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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 **an upgraded version of the first of my 'post-ANONYMA trial evaluations' published earlier as PATE_01. For the whole context and for more details the Conclusions of PATE_01 should be referred to!**

Data provided

The powering trial analysed according to the rational procedure promoted is one of the reference cases of an ongoing research project. 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 unspecified, more or less traditional procedure, few results have been provided.

Rational evaluation

The following analysis is solely based on extremely simple propeller, current and environment conventions and on the mean data reported, though without their confidence ranges. No prior data and parameters will be used, particularly not those derived from corresponding model tests. Thus the procedure and its results are as transparent and observer independent as necessary for the rational resolution of 'conflicts' of any type!

Subsequent trustworthy predictions (!) of the powering performance at loading conditions and sea states differing from those prevailing during the trials are *not* subject of this exercise. But in the Conclusions at the end of PATE_01 serious doubts concerning any traditional convention based on prior data are being expressed and future solutions are being outlined.

'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

Trial identification

Identify trial and evaluation

TID := "01.3"

EID := concat("PATE_" , TID)   EID = "PATE_01.3"

'Constants'

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

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

Trials conditions

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

Nominal propeller submergence

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

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

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

Wave

$$\psi_{WaveH} := \begin{bmatrix} 5 \\ 175 \\ 175 \\ 5 \\ 5 \\ 175 \\ 175 \\ 5 \end{bmatrix} \cdot deg$$

$H_{Wave} := 3.3 \cdot m$ wave height

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

Water depth

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

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 confidence radii of the mean values have been reported.

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

$$time := \begin{bmatrix} 5 & 21 \\ 5 & 48 \\ 6 & 04 \\ 6 & 28 \\ 6 & 44 \\ 7 & 7 \\ 7 & 25 \\ 7 & 46 \\ 8 & 10 \\ 8 & 29 \\ 8 & 41 \\ 9 & 5 \end{bmatrix} \quad \psi_{HG} := \begin{bmatrix} 180 \\ 0 \\ 0 \\ 180 \\ 180 \\ 0 \\ 0 \\ 180 \\ 180 \\ 0 \\ 0 \\ 180 \end{bmatrix} \cdot deg \quad V_{HA} := \begin{bmatrix} 35 \\ 11 \\ 11 \\ 35 \\ 41 \\ 10 \\ 10 \\ 42 \\ 44 \\ 8 \\ 7 \\ 45 \end{bmatrix} \cdot kts \quad \psi_{HA} := \begin{bmatrix} 5 \\ 160 \\ 160 \\ 5 \\ 5 \\ 160 \\ 155 \\ 5 \\ 5 \\ 165 \\ 160 \\ 0 \end{bmatrix} \cdot deg$$

Shaft frequency — Measured shaft power — Ship speed over ground

$$N_S := \begin{bmatrix} 52.47 \\ 52.47 \\ 66.58 \\ 66.60 \\ 82.26 \\ 82.27 \\ 94.85 \\ 94.86 \\ 102.81 \\ 102.88 \\ 104.89 \\ 104.87 \end{bmatrix} \cdot \frac{1}{min} \quad P_S := \begin{bmatrix} 1924 \\ 1758 \\ 3232 \\ 3639 \\ 6358 \\ 6038 \\ 9344 \\ 9730 \\ 12425 \\ 12055 \\ 12778 \\ 13248 \end{bmatrix} \cdot kW \quad V_{HG} := \begin{bmatrix} 6.657 \\ 8.210 \\ 11.044 \\ 7.967 \\ 11.442 \\ 14.018 \\ 15.784 \\ 13.049 \\ 14.256 \\ 17.152 \\ 17.380 \\ 14.211 \end{bmatrix} \cdot kts$$

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

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

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

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

Normalise data

At this stage for preliminary check of consistency only!

