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To whom it may concern

Powering performance of a bulk carrier during speed trials in ballast condition reduced to nominal no wind condition

MS 140910140
Correction of the labels of the plot of propulsive efficiencies reported, traditionally identified from model tests according to Dr. Hollenbach!

Preface

Preamble

The present analysis of a powering trial is **the second of my 'post-ANONYMA trial evaluations'**. **For the whole context and for more details the Conclusions of PATE_01 should be referred to!**

The evaluation is based on the data acquired during the trials with a sister ship of the one, whose trials took place in the East China Sea a fortnight later and the data of which have been analysed before in **the first of my 'post-ANONYMA trial evaluations'** PATE_01.1 and PATE_01.2.

As the trials and reference conditions have been the same these data sets and their evaluations provide the rare chance to compare many 'things'. A number of interesting comparisons are already offered; additional ones will be provided on request.

Data provided

The powering trial analysed according to the rational procedure promoted is another reference case of the ongoing research project mentioned. As usual only the anonymised data, just mean values of measured quantities and crude estimates of wind and waves, have been made available for the analysis.

Further, for comparison with the evaluation according to an undisclosed, more or less traditional procedure, few results have been provided..

'Disclaimer'

In spite of utmost care the following evaluation, in the meantime a document of more than thirty pages, may still contain mistakes. The author will gratefully appreciate and acknowledge any of those brought to his attention, so that he may correct them.

References

Reference:C:\PATEs\PATE_00.2.mcd

General remarks
Concepts
- Names
- Symbols
- Remarks

Units
Routines

Identify trial and evaluation

$TID := "02.1"$

$EID := concat("PATE\_", TID)$ $\quad EID = "PATE\_02.1"$

'Constants'

$D_P := 7.05\cdot m$ $\quad D_P := D_P\cdot\frac{1}{m}$ diameter of propeller

$h_S := 3.85\cdot m$ $\quad h_S := h_S\cdot\frac{1}{m}$ height of shaft above base

Trials conditions

$T_{aft} := 7.42\cdot m$ $\quad T_{aft} := T_{aft}\cdot\frac{1}{m}$ draft aft

Nominal propeller submergence

$h_{P.Tip} := h_S + \frac{D_P}{2}$ $\quad h_{P.Tip} = 7.375$

$s_{P.Tip} := T_{aft} - h_{P.Tip}$ $\quad s_{P.Tip} = 0.045$

At this small nominal submergence and the sea state reported the propeller may have been ventilating even at the down wind conditions.

Wave

$$\psi_{WaveH} := \begin{bmatrix} 70 \\ 110 \\ 110 \\ 70 \\ 70 \\ 110 \\ 110 \\ 70 \end{bmatrix}\cdot deg$$

$H_{Wave} := 1.0\cdot m$ wave height

$H_{Wave} := \frac{H_{Wave}}{m}$

Water depth

$d_{Water} := 65\cdot m$

Read results of PATE_01.1
for ready comparison with the results
of the following analysis of the trial
with a sister ship a fornight earlier

$Results_{01.1} := READPRN(\text{"Results\_PATE\_01.1"})$

$\left[Internal_{rat.01.1} \;\; Final_{rat.01.1} \;\; Internal_{trad.01.1} \;\; Final_{trad.01.1} \right] := Results_{01.1}$

$\left[Res_{sup.01.1} \;\; Res_{req.01.1} \right] := Internal_{rat.01.1}$

$$\begin{bmatrix} \Delta P_{S.sup.01.1} & v_{01.1} & V_{WG.01.1} \\ V_{HW.01.1} & p_{01.1} & P_{S.sup.01.1} \\ J_{HW.01.1} & p_{n.01.1} & K_{P.sup.01.1} \end{bmatrix} := Res_{sup.01.1}$$

$\left[\Delta P_{S.req.01.1} \;\; q_{01.1} \;\; P_{S.req.01.1} \;\; A_{req.01.1} \;\; X_{req.01.1} \right] := Res_{req.01.1}$

$\left[Run_{01.1} \;\; \Delta t_{01.1} \;\; V_{HW.rat.trial.01.1} \;\; P_{S.rat.trial.01.1} \;\; N_{S.rat.trial.01.1} \right] := Final_{rat.01.1}$

$\left[V_{WG.trad.corr.01.1} \;\; J_{HW.trad.corr.01.1} \;\; K_{P.sup.trad.01.1} \right] := Internal_{trad.01.1}$

$\left[Run \;\; \Delta t_{trad.01.1} \;\; V_{HW.trad.ref.01.1} \;\; P_{S.trad.ref.01.1} \;\; N_{S.trad.ref.01.1} \right] := Final_{trad.01.1}$

Mean values reported

For ready reference the matrices of the mean values of the measured magnitudes, alias 'quantities', are printed here and converted to SI Units. Further down intermediate results are printed as well to permit checks óf plausibility.

It is noted here explicitly, that no confdence radii of the mean values have been reported.

Day time / Heading / Rel. wind velocity / Rel. wind direction

$$time := \begin{bmatrix} 12 & 56 \\ 13 & 27 \\ 13 & 44 \\ 14 & 12 \\ 14 & 30 \\ 14 & 56 \\ 15 & 13 \\ 15 & 37 \\ 15 & 57 \\ 16 & 18 \\ 16 & 30 \\ 16 & 57 \end{bmatrix} \quad \psi_{HG} := \begin{bmatrix} 74 \\ 256 \\ 256 \\ 76 \\ 75 \\ 246 \\ 247 \\ 75 \\ 73 \\ 248 \\ 248 \\ 72 \end{bmatrix} \cdot deg \quad V_{HA} := \begin{bmatrix} 5 \\ 12 \\ 17 \\ 13 \\ 18 \\ 22 \\ 25 \\ 18 \\ 18 \\ 24 \\ 24 \\ 19 \end{bmatrix} \cdot kts \quad \psi_{HA} := \begin{bmatrix} 30 \\ 40 \\ 40 \\ 40 \\ 50 \\ 40 \\ 30 \\ 50 \\ 50 \\ 25 \\ 25 \\ 45 \end{bmatrix} \cdot deg$$

Shaft frequency / Measured shaft power / Ship speed over ground

$$N_S := \begin{bmatrix} 52.06 \\ 52.05 \\ 66.00 \\ 66.01 \\ 82.53 \\ 82.54 \\ 95.27 \\ 95.26 \\ 103.08 \\ 103.07 \\ 106.47 \\ 106.46 \end{bmatrix} \cdot \frac{1}{min} \quad P_S := \begin{bmatrix} 1666 \\ 1615 \\ 3010 \\ 3149 \\ 6041 \\ 5940 \\ 9274 \\ 9555 \\ 12188 \\ 11767 \\ 13060 \\ 13579 \end{bmatrix} \cdot kW \quad V_{HG} := \begin{bmatrix} 9.230 \\ 7.245 \\ 9.778 \\ 11.223 \\ 13.958 \\ 12.786 \\ 14.608 \\ 15.047 \\ 15.937 \\ 16.001 \\ 16.478 \\ 15.986 \end{bmatrix} \cdot kts$$

Further it is mentioned here, that in Mathcad the operational indices standardly start from zero as usual in mathematics and thus in the mathematical subroutines available in the Numericl Recipes subroutine package. Thus the possible change of the standard, resulting in intransparent code, is not a viable choice..

'Duration' of measurements

$s_{mean} := 1\ nm$ $\qquad s_{mean} := \frac{s_{mean}}{m}$ $\qquad$ Distances sailed at each run

Sailing the same distance at different speeds, here one nautical mile, is in accordance with the name 'miles runs', in German 'Meilen-Fahrten', but has the disadvantage, that the average values derived from the sampled values have wider confidence ranges at the higher speeds.

'Non-dimensionalise' magnitudes

$V_{HA} := V_{HA} \cdot \frac{sec}{m}$ $\qquad N_S := N_S \cdot sec$ $\qquad P_S := P_S \cdot \frac{1}{MW}$ $\qquad V_{HG} := V_{HG} \cdot \frac{sec}{m}$

Times of measurements

$ni := last(time^{<0>})$ $\qquad i := 0 .. ni$

$dur_i := \frac{s_{mean}}{V_{HG_i}}$ $\qquad t := time^{<0>} + time^{<1>} \cdot \frac{min}{hr} + \frac{dur}{2} \cdot \frac{sec}{hr}$

$t_m := mean(t)$ $\qquad \Delta t := t - t_m$

Normalise data

At this stage for preliminary check of consistency only!

