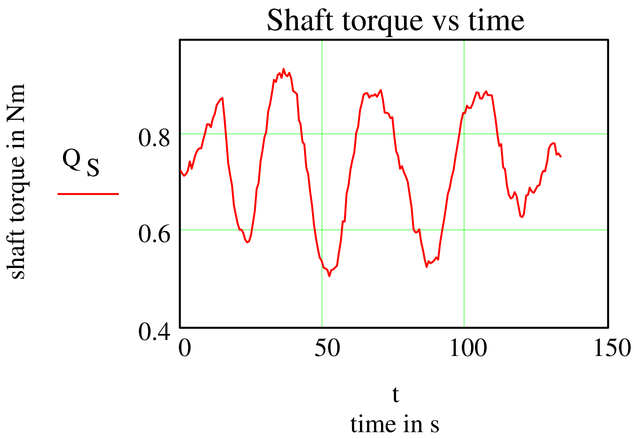
$N_S := Dat_{fair}^{\langle 1 \rangle}$ $V_G := Dat_{fair}^{\langle 2 \rangle}$ $A := Dat_{fair}^{\langle 3 \rangle}$ $Q_S := Dat_{fair}^{\langle 4 \rangle}$

$Q_P := Q_S$


Shaft frequency vs time
shaft frequency in 1/s
N S
11
10
9
8
0
50
100
150
t
time in s


Hull speed over ground vs time
hulll speed over ground in m/s
V G
1.38
1.36
1.34
1.32
1.3
0
50
100
150
t
time in s


Acceleration vs time
acceleration in m/s^2
A
0.01
0.005
0
−0.005
−0.01
0
50
100
150
t
time in s



Parameters identified

Hull speed

$V_{C_i} := 0.0$

Mean current in the tank
assumed for lack of more precise information.

$V_H := V_G - V_C$

$V_{H.mean} := \mathrm{mean}(V_H)$ $\quad V_{H.mean} = 1.3417$

$\Delta V_{H_i} := V_{H_i} - V_{H.mean}$

Hull advance ratio

$$J_{H_i} := \frac{V_{H_i}}{D \cdot N_{S_i}}$$

$J_{H.mean} := \mathrm{mean}(J_H)$ $\quad J_{H.mean} = 0.6984$

$\Delta J_{H_i} := J_{H_i} - J_{H.mean}$

Shaft power

$P_{P_i} := 2 \cdot \pi \cdot N_{S_i} \cdot Q_{P_i}$

$P_{P_i} := P_{P_i}$

$P_{P.mean} := \mathrm{mean}(P_P)$ $\quad \Delta P_{P_i} := P_{P_i} - P_{P.mean}$

$P_{P.mean} = 46.4870$

Set up of equations

$A_{P_{i,0}} := -V_{H_i}$

$A_{P_{i,1}} := -V_{H_i} \cdot \Delta V_{H_i}$

$A_{P_{i,2}} := P_{P_i}$

$A_{P_{i,3}} := P_{P_i} \cdot \Delta J_{H_i}$

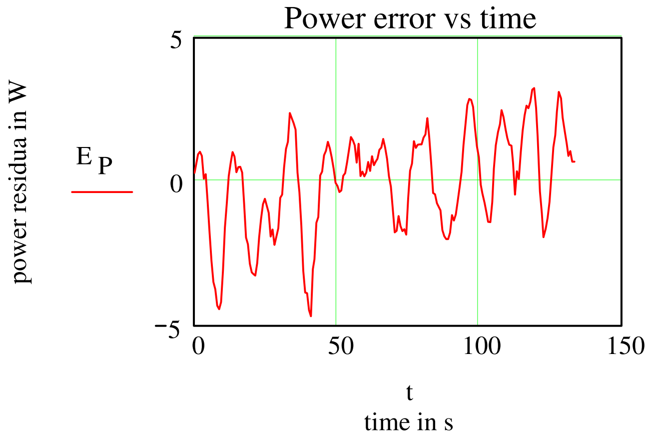
$B_{P_i} := \left[(1 + m_x) \cdot M \cdot A_i - F_F \right] \cdot V_{H_i}$

Solution of equations

$X_P := \text{geninv}(A_P) \cdot B_P$

$$X_P = \begin{bmatrix} 29.2225 \\ 59.2086 \\ 0.4821 \\ -0.0603 \end{bmatrix}$$

$E_P := B_P - A_P \cdot X_P$



At this stage it is noted that the residua exhibit a roughly linear trend with time.

This trend may be assumed to be due to a change in the inclination of the free surface.