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

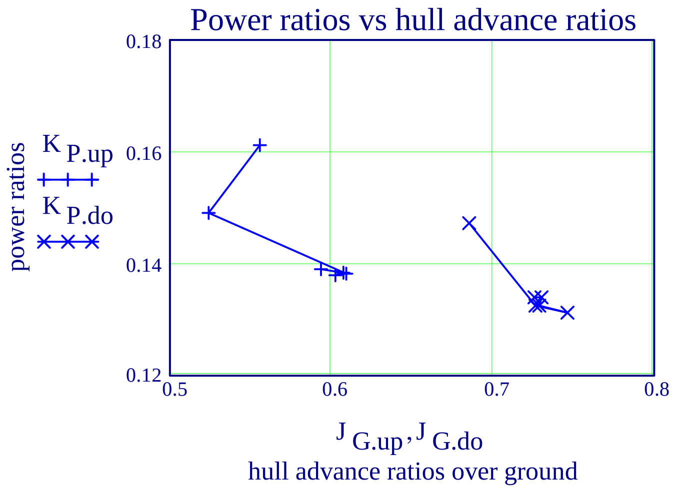
Sort runs

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

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

$J_{G.up} = \begin{bmatrix} 0.555 \\ 0.524 \\ 0.609 \\ 0.602 \\ 0.607 \\ 0.593 \end{bmatrix}$ $\quad K_{P.up} = \begin{bmatrix} 0.161 \\ 0.149 \\ 0.138 \\ 0.138 \\ 0.138 \\ 0.139 \end{bmatrix}$ $\quad J_{G.do} = \begin{bmatrix} 0.685 \\ 0.726 \\ 0.746 \\ 0.729 \\ 0.730 \\ 0.725 \end{bmatrix}$ $\quad K_{P.do} = \begin{bmatrix} 0.147 \\ 0.133 \\ 0.131 \\ 0.132 \\ 0.134 \\ 0.134 \end{bmatrix}$

Scrutinise data



Evidently the values at the first double run are outliers eliminated without further study of possible reasons in PATE_01.1. 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.

In order to study the effect of a further reduction of data, of smaller data sets in general, in practice typically only three double runs are being performed, the following analysis is based on the data of the third, the fourth and the sixth double run only.

Data eliminated

$ne := 6 \qquad ni := last(t) - ne$

$i := 0 .. ni$

$$run := \begin{bmatrix} 4 \\ 5 \\ 6 \\ 7 \\ 10 \\ 11 \end{bmatrix}$$

$\Delta t_{red_i} := \Delta t_{run_i} \qquad \Psi_{HG.red_i} := \Psi_{HGrun_i} \qquad V_{HA.red_i} := V_{HArun_i}$

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

$N_{S.red_i} := N_{Srun_i} \qquad P_{S.red_i} := P_{Srun_i} \qquad V_{HG.red_i} := V_{HG}\left(run_i\right)$

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

Normalise reduced data

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

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

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

$J_{HG.up} = \begin{bmatrix} 0.609 \\ 0.602 \\ 0.593 \end{bmatrix}$ $\quad K_{P.up} = \begin{bmatrix} 0.138 \\ 0.138 \\ 0.139 \end{bmatrix}$ $\quad J_{HG.do} = \begin{bmatrix} 0.746 \\ 0.729 \\ 0.725 \end{bmatrix}$ $\quad K_{P.do} = \begin{bmatrix} 0.131 \\ 0.132 \\ 0.134 \end{bmatrix}$

Read results of PATE_01.1

**for ready comparison with the results
of the foregoing analysis of the trial
ignoring only the data of the first double run,
different from the traditional analysis!**

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

$\left[\text{Internal}_{rat.01.1} \;\; \text{Final}_{rat.01.1} \;\; \text{Internal}_{trad.01.1} \;\; \text{Final}_{trad.01.1}\right] := \text{Record}_{01.1}$

$\left[\text{Res}_{sup.01.1} \;\; \text{Res}_{req.01.1}\right] := \text{Internal}_{rat.01.1}$

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

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

$\left[\text{Run}_{01.1} \;\; \Delta t_{01.1} \;\; V_{HW.rat.trial.01.1} \;\; P_{S.rat.trial.01.1} \;\; N_{S.rat.trial.01.1}\right] := \text{Final}_{rat.01.1}$

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

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

Read results of PATE_01.2
for ready comparison with the results
of the foregoing analysis of the trial
ignoring the data of the first two double run,
different from the traditional analysis!