$J_{HG_i} := J\left(D_P, V_{HG_i}, N_{S_i}\right)$ $\qquad K_{P.orig_i} := KP\left(\rho, D_P, P_{S_i}, N_{S_i}\right)$

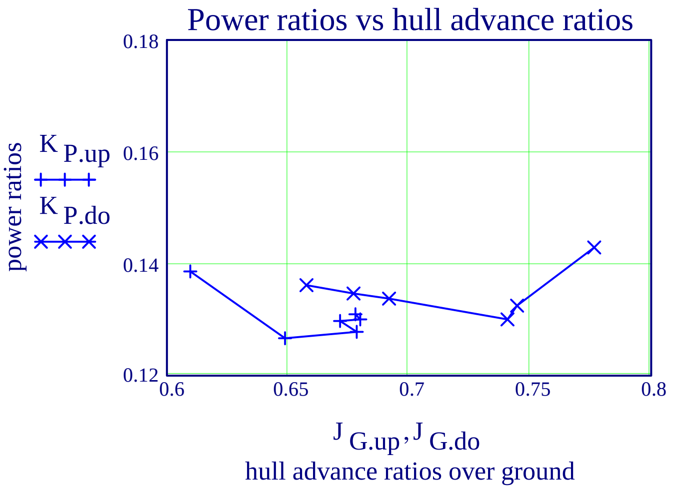
Sort runs

$S := Sort\_runs\left(J_{HG}, K_{P.orig}, \psi_{HG}\right)$

$J_{G.up} := S^{<0>}$ $\qquad K_{P.up} := S^{<1>}$ $\qquad J_{G.do} := S^{<2>}$ $\qquad K_{P.do} := S^{<3>}$

$J_{G.up} = \begin{bmatrix} 0.609 \\ 0.649 \\ 0.678 \\ 0.671 \\ 0.680 \\ 0.678 \end{bmatrix}$ $\qquad K_{P.up} = \begin{bmatrix} 0.139 \\ 0.127 \\ 0.128 \\ 0.130 \\ 0.130 \\ 0.131 \end{bmatrix}$ $\qquad J_{G.do} = \begin{bmatrix} 0.776 \\ 0.744 \\ 0.740 \\ 0.692 \\ 0.677 \\ 0.657 \end{bmatrix}$ $\qquad K_{P.do} = \begin{bmatrix} 0.143 \\ 0.132 \\ 0.130 \\ 0.134 \\ 0.135 \\ 0.136 \end{bmatrix}$

Scrutinise data



Evidently the values at the first double run are outliers to be eliminated without further study of possible reasons. In the traditional evaluation the values at the first two double runs, i. e. the first four data sets have been ignored. For ready comparison of results the same data set has been used in PATE_01.2.

Outlying data eliminated

$ne := 2$ $\qquad ni := last(t) - ne$

$i := 0 .. ni$

$\Delta t_{red_i} := \Delta t_{i+ne}$ $\qquad \Psi_{HG.red_i} := \Psi_{HG_{i+ne}}$ $\qquad V_{HA.red_i} := V_{HA_{i+ne}}$

$\Delta t := \Delta t_{red}$ $\qquad \Psi_{HG} := \Psi_{HG.red}$ $\qquad V_{HA} := V_{HA.red}$

$N_{S.red_i} := N_{S_{i+ne}}$ $\qquad P_{S.red_i} := P_{S_{i+ne}}$ $\qquad V_{HG.red_i} := V_{HG_{i+ne}}$

$N_S := N_{S.red}$ $\qquad P_S := P_{S.red}$ $\qquad V_{HG} := V_{HG.red}$

Normalise reduced data

$J_{HG_i} := J\left(D_P, V_{HG_i}, N_{S_i}\right)$ $\qquad K_{P_i} := KP\left(\rho, D_P, P_{S_i}, N_{S_i}\right)$

$S := Sort\_runs\left(J_{HG}, K_P, \Psi_{HG}\right)$

$J_{HG.up} := S^{\langle 0 \rangle}$ $\qquad K_{P.up} := S^{\langle 1 \rangle}$ $\qquad J_{HG.do} := S^{\langle 2 \rangle}$ $\qquad K_{P.do} := S^{\langle 3 \rangle}$

$$J_{HG.up} = \begin{bmatrix} 0.649 \\ 0.678 \\ 0.671 \\ 0.680 \\ 0.678 \end{bmatrix} \quad K_{P.up} = \begin{bmatrix} 0.127 \\ 0.128 \\ 0.130 \\ 0.130 \\ 0.131 \end{bmatrix} \quad J_{HG.do} = \begin{bmatrix} 0.744 \\ 0.740 \\ 0.692 \\ 0.677 \\ 0.657 \end{bmatrix} \quad K_{P.do} = \begin{bmatrix} 0.132 \\ 0.130 \\ 0.134 \\ 0.135 \\ 0.136 \end{bmatrix}$$

Analyse power supplied

including identification of tidal current

Conventions adopted

Propeller power convention

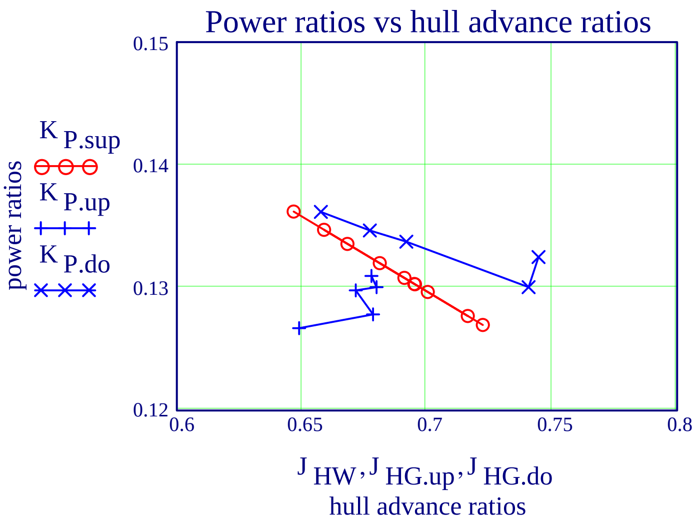
$$PS_{sup}(p, N, V) := p_0 \cdot N^3 + p_1 \cdot N^2 \cdot V$$

Tidal current velocity convention

$$VC(v, \omega_T, \Delta t) := v_0 + v_1 \cdot \cos(\omega_T \cdot \Delta t) + v_2 \cdot \sin(\omega_T \cdot \Delta t)$$

$$Res_{sup} := Supplied_T(\rho, D_P, \Delta t, V_{HG}, \psi_{HG}, N_S, P_S)$$

$$\begin{bmatrix} \Delta P_{S.sup} & v & V_{WG} \\ V_{HW} & p & P_{S.sup} \\ J_{HW} & p_n & K_{P.sup} \end{bmatrix} := Res_{sup}$$



$$p = \begin{bmatrix} 3.841 \\ -0.309 \\ 0.013 \\ 3.014 \cdot 10^{-3} \end{bmatrix}$$

$$p_n = \begin{bmatrix} 0.2152 \\ -0.1222 \end{bmatrix}$$

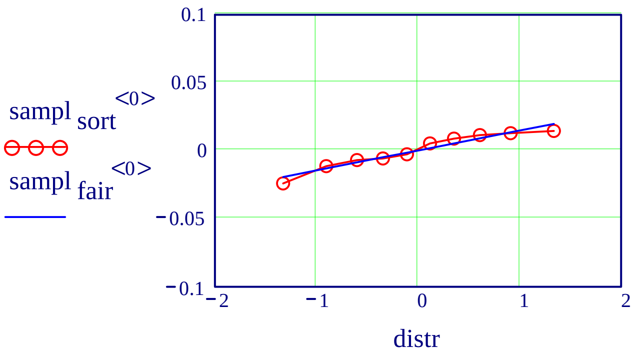
Nota bene: The propeller performance in the behind condition identified is that at the hull condition, the loading condition and the sea condition prevailing at the trials!

Supplied power residua

Check distribution of residua

Values of random variables need to be tested for normal distribution before using mean values and and standard deviations.

$[\text{distr} \;\; \text{sampl}_{sort} \;\; \text{sampl}_{fair} \;\; \text{distr}_{par}] := \text{norm\_distr}(\Delta P_{S.sup})$



$$\text{distr}_{par} = \begin{bmatrix} 4.305\cdot10^{-4} \\ 0.015 \\ 4.626\cdot10^{-3} \end{bmatrix}$$

According to the result plotted the following error analysis is justified.