Trend of residua identified

$t_m := \text{mean}(t)$

$\Delta t := t - t_m$

$A_{E_{i,0}} := 1$

$A_{E_{i,1}} := \Delta t_i$

$A_{E_{i,2}} := (\Delta t_i)^2$

$X_E := \text{geninv}(A_E) \cdot E_P$

$$X_E = \begin{bmatrix} -0.004483 \\ 0.019872 \\ 0.000003 \end{bmatrix}$$

The analysis shows that the trend is in fact linear.

$$P_{E.trend} := A_E \cdot X_E$$

Total change of inclination identified

$$\Delta t := t_{ni} - t_0$$

$$\Delta P_E := P_{E.trend_{ni}} - P_{E.trend_0} \qquad \Delta P_E = 2.6470$$

$$\alpha := \frac{\Delta P_E}{M \cdot g \cdot V_{H.mean}} \qquad \alpha = 0.000141$$

At the same time it is noticed, that the basic value is strictly accidental!

Solution iterated to account for correlation of power residua with time

$$P_P := P_P + A_E \cdot X_E$$

$$A_{P_{i,2}} := P_{P_i}$$

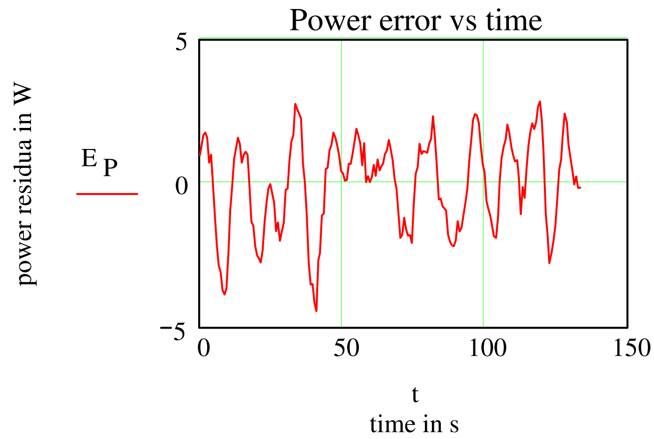
$$A_{P_{i,3}} := P_{P_i} \cdot \Delta J_{H_i}$$

$$X_P := \text{geninv}(A_P) \cdot B_P$$

$$X_P = \begin{bmatrix} 32.2455 \\ 66.4285 \\ 0.5734 \\ 0.3859 \end{bmatrix}$$

$$E_P := B_P - A_P \cdot X_P$$

$$P_{P.mean} := \text{mean}(P_P)$$



$E_{P.slope} := slope(t, E_P)$ $E_{P.slope} = 0.0081$ There is still something left!

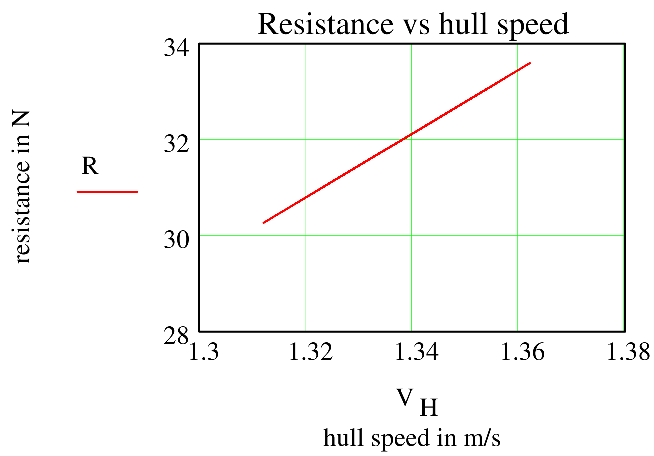
$E_{P.dev} := stdev(E_P)$ $E_{P.dev} = 1.5969$

$P_{P.mean} = 46.487$ $\frac{E_{P.dev}}{P_{P.mean}} = 0.0344$

In the following the results of the present analysis are compared with those obtained in the earlier analysis including the thrust measurements, the 'model' test documented on my webiste under 'News on ship powering trials' od directly via the link in the Reference.

Resistance identified

$R_i := X_{P_0} + X_{P_1} \cdot \Delta V_{H_i}$



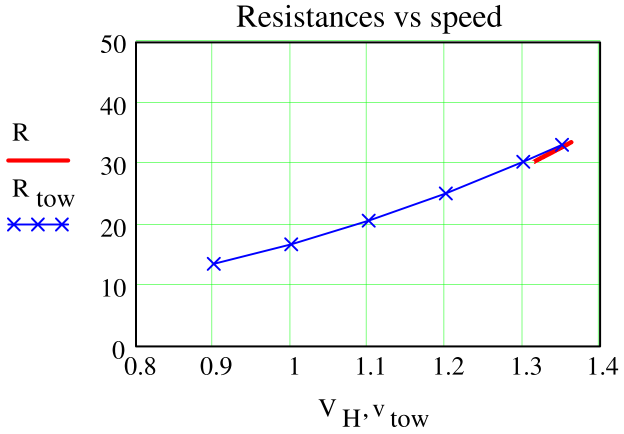
Resistance compared with towing resistance

$$Data_{tow} := \begin{bmatrix} 0.90 & 13.6 \\ 1.00 & 16.8 \\ 1.10 & 20.7 \\ 1.20 & 25.2 \\ 1.30 & 30.4 \\ 1.35 & 33.2 \end{bmatrix}$$

Values v in m/s, of R in N read from Fig. 3.4 in VWS Bericht Nr. 1126/88.