$$Record_{01.2} := READPRN(\text{"Results\_PATE\_01.2"})$$

$$\left[Internal_{rat.01.2}\ \ Final_{rat.01.2}\ \ Internal_{trad.01.2}\ \ Final_{trad.01.2}\right] := Record_{01.2}$$

$$\left[Res_{sup.01.2}\ \ Res_{req.01.2}\right] := Internal_{rat.01.2}$$

$$\begin{bmatrix} \Delta P_{S.sup.01.2} & v_{01.2} & V_{WG.01.2} \\ V_{HW.01.2} & p_{01.2} & P_{S.sup.01.2} \\ J_{HW.01.2} & p_{n.01.2} & K_{P.sup.01.2} \end{bmatrix} := Res_{sup.01.2}$$

$$\left[\Delta P_{S.req.01.2}\ \ q_{01.2}\ \ P_{S.req.01.2}\ \ A_{req.01.2}\ \ X_{req.01.2}\right] := Res_{req.01.2}$$

$$\left[Run_{01.2}\ \ \Delta t_{01.2}\ \ V_{HW.rat.trial.01.2}\ \ P_{S.rat.trial.01.2}\ \ N_{S.rat.trial.01.2}\right] := Final_{rat.01.1}$$

$$\left[V_{WG.trad.corr.01.2}\ \ J_{HW.trad.corr.01.2}\ \ K_{P.sup.trad.01.2}\right] := Internal_{trad.01.2}$$

$$\left[Run\ \ \Delta t_{trad.01.2}\ \ V_{HW.trad.ref.01.2}\ \ P_{S.trad.ref.01.2}\ \ N_{S.trad.ref.01.2}\right] := Final_{trad.01.2}$$

Analyse power supplied

including identification of tidal current

Conventions adopted

Propeller power convention

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

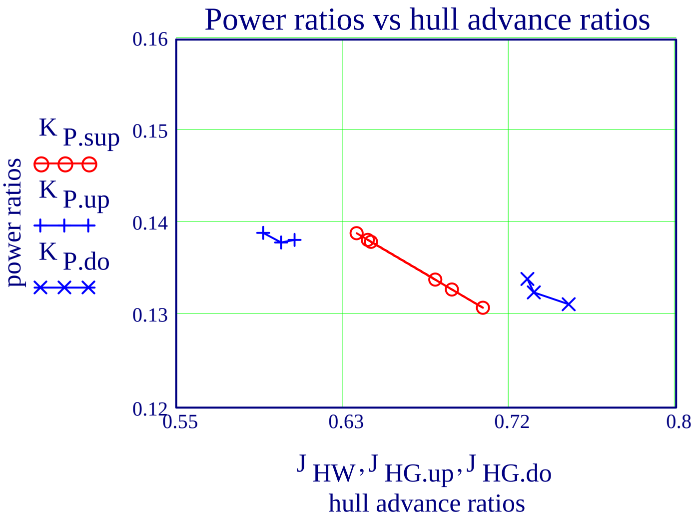
Tidal current velocity convention

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

Evaluate

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

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



$$p = \begin{bmatrix} 3.945 \\ -0.325 \\ 0.014 \\ 1.561 \cdot 10^{-3} \end{bmatrix}$$

$$p_n = \begin{bmatrix} 0.221 \\ -0.128 \end{bmatrix}$$

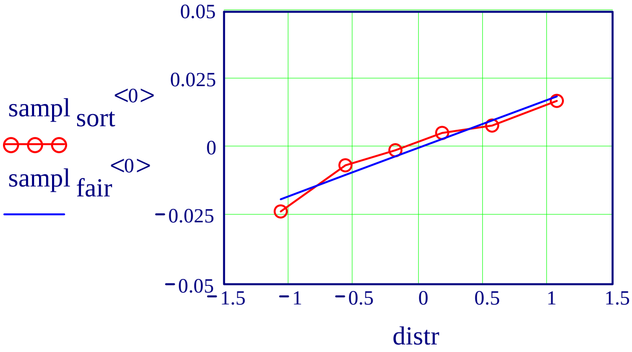
Nota bene: The propeller performance in the behind condition identified is that at the hull condition, the loading condition and the sea condition prevailing at the trials!