95 % confidence radius

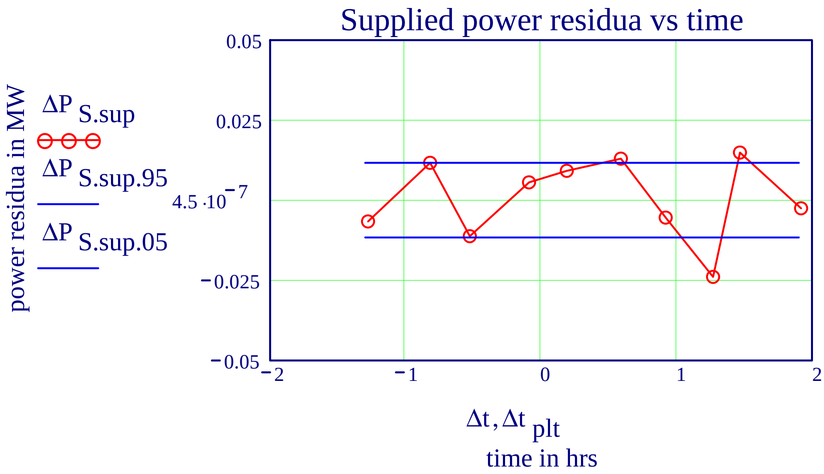
number of samples — of parameters — of degrees of freedom

$n_s := ni + 1$ $\quad$ $n_p := 4$ $\quad$ $f := n_s - n_p$

$P_{S.sup.95} := C_{95}(\Delta P_{S.sup}, f)$ $\quad$ $P_{S.sup.95}\cdot\frac{MW}{kW} = 11.7$ kW

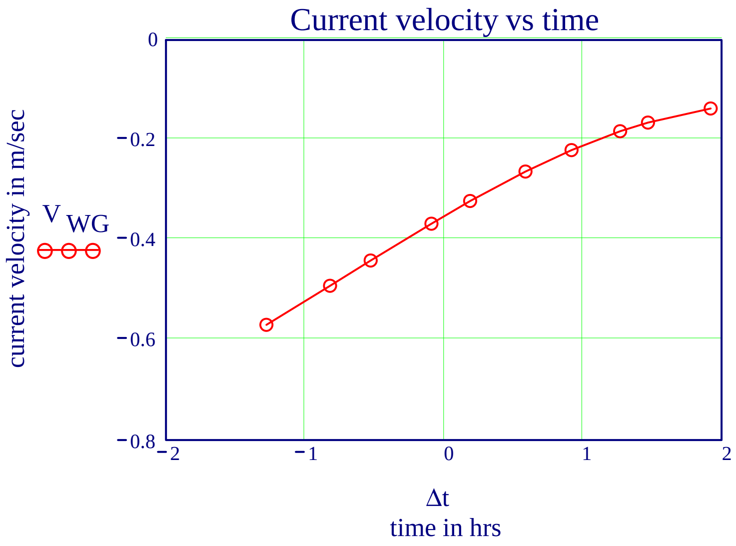
$k := 0 .. 1$ $\quad$ $\Delta t_{plt_0} := -1.3$ $\quad$ $\Delta t_{plt_1} := 1.9$

$\Delta P_{S.sup.95_k} := P_{S.sup.95}$ $\quad$ $\Delta P_{S.sup.05_k} := -P_{S.sup.95}$



Accordingly the conventions adopted 'describe' the power data perfectly well! The relatively small value of the confidence radius cannot be judged objectively, as the confidence ranges of the mean values have not been provided as in case of the analysis of the ANONYMA trials.

Current velocity identified



$$V_{WG} \cdot \frac{m}{kts \cdot sec} = \begin{bmatrix} -1.107 \\ -0.956 \\ -0.858 \\ -0.714 \\ -0.627 \\ -0.512 \\ -0.429 \\ -0.355 \\ -0.321 \\ -0.266 \end{bmatrix} kts$$

During the trials the current changed more than half a knot!

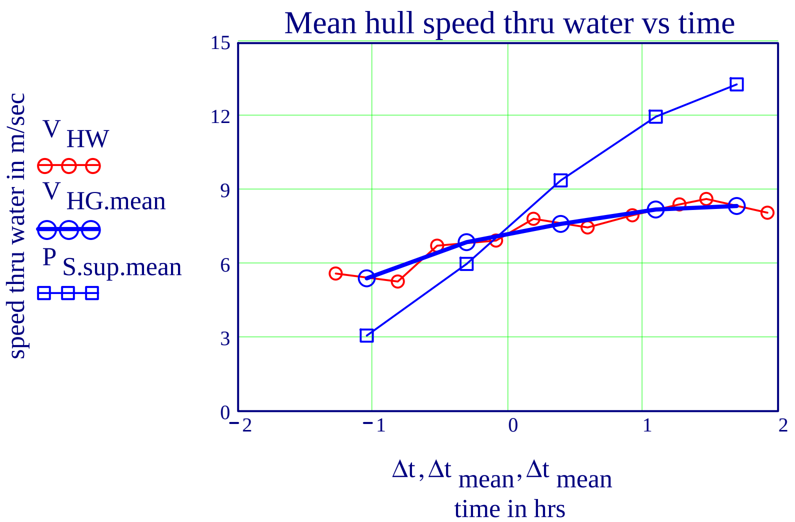
$V_{WG.mean} := v_0$ $\qquad V_{WG.mean} \cdot \frac{m}{kts \cdot sec} = -0.908$ Nominal mean current in kts

$V_{WG.ampl} := \sqrt{(v_1)^2 + (v_2)^2}$ $\qquad V_{WG.ampl} \cdot \frac{m}{kts \cdot sec} = 0.664$ Nominal tidal amplitude in kts

Mean velocity over ground and mean power

$nj := \frac{ni - 1}{2}$ $\qquad j := 0 .. nj$ $\qquad \Delta t_{mean_j} := \frac{\Delta t_{2 \cdot j} + \Delta t_{2 \cdot j + 1}}{2}$

$V_{HG.mean_j} := \frac{V_{HG_{2 \cdot j}} + V_{HG_{2 \cdot j + 1}}}{2}$ $\qquad P_{S.sup.mean_j} := \frac{P_{S.sup_{2 \cdot j}} + P_{S.sup_{2 \cdot j + 1}}}{2}$



In the present case the mean speed over ground happens to be equal to the speed over ground at the mean time between the two corresponding runs.

Scrutinise results of an undisclosed traditional evaluation

Part 1 concerning the speed through the water

Data used in the traditional evaluation

$j := 0 .. ni - 2$

$\Delta t_{trad_j} := \Delta t_{j+2}$ $\quad \Psi_{HG.trad_j} := \Psi_{HG_{j+2}}$ $\quad V_{WG.trad_j} := V_{WG_{j+2}}$

$N_{S.trad_j} := N_{S_{j+2}}$ $\quad P_{S.trad_j} := P_{S_{j+2}}$ $\quad V_{HG.trad_j} := V_{HG_{j+2}}$

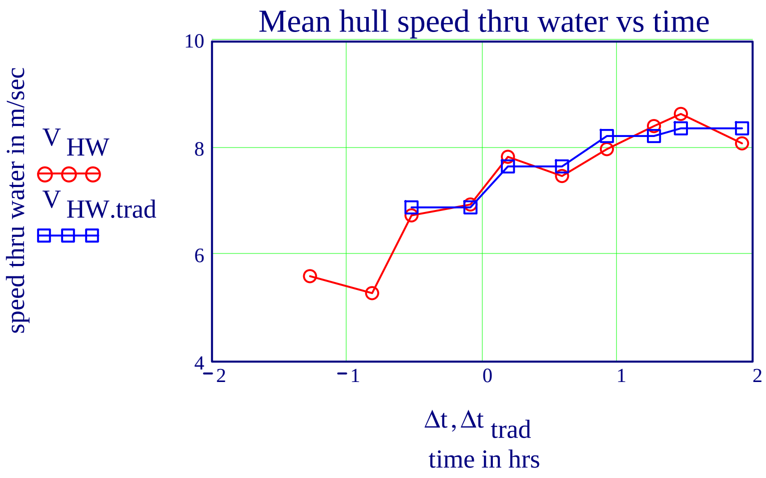
$V_{HW.rat_j} := V_{HW_{j+2}}$ $\quad V_{WG.rat_j} := V_{WG_{j+2}}$

$J_{HW.rat_j} := J_{HW_{j+2}}$ $\quad K_{P.rat_j} := K_{P_{j+2}}$ $\quad K_{P.sup.rat_j} := K_{P.sup_{j+2}}$

Hull speed thru water reported

$$V_{HW.trad} := \begin{pmatrix} 13.39 \\ 13.39 \\ 14.88 \\ 14.88 \\ 15.99 \\ 15.99 \\ 16.27 \\ 16.27 \end{pmatrix} \cdot kts \qquad V_{HW.trad} := V_{HW.trad} \cdot \frac{sec}{m}$$

$$J_{HW.trad_j} := \frac{V_{HW.trad_j}}{D_P \cdot N_{S.trad_j}} \qquad J_{HW.trad} = \begin{pmatrix} 0.710 \\ 0.710 \\ 0.684 \\ 0.684 \\ 0.679 \\ 0.679 \\ 0.669 \\ 0.669 \end{pmatrix}$$



Current velocity identified
by traditional procedure

$$V_{WG.trad_j} := \left(V_{HG.trad_j} - V_{HW.trad_j}\right)\cdot dir\left(\psi_{HG.trad_j}\right)$$