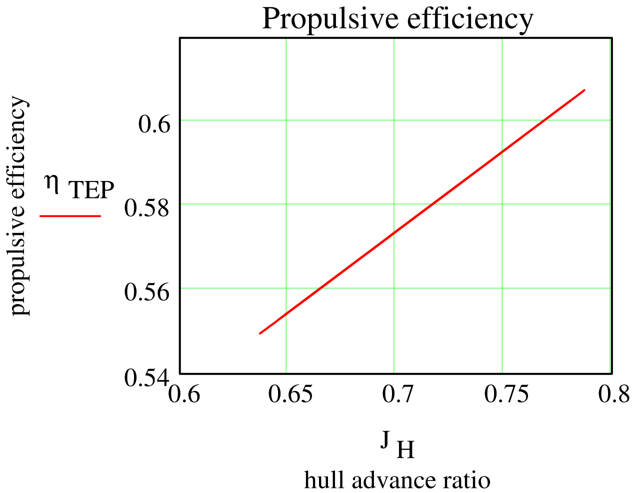
They conicide with those in VWS Report No. 1100/87.

$$v_{tow} := Data_{tow}^{\langle 0 \rangle} \qquad R_{tow} := Data_{tow}^{\langle 1 \rangle}$$



Propulsive efficiency identified

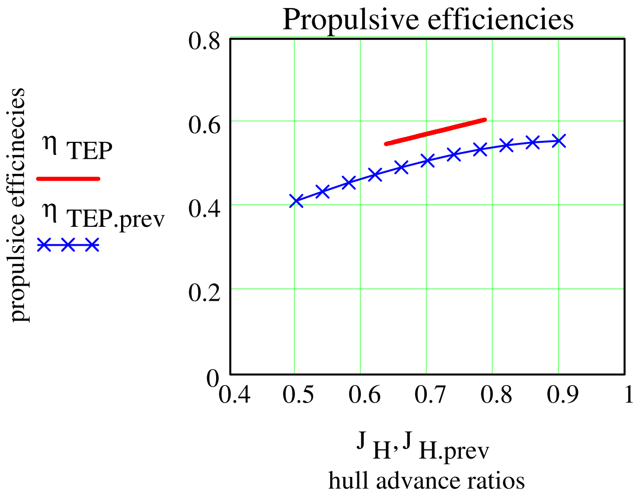
$$\eta_{TEP_i} := X_{P_2} + X_{P_3} \cdot \Delta J_{H_i}$$



Propulsive efficiency compared with previous values

$$J_{H.prev} := \begin{bmatrix} 0.5000 \\ 0.5400 \\ 0.5800 \\ 0.6200 \\ 0.6600 \\ 0.7000 \\ 0.7400 \\ 0.7800 \\ 0.8200 \\ 0.8600 \\ 0.9000 \end{bmatrix} \qquad \eta_{TEP.prev} := \begin{bmatrix} 0.4141 \\ 0.4363 \\ 0.4572 \\ 0.4765 \\ 0.4942 \\ 0.5103 \\ 0.5245 \\ 0.5366 \\ 0.5464 \\ 0.5536 \\ 0.5577 \end{bmatrix}$$

In the range of interest the previous values are the same for rational and traditional evaluations.



While after accounting for the trend in the residua the model resistance is nearly exactly the same as the towing resistance reported, the resulting propulsive efficiency is 'still' about 14 % larger than previously obtained, implying that the actual power is less by that percentage.

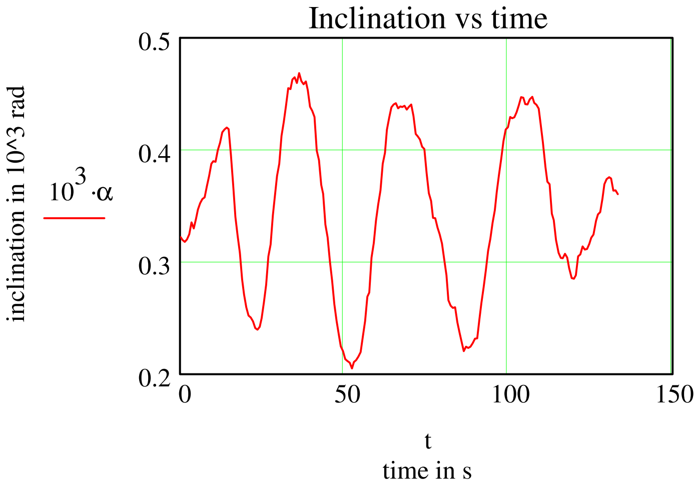
Inclination of model identified

$c := 0.14$

For this exercise based on the propulsive efficiency determined traditionally! In future to be identified from repeated trials!