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.

$$\begin{bmatrix} distr & sampl_{sort} & sampl_{fair} & distr_{par} \end{bmatrix} := norm\_distr\left(\Delta P_{S.sup}\right)$$



$$distr_{par} = \begin{bmatrix} 1.452\cdot 10^{-4} \\ 0.018 \\ 7.226\cdot 10^{-3} \end{bmatrix}$$

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

95 % confidence radius

number of samples — of parameters — of degrees of freedom

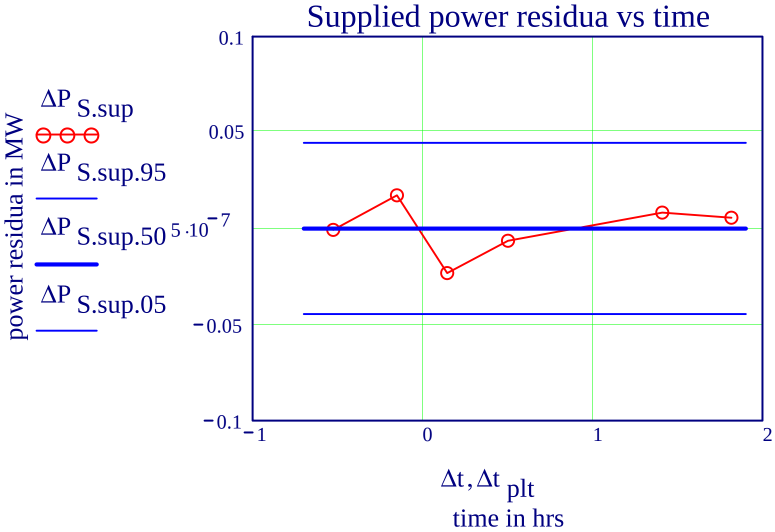
$n_S := ni + 1$ $\quad n_p := 4$ $\quad f := n_S - n_p$

$P_{S.sup.95} := C_{95}\left(\Delta P_{S.sup}, f\right)$ $\quad P_{S.sup.95}\cdot\frac{MW}{kW} = 44.6$ kW

$k := 0..1$ $\quad \Delta t_{plt_0} := -0.7$ $\quad \Delta t_{plt_1} := 1.9$

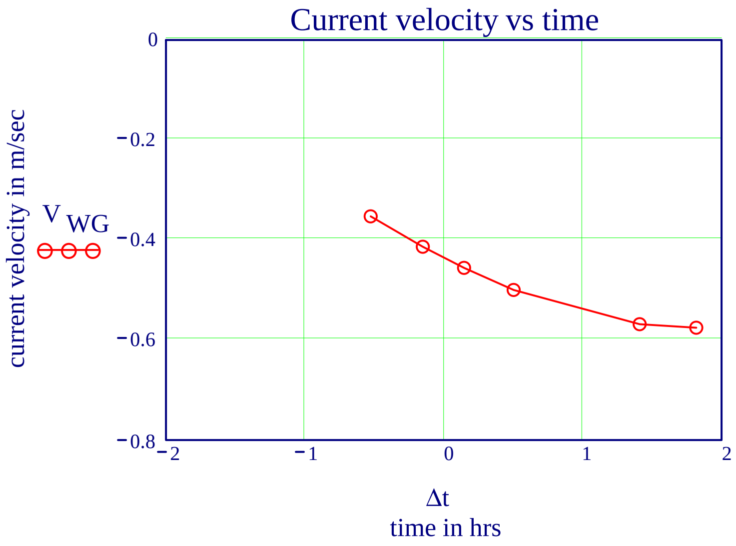
$\Delta P_{S.sup.05_k} := -P_{S.sup.95}$ $\quad \Delta P_{S.sup.50_k} := 0$ $\quad \Delta P_{S.sup.95_k} := P_{S.sup.95}$

Supplied power residua vs time



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



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

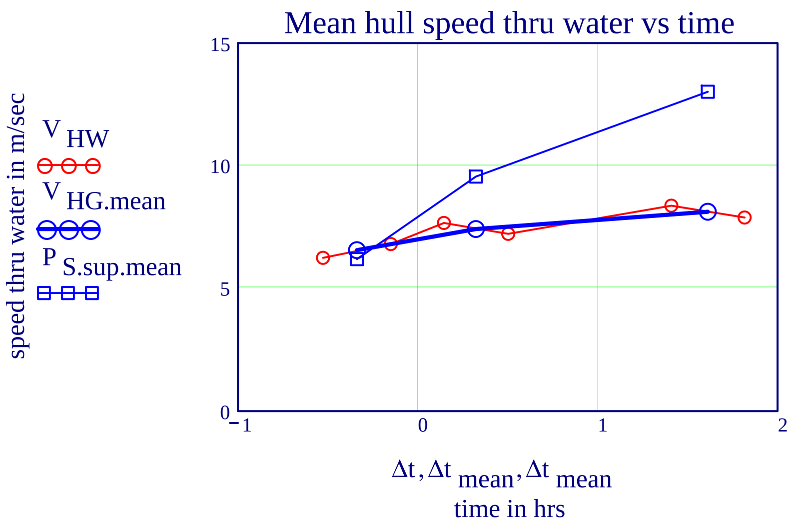
$V_{WG.mean} := v_0$ $\qquad V_{WG.mean} \cdot \frac{m}{kts \cdot sec} = -0.420$ Nominal mean current in kts