Tidal approximation
as in the rational evaluation

$$A_{WG.trad_{j,0}} := 1$$

$$A_{WG.trad_{j,1}} := \cos\left(\omega_T\cdot\Delta t_{trad_j}\right)$$

$$A_{WG.trad_{j,2}} := \sin\left(\omega_T\cdot\Delta t_{trad_j}\right)$$

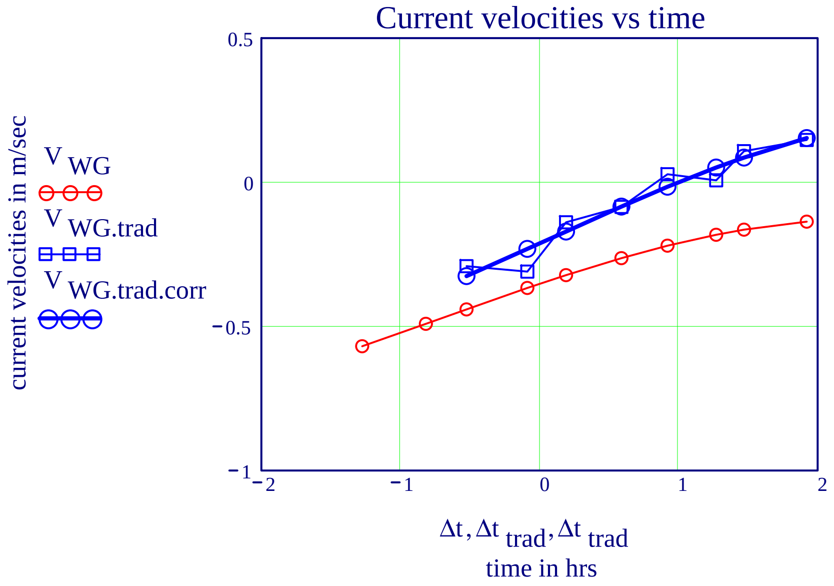
$$X_{WG.trad} := geninv\left(A_{WG.trad}\right)\cdot V_{WG.trad}$$

$$X_{WG.trad} = \begin{bmatrix} -0.195 \\ -0.017 \\ 0.433 \end{bmatrix}$$

$$V_{WG.trad.corr} := A_{WG.trad}\cdot X_{WG.trad}$$

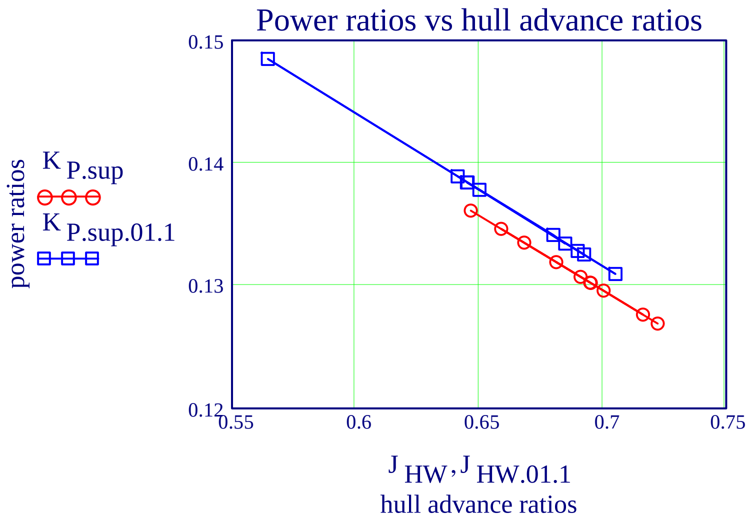
$$\Delta V_{WG.trad} := V_{WG.trad} - V_{WG.trad.corr}$$

$$V_{HW.trad.corr_j} := V_{HG.trad_j} + V_{WG.trad.corr_j}\cdot dir\left(\psi_{HG.trad_j}\right)$$



Compare with results of PATE_01

Powering performance



$\Delta K_P := p_{n.01.1} - p_n$ $\qquad \Delta K_P = \begin{bmatrix} 4.029 \cdot 10^{-3} \\ -3.043 \cdot 10^{-3} \end{bmatrix}$

The powering performances in the behind conditon identified fpr both ships are differing only slightly in values.

Curent

Identified

$V_{WG.mean} \cdot \frac{m}{kts \cdot sec} = -0.908$ Nominal mean current in kts

$V_{WG.ampl} \cdot \frac{m}{kts \cdot sec} = 0.664$ Nominal tidal amplitude in kts

Identified for the trail a fortnight later

$V_{WG.mean.01.1} := v_{01.1_0}$

$V_{WG.ampl.01.1} := \sqrt{\left(v_{01.1_1}\right)^2 + \left(v_{01.1_2}\right)^2}$

$V_{WG.mean.01.1} \cdot \frac{m}{kts \cdot sec} = -0.694$ Nominal mean current in kts

$V_{WG.ampl.01.1} \cdot \frac{m}{kts \cdot sec} = 0.493$ Nominal tidal amplitude in kts

Nominal mean currents and tidal amplitudes compared

Nominal mean currents in kts

Nominal tidal amplitudes in kts

Rational

$V_{WG.mean} \cdot \frac{m}{kts \cdot sec} = -0.908$

$V_{WG.ampl} \cdot \frac{m}{kts \cdot sec} = 0.664$

Traditional

$v := X_{WG.trad}$

$V_{WG.mean} := v_0$

$V_{WG.ampl} := \sqrt{(v_1)^2 + (v_2)^2}$

$V_{WG.mean} \cdot \frac{m}{kts \cdot sec} = -0.378$

$V_{WG.ampl} \cdot \frac{m}{kts \cdot sec} = 0.842$

Mean difference of traditionally identified current

In view of the intricate current conditions in the East China Sea the comparison of the nominal tidal currents is not particularly meaningful, while the results plotted suggest the comparison of the mean difference in the currents identified being more reasonable in the present context.

$\Delta V_{WG} := V_{WG.trad} - V_{WG.rat}$

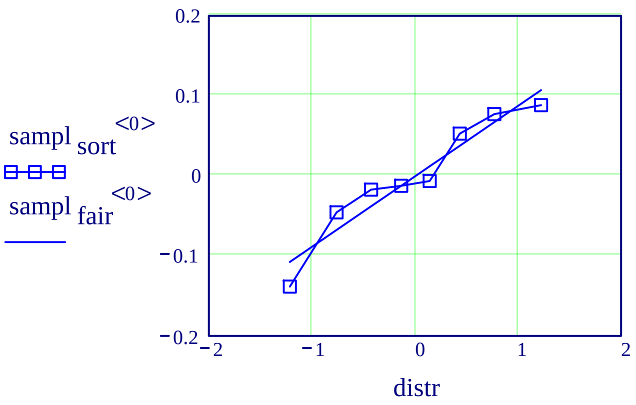
$\Delta V_{WG.mean} := \text{mean}(\Delta V_{WG})$

$\Delta V_{WG.mean} \cdot \frac{m}{kts \cdot sec} = 0.378$ kts

Check distribution of differences in current

$\Delta\Delta V_{WG_j} := \Delta V_{WG_j} - \Delta V_{WG.mean}$

$[\text{distr} \;\; \text{sampl}_{sort} \;\; \text{sampl}_{fair} \;\; \text{distr}_{par}] := \text{norm\_distr}(\Delta\Delta V_{WG})$



$\text{distr}_{par} = \begin{bmatrix} 0.000 \\ 0.088 \\ 0.031 \end{bmatrix}$

According to the plot of differences in currents identified and the subsequent check of the distribution the differences are 'of cause' not quite normally distributed. Thus the following analysis is not quite justified.

95 % confidence radius

number of samples $n_s := ni - 1$

of parameters $n_p := 3$

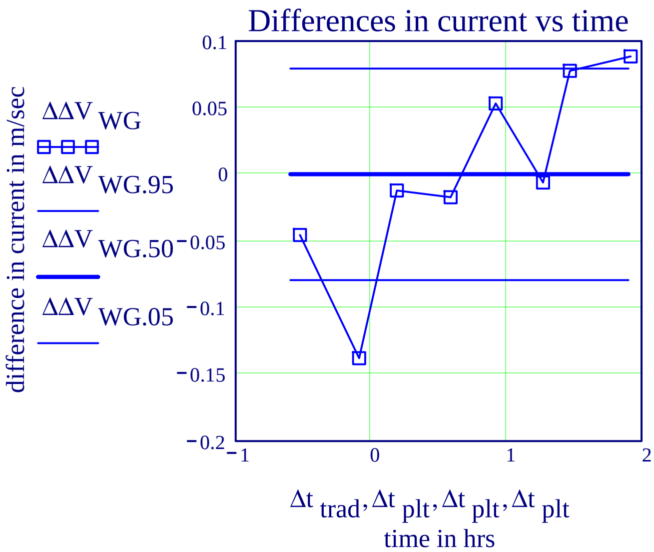
of degrees of freedom $f := n_s - n_p$

$\Delta\Delta V_{WG.95.rad} := C_{95}\left(\Delta\Delta V_{WG}, f\right)$

$\Delta\Delta V_{WG.95.rad} \cdot \frac{m}{kts \cdot sec} = 0.154$ kts

$k := 0 .. 1$ $\Delta t_{plt_0} := -0.6$ $\Delta t_{plt_1} := 1.9$

$\Delta\Delta V_{WG.95_k} := \Delta\Delta V_{WG.95.rad}$ $\Delta\Delta V_{WG.50_k} := 0$ $\Delta\Delta V_{WG.05_k} := -\Delta\Delta V_{WG.95.rad}$



As has been observed again and again the traditional method does not permit correctly to identify the current.