See Conclusions!

$$\alpha_i := \frac{c \cdot P_{P_i}}{M \cdot g \cdot V_{H_i}}$$



The inclinition thus identified is strongly correlated with the acceleration.

$$\Delta P_{O_i} := M \cdot g \cdot V_{H_i} \cdot \alpha_i$$

$$P_{P_i} := P_{P_i} + \Delta P_{O_i}$$

$$A_{P_{i,2}} := P_{P_i}$$

$$A_{P_{i,3}} := P_{P_i} \cdot \Delta J_{H_i}$$

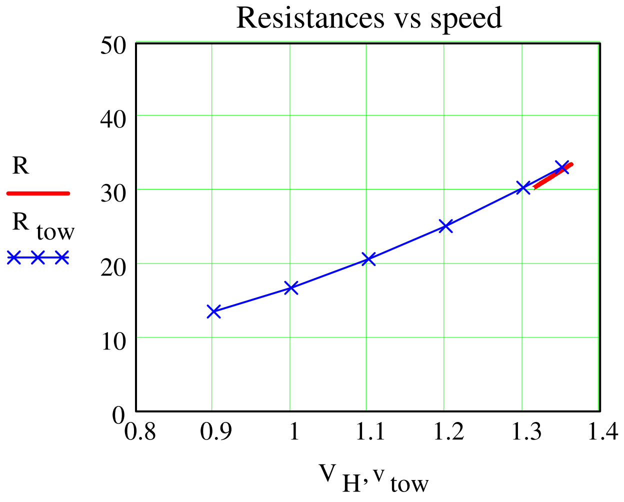
$$X_P := \text{geninv}\left(A_P\right) \cdot B_P$$

$$X_P = \begin{bmatrix} 32.2455 \\ 66.4285 \\ 0.5030 \\ 0.3385 \end{bmatrix}$$

$$E_P := B_P - A_P \cdot X_P$$

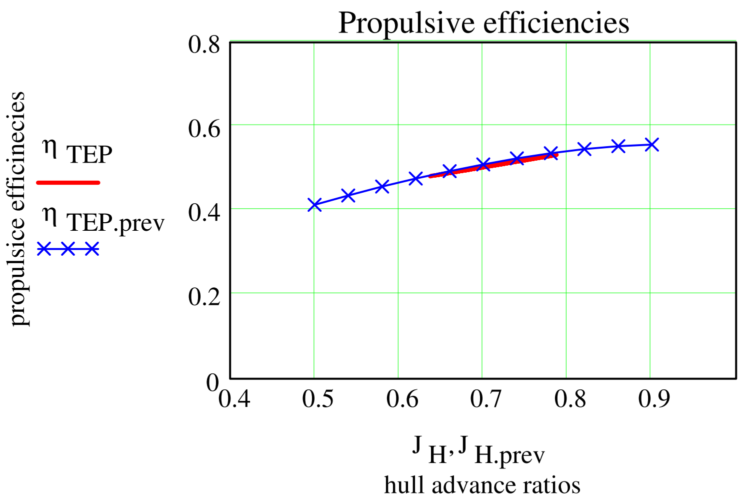
Resistance identified

$$R_i := X_{P_0} + X_{P_1} \cdot \Delta V_{H_i}$$



Propulsive efficiency identified

$$\eta_{TEP_i} := X_{P_2} + X_{P_3} \cdot \Delta J_{H_i}$$



Conclusions

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 an hour full scale will be possible for detailed monitoring of the powering performasnce of ships.

Evidently extremely small changes of the surface inclination will not effect the resistance, but the propulsive efficiency. Quite 'naturally' the values of the latter will increase if the model is moving 'down-hill'.

Thus for **trustworthy trials and monitoring** level surface has to be established at least computationally and in view of the omnipresent noise may thus require a number of repeated quasi-steady tests or, much simpler if possible, an extended test covering more than four cycles and maybe of shorter periods.

Assuming full scale tests over one hour covering 12 to 16 periods will permit to analyse 'all possible' sections, always over full periods, and thus establish confidence in the results. The model data at hand of only four periods permitted only for a rudimentary test of this proposed procedure.

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 have to be applied. The pertinent development may be subject of a master's or even a doctoral thesis.

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