$V_{WG.ampl} := \sqrt{(v_1)^2 + (v_2)^2}$ $\qquad V_{WG.ampl} \cdot \frac{m}{kts \cdot sec} = 0.699$ Nominal tidal amplitude in kts

Mean velocity over ground and mean power

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

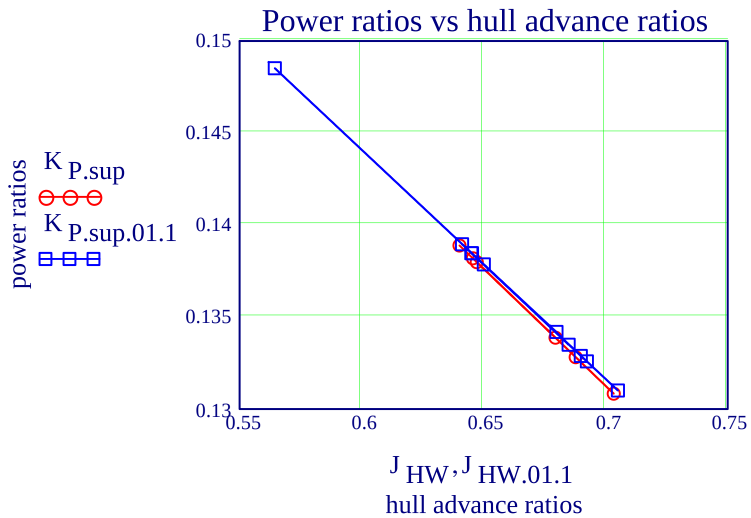
$V_{HG.mean_j} := \frac{V_{HG_{2 \cdot j}} + V_{HG_{2 \cdot j + 1}}}{2}$ $\qquad P_{S.sup.mean_j} := \frac{P_{S.sup_{2 \cdot j}} + P_{S.sup_{2 \cdot j + 1}}}{2}$



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.

Compare with results of PATE_01.1

Powering performances



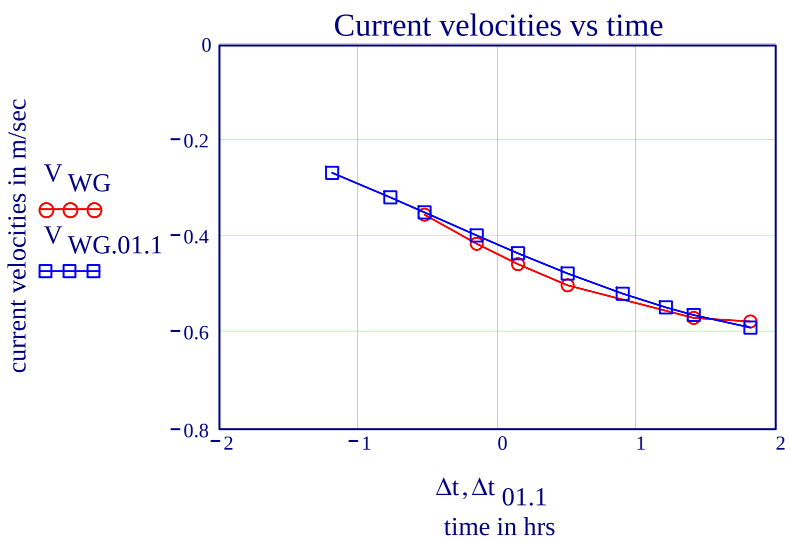
$$p_{01.1} = \begin{bmatrix} 3.914 \\ -0.317 \\ 0.027 \\ 2.402\cdot 10^{-3} \end{bmatrix}$$

$$p = \begin{bmatrix} 3.945 \\ -0.325 \\ 0.014 \\ 1.561\cdot 10^{-3} \end{bmatrix}$$

$$\Delta K_P := p_{n.01.1} - p_n \qquad \Delta K_P = \begin{bmatrix} -1.766\cdot 10^{-3} \\ 2.974\cdot 10^{-3} \end{bmatrix}$$

The powering performances in the behind conditon identified for the two different data sets are differing only very slightly in value and in tendency.