Shaft power ratios vs hull advance ratios

$$V_{HW.trad.corr_j} := V_{HW.rat_j} - \Delta V_{WG.mean} \cdot dir\left(\Psi_{HG.trad_j}\right)$$

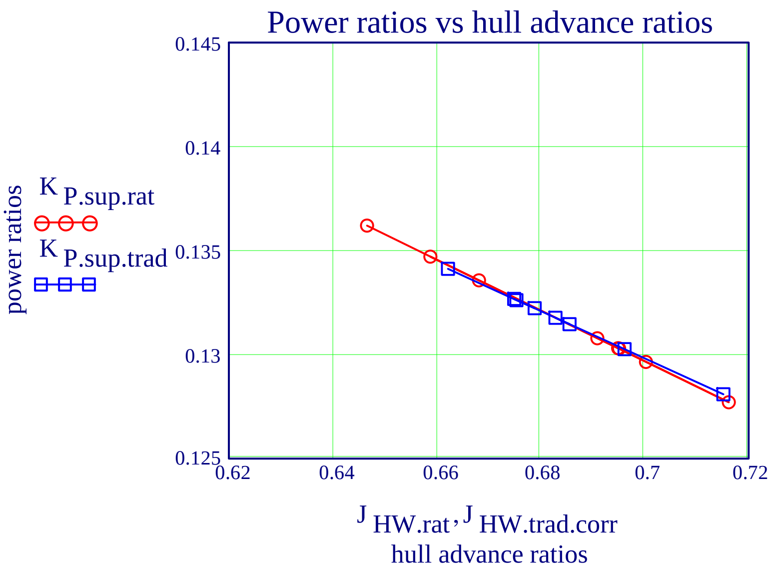
$$J_{HW.trad.corr_j} := \frac{V_{HW.trad.corr_j}}{D_P \cdot N_{S.trad_j}}$$

Fairing power ratios

$$A_{KP_{j,k}} := \left(J_{HW.trad.corr_j}\right)^k$$

$$X_{KP} := geninv\left(A_{KP}\right) \cdot K_{P.rat}$$

$$K_{P.sup.trad} := A_{KP} \cdot X_{KP}$$



Evidently the power ratios versus the advance ratios identified differ significantly in tendency. There may be many reasons, among them the surface effect due to the extremely small nominal propeller submergence not correctly being accounted for in the undisclosed traditional procedure.

Scrutinise results of an undisclosed traditional evaluation

End of Part 1 concerning the hull speed through the water

Analyse power required

Specify relative environmental conditions

Relative wind from ahead

$V_{HA.x_i} := -V_{HA_i} \cdot \cos(\psi_{HA_i})$

$$V_{HA.x} = \begin{bmatrix} -7.574 \\ -5.123 \\ -7.094 \\ -8.670 \\ -8.267 \\ -7.094 \\ -8.019 \\ -7.936 \\ -7.936 \\ -8.859 \end{bmatrix}$$

Check wind speed over ground

$V_{AG_i} := (V_{HA.x_i} - V_{HG_i}) \cdot dir(\psi_{HG_i})$

Approximate quadratically

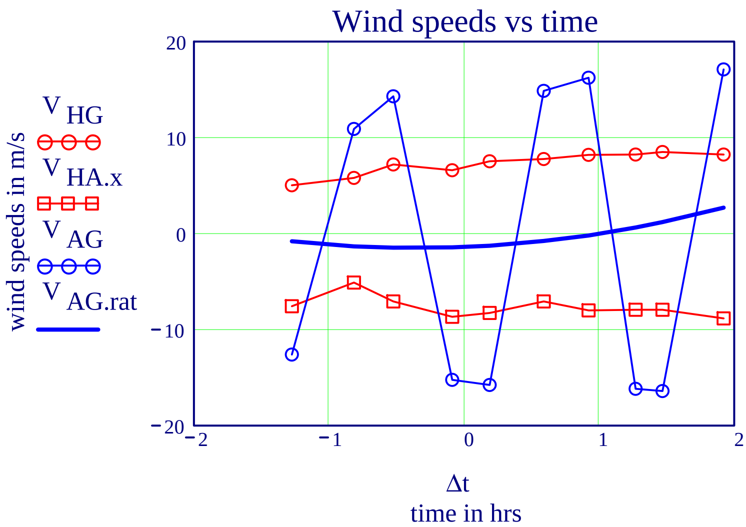
$k := 0 .. 2$

$A_{AG_{i,k}} := (\Delta t_i)^k$

$X_{AG} := geninv(A_{AG}) \cdot V_{AG}$

$$X_{AG} = \begin{bmatrix} -1.417 \\ 0.579 \\ 0.815 \end{bmatrix}$$

$V_{AG.rat} := A_{AG} \cdot X_{AG}$



$$V_{AG.rat} = \begin{bmatrix} -0.823 \\ -1.344 \\ -1.496 \\ -1.464 \\ -1.281 \\ -0.799 \\ -0.200 \\ 0.625 \\ 1.184 \\ 2.689 \end{bmatrix}$$

Relative wind speed corrected

$\Delta V_{AG} := V_{AG.rat} - V_{AG}$

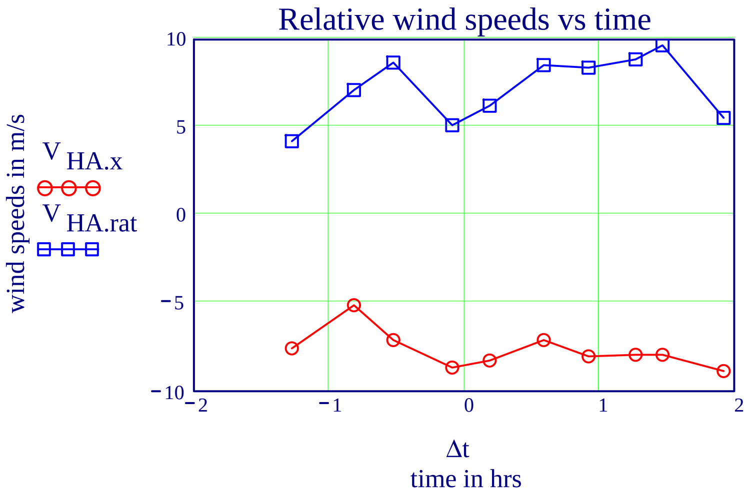
$$\Delta V_{AG} = \begin{bmatrix} 11.781 \\ -12.241 \\ -15.770 \\ 13.784 \\ 14.501 \\ -15.633 \\ -16.419 \\ 16.793 \\ 17.597 \\ -14.394 \end{bmatrix}$$

Evidently the differences depend on the direction of the runs relative the wind.

As oscillations of the wind speed over ground are not expected to correlate with the varying directions of the runs, a correction of this systematic effect, in the measured relative wind speed, maybe due to the installation of the wind meter, is appropriate. But it is worth noting, that the corrected values remain nominal values!

$$V_{HA.rat_i} := V_{HG_i} + V_{AG.rat_i} \cdot dir\left(\psi_{HG_i}\right)$$

$$V_{HA.rat} = \begin{bmatrix} 4.207 \\ 7.118 \\ 8.676 \\ 5.114 \\ 6.234 \\ 8.539 \\ 8.399 \\ 8.857 \\ 9.661 \\ 5.535 \end{bmatrix}$$



Conventions adopted

First power' convention

$$P_{S.req.0}(q, V_{HW}) := q_0 \cdot V_{HW}^3$$

Second power convention

$$P_{S.req.1}(q, V_{HW}, V_{HA}) := q_1 \cdot V_{HA} \cdot |V_{HA}| \cdot V_{HW}$$

Evaluation

$$Res_{req} := Required(V_{HG}, P_{S.sup}, V_{HA.rat})$$

$$[\Delta P_{S.req} \ \ q \ \ P_{S.req} \ \ A_{req} \ \ X_{req}] := Res_{req}$$

$$q = \begin{bmatrix} 0.026 \\ -4.606 \cdot 10^{-3} \\ 0.583 \\ 0.157 \end{bmatrix} \qquad q_{01.2} =$$

Evidently in this case of nearly no wind the standard evaluation does not permit to identify meaningful parameters of the partial powers. Thus the power parameter of the first partial power identified for the sister ship in PATE_01.2 is being used. A similar procedure had already to be adopted in the analysis of the ANANYMA trials, though for a different reason!

Evaluation modified

$$X_{req.0} := q_{01.1_0} \qquad X_{req.0} = 0.0181$$

Evaluation

$$Res_{req} := Required_R(V_{HG}, P_{S.sup}, V_{HA.rat}, X_{req.0})$$

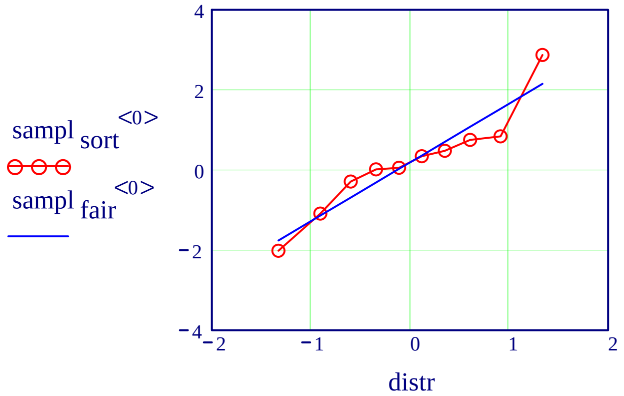
$$[\Delta P_{S.req} \ \ q \ \ P_{S.req} \ \ A_{req} \ \ X_{req}] := Res_{req}$$

$$q = \begin{bmatrix} 0.0181 \\ 0.0025 \\ 1.2830 \\ 0.1573 \end{bmatrix} \qquad q_{01.1} = \begin{bmatrix} 0.0181 \\ 0.0017 \\ 0.4122 \\ 0.2142 \end{bmatrix}$$

Thus the procedure adopted results in a value of parameter for the second partial power at least in the range expected for a sister ship at nearly the same conditions, although at much less wind.speed and wave height.