Currents



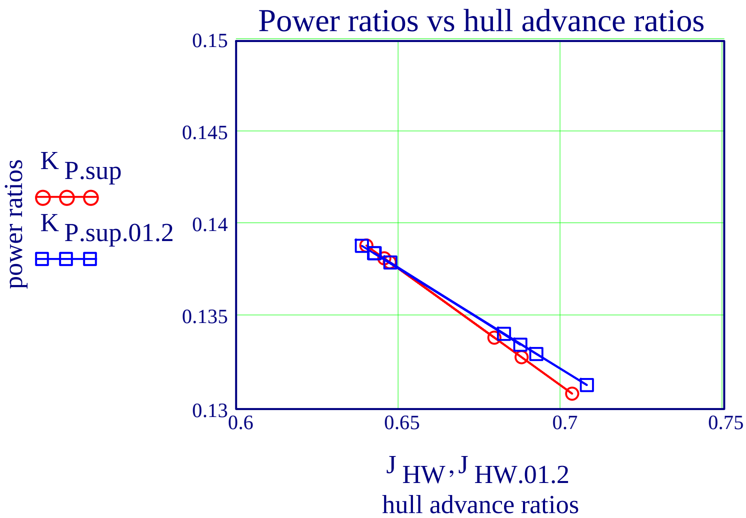
$$V_{WG.01.1.red_i} := V_{WG.01.1_{i+2}}$$

$$\Delta V_{WG} := V_{WG.01.1.red} - V_{WG} \qquad \mathrm{mean}\left(\Delta V_{WG}\right)\cdot\frac{m}{kts\cdot sec} = 0.048 \quad kts$$

The currents identified for the two different data sets are also slightly differing .

Compare with results of PATE_01.2

Powering performances



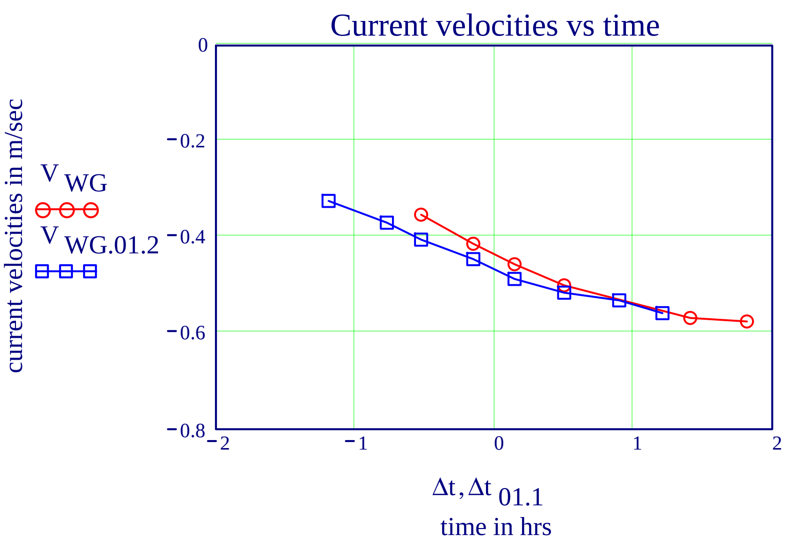
$$p_{01.2} = \begin{bmatrix} 3.744 \\ -0.281 \\ 0.029 \\ 1.306 \cdot 10^{-3} \end{bmatrix}$$

$$p = \begin{bmatrix} 3.945 \\ -0.325 \\ 0.014 \\ 1.561 \cdot 10^{-3} \end{bmatrix}$$

$$\Delta K_P := p_{n.01.2} - p_n \qquad \Delta K_P = \begin{bmatrix} -0.011 \\ 0.017 \end{bmatrix}$$

The powering performances in the behind conditon identified for the two different data sets are differing in value and in tendency slightly more than in the case before.

Currents



$$V_{WG.01.2.red_i} := V_{WG.01.2_{i+2}}$$

$$\Delta V_{WG} := V_{WG.01.2.red} - V_{WG} \qquad \text{mean}\left(\Delta V_{WG}\right) \cdot \frac{m}{kts \cdot sec} = -0.024 \text{ kts}$$

The currents identified for the two different data sets are also differing slightly more than in the case before.