Check distribtution

$\left[\text{distr} \;\; \text{sampl}_{sort} \;\; \text{sampl}_{fair} \;\; \text{distr}_{par} \right] := \text{norm\_distr}\left(\Delta P_{S.req}\right)$



$$\text{distr}_{par} = \begin{bmatrix} 0.201 \\ 1.465 \\ 0.463 \end{bmatrix}$$

According to this plot the normal distribution of the power residua is distorted by outliers!

95 % confidence radius

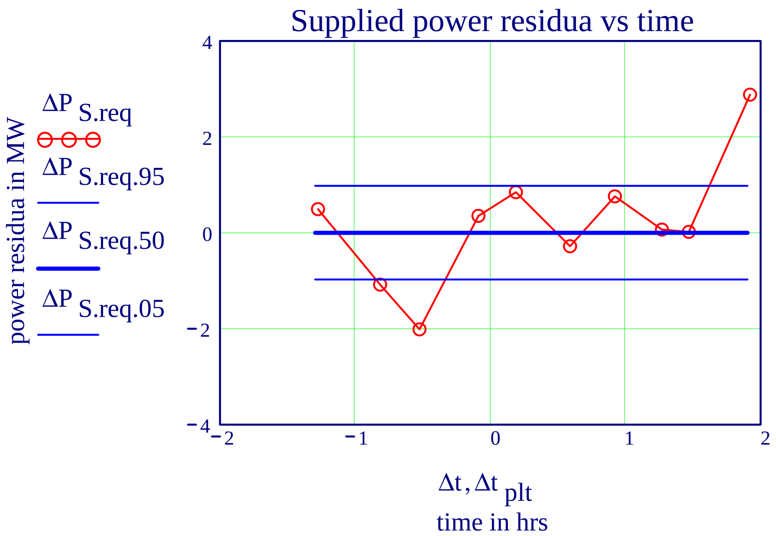
number of samples — of parameters — of degrees of freedom

$n_s := ni + 1$ $\quad n_p := 2$ $\quad f := n_s - n_p$

$P_{S.req.95} := C_{95}\left(\Delta P_{S.req}, f\right)$ $\quad P_{S.req.95} = 0.978$

$k := 0 .. 1$ $\quad \Delta t_{plt_0} := -1.3$ $\quad \Delta t_{plt_1} := 1.9$

$\Delta P_{S.req.05_k} := -P_{S.req.95}$ $\quad \Delta P_{S.req.50_k} := 0$ $\quad \Delta P_{S.req.95_k} := P_{S.req.95}$



$$q = \begin{bmatrix} 0.018 \\ 2.521 \cdot 10^{-3} \\ 1.283 \\ 0.157 \end{bmatrix}$$

As usual the required power residua are much larger than in case of the supplied power due to the uncertainties in the wind measurements and the crude wave observations.

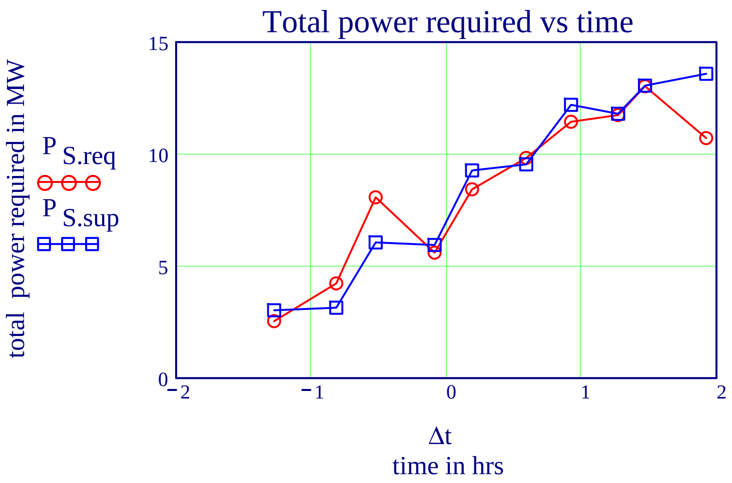
In view of the values of the powers measured the value of the confidence radius is felt to be quite realistic, the relative values ranging from 10 to 2.5 %.

$$p_{S_i} := \frac{P_{S.req.95}}{P_{S_i}}$$

$$p_S = \begin{bmatrix} 0.325 \\ 0.311 \\ 0.162 \\ 0.165 \\ 0.105 \\ 0.102 \\ 0.080 \\ 0.083 \\ 0.075 \\ 0.072 \end{bmatrix}$$

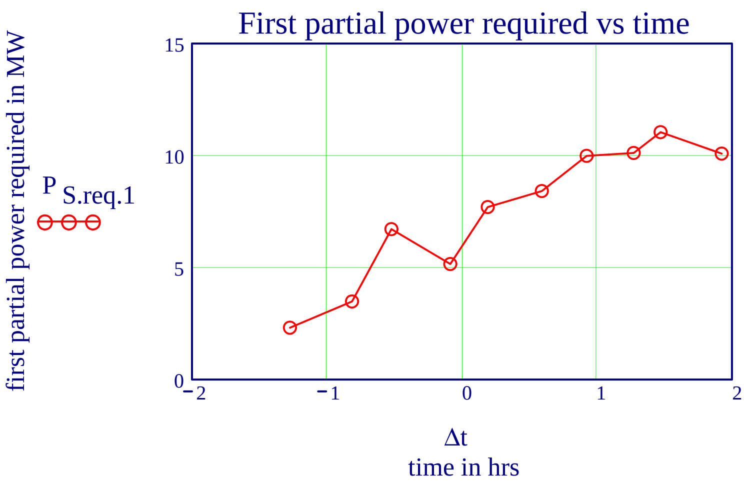
Powers required

Total power required



First partial power required

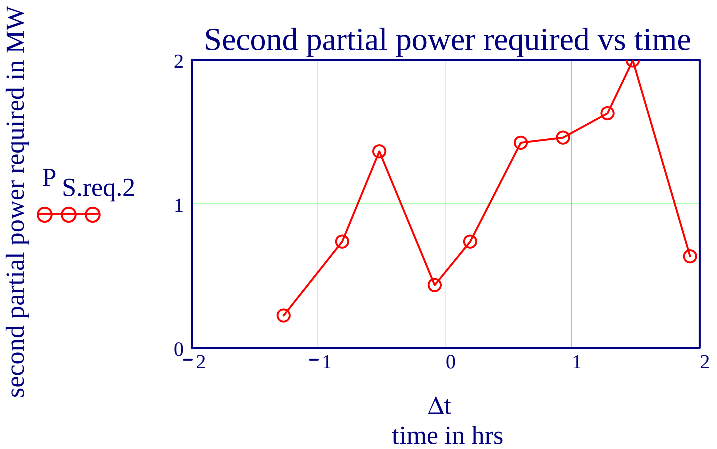
$$P_{S.req.1} := A_{req}^{\langle 0 \rangle} \cdot X_{req_0}$$



$$P_{S.req.1} = \begin{bmatrix} 2.305 \\ 3.485 \\ 6.705 \\ 5.154 \\ 7.686 \\ 8.400 \\ 9.981 \\ 10.101 \\ 11.032 \\ 10.073 \end{bmatrix}$$

Second partial power required

$$P_{S.req.2} := A_{req}^{\langle 1 \rangle} \cdot X_{req_1}$$



$$P_{S.req.2} = \begin{bmatrix} 0.224 \\ 0.737 \\ 1.362 \\ 0.434 \\ 0.736 \\ 1.423 \\ 1.458 \\ 1.627 \\ 1.994 \\ 0.635 \end{bmatrix}$$

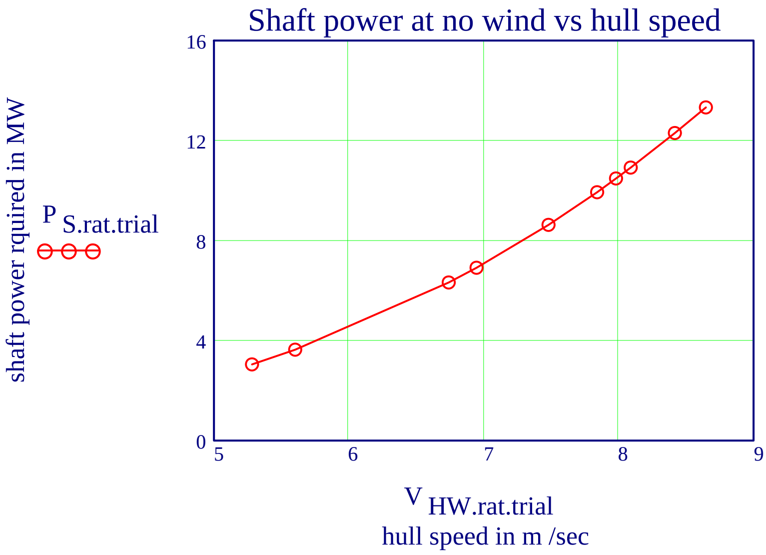
Re-order runs

$R_{i,0} := i + 2 \qquad R^{\langle 1 \rangle} := V_{HW} \qquad R := \mathrm{csort}(R, 1) \qquad Run := R^{\langle 0 \rangle}$

Nominal power vs hull speed
at the nominal no wind condition

$V_{HW.rat.trial} := R^{\langle 1 \rangle}$

$C_{PV} := q_0 + q_1 \qquad C_{PV} = 0.02063 \qquad P_{S.rat.trial_i} := C_{PV} \cdot \left(V_{HW.rat.trial_i}\right)^3$



$$P_{S.rat.trial} = \begin{bmatrix} 3.040 \\ 3.623 \\ 6.315 \\ 6.911 \\ 8.625 \\ 9.932 \\ 10.477 \\ 10.911 \\ 12.291 \\ 13.317 \end{bmatrix}$$

Nota bene: The power at the nominal no wind condition identified is that at the hull condition, the loading condition and the sea condition prevailing at the trials!

Powering performance

at the nominal no wind condition

Normalise power coefficient

$$C_{PV.n} := \frac{C_{PV} \cdot 10^6}{\rho \cdot D_P^{\,2}}$$

Identify equilibrium

$J := 0.5 \qquad K := 0.15$ Initial values

Given

$$K = p_{n_0} + p_{n_1} \cdot J$$

$$K = C_{PV.n} \cdot J^3$$

Solve

$$\begin{bmatrix} J_{HW.noVAW} \\ K_{P.noVAW} \end{bmatrix} := \mathrm{Find}(J, K)$$

$J_{HW.noVAW} = 0.687 \qquad K_{P.noVAW} = 0.131$

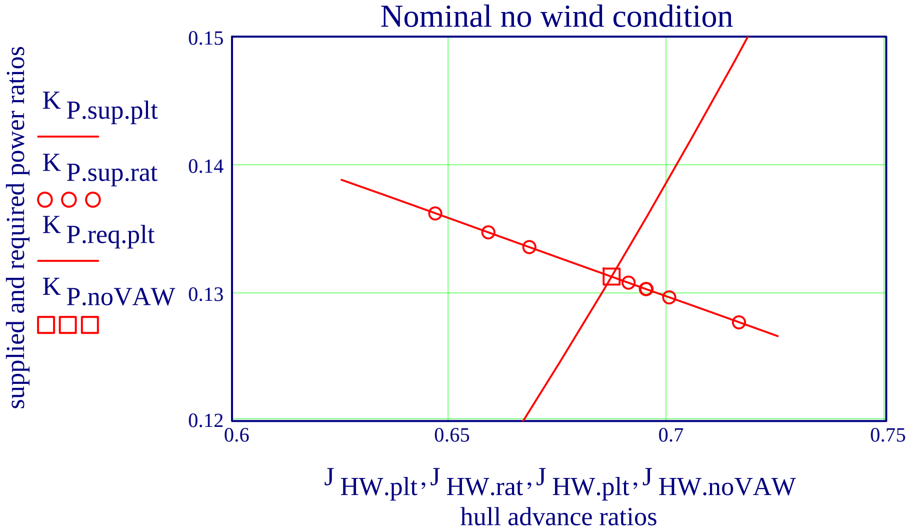
Results plotted

$k := 0 .. 10$

$$J_{HW.plt_k} := 0.625 + 0.01 \cdot k$$

$$K_{P.sup.plt_k} := p_{n_0} + p_{n_1} \cdot J_{HW.plt_k}$$

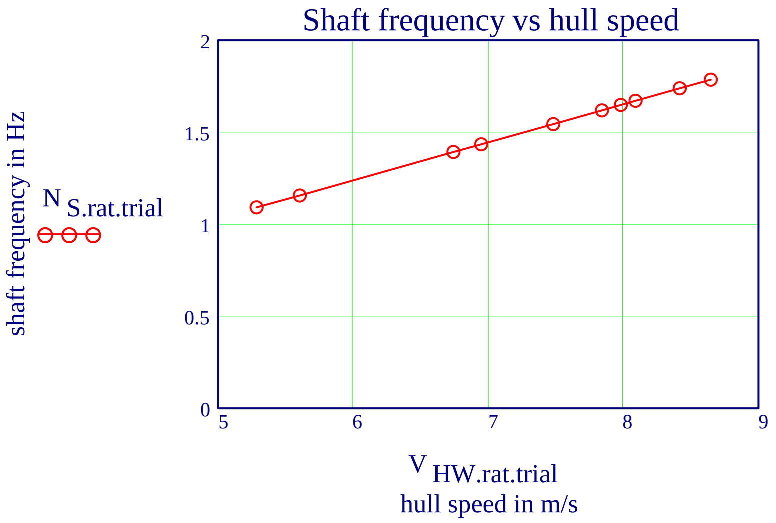
$$K_{P.req.plt_k} := C_{PV.n} \cdot \left(J_{HW.plt_k}\right)^3$$



Frequency of shaft rev's
at the nominal no wind condition

According to the conventions adopted the result is obtained according to the following simple rule.

$$N_{S.rat.trial_i} := \frac{V_{HW.rat.trial_i}}{J_{HW.noVAW} \cdot D_P}$$



$$N_{S.rat.trial} = \begin{bmatrix} 1.091 \\ 1.156 \\ 1.392 \\ 1.434 \\ 1.544 \\ 1.618 \\ 1.647 \\ 1.670 \\ 1.738 \\ 1.785 \end{bmatrix}$$

The very clumsy check of consistency performed in case of ANONYMA was neither necessary nor transparent!

Scrutinise results of an undisclosed traditional evaluation

Part 2 concerning the powers supplied and required

The results of the traditional evaluation are those predicted for the reference condition, which differes only slightly from the trials condition.

Trials condition

$T_{aft.trial} := 7.42 \cdot m$

$T_{fore.trial} := 6.12 \cdot m$

$D_{Vol.trial} := 58894.1 \cdot m^3$

Reference condition

$T_{aft.ref} := 7.60 \cdot m$

$T_{fore.ref} := 6.10 \cdot m$

$D_{Vol.ref} := 59649.0 \cdot m^3$

Propeller power supplied (delivered) and shaft frequency at reference condition reported

$$V_{HW.trad} = \begin{bmatrix} 6.888 \\ 6.888 \\ 7.655 \\ 7.655 \\ 8.226 \\ 8.226 \\ 8.370 \\ 8.370 \end{bmatrix} \quad P_{S.trad} := \begin{bmatrix} 5.9284 \\ 5.9191 \\ 9.1332 \\ 9.4898 \\ 12.1716 \\ 11.7092 \\ 13.0222 \\ 13.5097 \end{bmatrix} \cdot MW \quad N_{S.trad} := \begin{bmatrix} 75.8 \\ 81.8 \\ 94.6 \\ 89.4 \\ 97.5 \\ 102.7 \\ 105.0 \\ 99.7 \end{bmatrix} \cdot rpm \quad \eta_D := \begin{bmatrix} 0.828 \\ 0.824 \\ 0.801 \\ 0.808 \\ 0.788 \\ 0.780 \\ 0.770 \\ 0.781 \end{bmatrix}$$

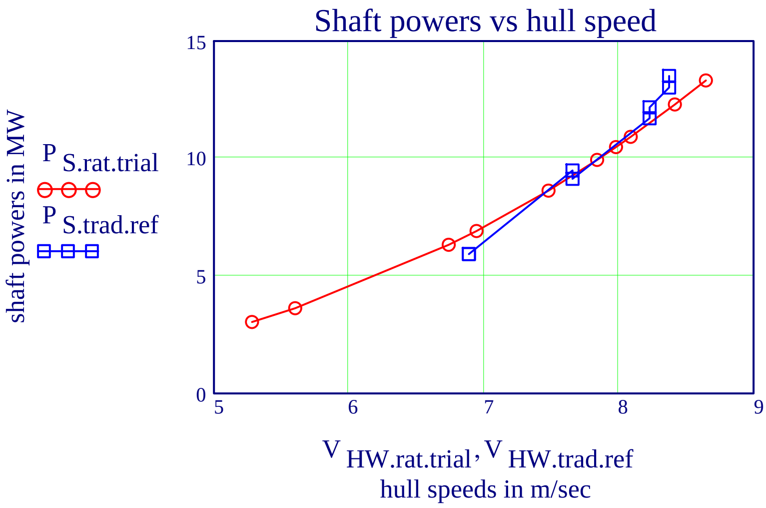
$$P_{S.trad} := \frac{P_{S.trad}}{MW} \qquad N_{S.trad} := \frac{N_{S.trad}}{Hz}$$

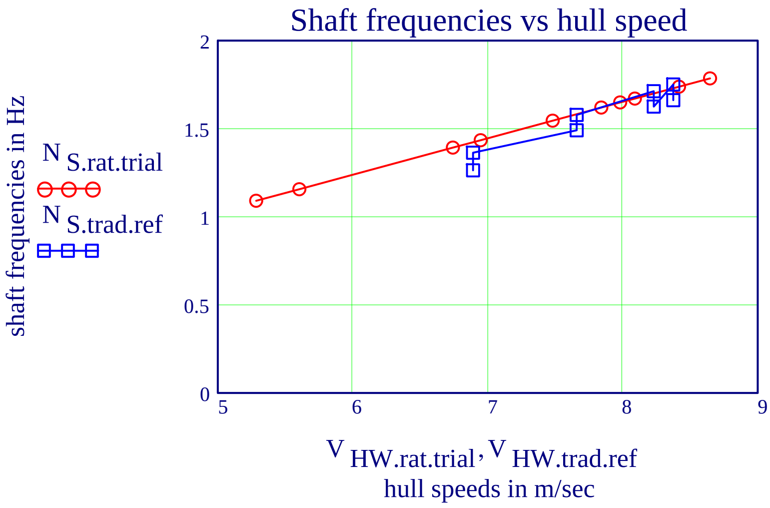
$ref^{\langle 0 \rangle} := V_{HW.trad}$ $\quad ref^{\langle 1 \rangle} := P_{S.trad}$ $\quad ref^{\langle 2 \rangle} := N_{S.trad}$ $\quad ref^{\langle 3 \rangle} := \eta_D$

$ref := csort(ref, 0)$

$V_{HW.trad.ref} := ref^{\langle 0 \rangle}$ $\quad P_{S.trad.ref} := ref^{\langle 1 \rangle}$ $\quad N_{S.trad.ref} := ref^{\langle 2 \rangle}$ $\quad \eta_{D.trad} := ref^{\langle 1 \rangle}$

As far as has been disclosed the results of the traditional evaluation are based on the considerable number of nine small corrections and most importantly on the 'calculated propulsive efficiency values' reported, as has been explicitly stated in a remark.





Evidently the results of the rational evaluation at the trials condition, requiring no prior data, and the results of the traditional evaluation at the only slightly different reference condition, requiring very many prior data, last but not least the computed values of the propulsive efficiency, are very nearly the same, not to say 'identical'.

Computed values of the propulsive efficiency analysed

$k := 0 .. 1$

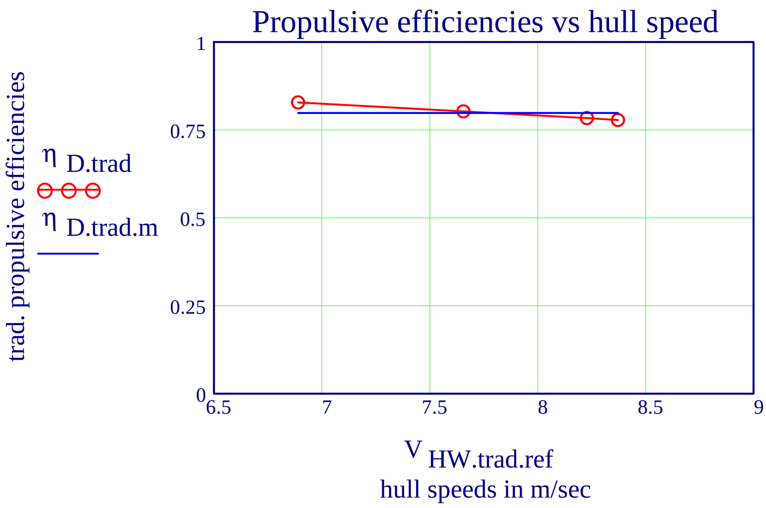
$A_{eta_{j,k}} := \left(V_{HW.trad.ref_j}\right)^k$

$X_{eta} := \text{geninv}\left(A_{eta}\right) \cdot \eta_D$

$\eta_{D.trad} := A_{eta} \cdot X_{eta}$

$\eta_{D.trad.mean} := \text{mean}\left(\eta_{D.trad}\right)$

$\eta_{D.trad.m_j} := \eta_{D.trad.mean}$



This analysis shows that the traditional evaluation is practically in accordance with the convention, implying that the propeller is permanently operating at the same normalised condition, resulting in the quadratic resistance law..

$C_{RV.tot} := \eta_{D.trad.mean} \cdot C_{PV}$

$R_{HW.trad.tot_j} := C_{RV.tot} \cdot \left(V_{HW.trad.ref_j}\right)^2$

How the computed values of the propulsive efficiency have been arrived at in the traditional evaluation remains undisclosed, while **the resistance and the propulsive efficiency can be identified in a rational way solely from data acquired at quasi-steady monitoring tests without any prior information what-so-ever being necessary,** as has been shown in a 'model' study published on my website and in the Festschrift 'From METEOR 1988 to ANONYMA 2013 and further' also to be found on the website.

Scrutinise results of an undisclosed traditional evaluation

End of Part 2 concerning the powers supplied and required

Recording results
of the rational evaluation at the trial condition
of the traditional evaluation at the reference condition

$$
\text{Record} := \left|
\begin{array}{l}
\text{Internal}_{\text{rat}} \leftarrow \left[\text{Res}_{\text{sup}} \;\; \text{Res}_{\text{req}} \right] \\
\text{Final}_{\text{rat}} \leftarrow \left[\text{Run} \;\; \Delta t \;\; V_{\text{HW.rat.trial}} \;\; P_{\text{S.rat.trial}} \;\; N_{\text{S.rat.trial}} \right] \\
\text{Internal}_{\text{trad}} \leftarrow \left[V_{\text{WG.trad.corr}} \;\; J_{\text{HW.trad.corr}} \;\; K_{\text{P.sup.trad}} \right] \\
\text{Final}_{\text{trad}} \leftarrow \left[\text{Run} \;\; \Delta t_{\text{trad}} \;\; V_{\text{HW.trad.ref}} \;\; P_{\text{S.trad.ref}} \;\; N_{\text{S.trad.ref}} \right] \\
\text{record} \leftarrow \left[\text{Internal}_{\text{rat}} \;\; \text{Final}_{\text{rat}} \;\; \text{Internal}_{\text{trad}} \;\; \text{Final}_{\text{trad}} \right] \\
\text{record}
\end{array}
\right.
$$

$\text{File} := \text{concat}(\text{"Results\_"}, \text{EID})$

$\text{WRITEPRN}(\text{File}) := \text{Record}$

Print final rational results

$\text{final}_{\text{rat}}^{\langle 0 \rangle} := \text{Run}$

$\text{final}_{\text{rat}}^{\langle 1 \rangle} := V_{\text{HW.rat.trial}} \cdot \dfrac{m}{\text{kts} \cdot \text{sec}}$

$\text{final}_{\text{rat}}^{\langle 2 \rangle} := P_{\text{S.rat.trial}}$

$\text{final}_{\text{rat}}^{\langle 3 \rangle} := N_{\text{S.rat.trial}} \cdot \dfrac{\min}{\text{sec}}$

$$
\text{final}_{\text{rat}} = \begin{bmatrix}
3.000 & 10.267 & 3.040 & 65.441 \\
2.000 & 10.885 & 3.623 & 69.380 \\
4.000 & 13.100 & 6.315 & 83.496 \\
5.000 & 13.500 & 6.911 & 86.046 \\
7.000 & 14.535 & 8.625 & 92.642 \\
6.000 & 15.235 & 9.932 & 97.103 \\
8.000 & 15.508 & 10.477 & 98.846 \\
11.000 & 15.720 & 10.911 & 100.193 \\
9.000 & 16.356 & 12.291 & 104.251 \\
10.000 & 16.799 & 13.317 & 107.074
\end{bmatrix}
$$

Conclusions

For the whole context and for more details the Conclusions of PATE_01 should be referred to!

In this case of nearly ideal environmental trial conditions the (accidental) coincidence of the the final results of rational and traditional evaluations is not as perfect as in case of the sister ship at heavy wind and higher waves.

While the current and the powering performance are in perfect agreement with the results of the rational evaluation, the somewhat erratic final results of the traditional evaluation remain unexplained.

While the identification of the propeller powering performance in the behind condition poses no problems at all, it does not come as a surprise, that the rational evaluation suffers from ill-conditioned equations for the identifcation of the parameters of the partial powers at ideal conditions. In the present case a reliable value for the first partial power happened to be available.

The rational procedure to overcome the problem is to perform quasi-steady tests as has been stated over and over again and as have been performed with the METEOR, CORSAIR and a model. The data acquired at the model test have recently being used to demonstrate the feasibility of the full scale identification of resistance and propulsive efficiency.

END
Powering performance of a bulk carrier during speed trials in ballast condition reduced to nominal no wind condition