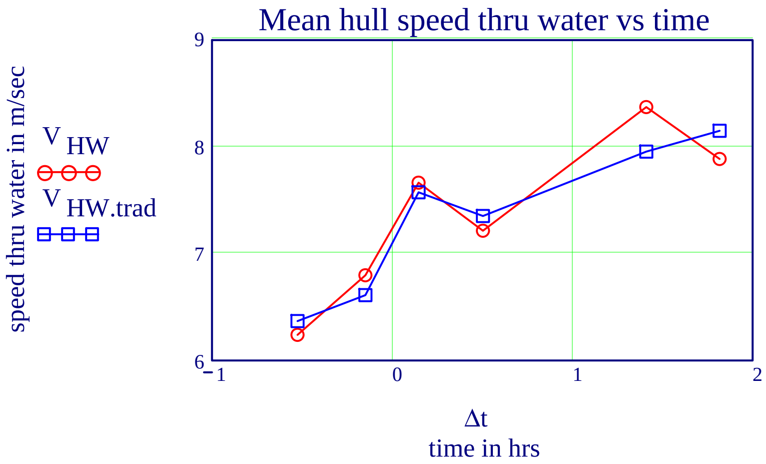
Scrutinise results of an undisclosed traditional evaluation

Part 1 concerning the speed through the water

Hull speed thru water reported

$$V_{HW.trad} := \begin{bmatrix} 12.38 \\ 12.85 \\ 14.72 \\ 14.29 \\ 15.46 \\ 15.84 \\ 16.23 \\ 15.80 \end{bmatrix} \cdot kts \qquad V_{HW.trad} := V_{HW.trad} \cdot \frac{sec}{m}$$

$$J_{HW.trad_i} := \frac{V_{HW.trad_i}}{D_P \cdot N_{S_i}} \qquad J_{HW.trad} = \begin{bmatrix} 0.659 \\ 0.684 \\ 0.679 \\ 0.660 \\ 0.645 \\ 0.661 \end{bmatrix}$$



**Current velocity identified
by traditional procedure**

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

**Tidal approximation
as in the rational evaluation**

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

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

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

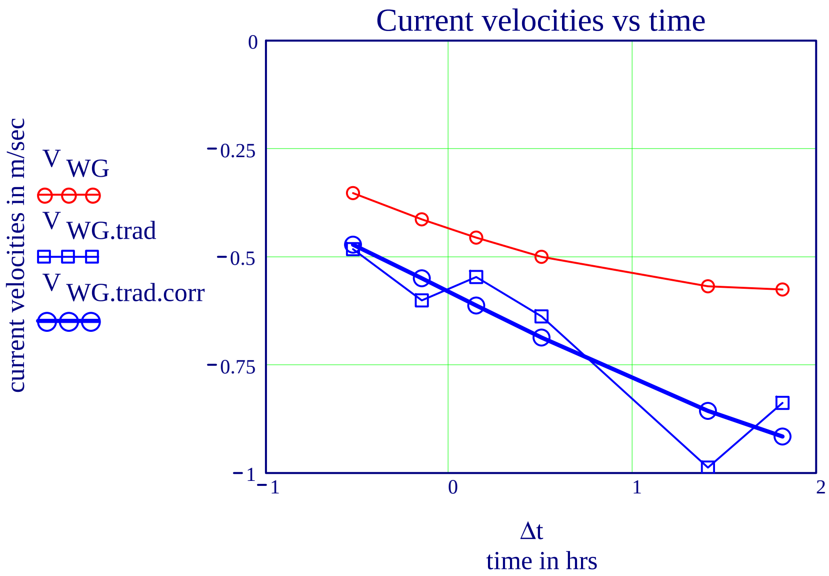
$$X_{WG.trad} := geninv\left(A_{WG.trad}\right) \cdot V_{WG.trad}$$

$$X_{WG.trad} = \begin{bmatrix} -0.586 \\ 4.124 \cdot 10^{-3} \\ -0.418 \end{bmatrix}$$

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

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

$$V_{HW.trad.corr_i} := V_{HG_i} + V_{WG.trad.corr_i} \cdot dir\left(\psi_{HG_i}\right)$$



Nominal mean currents and tidal amplitudes compared

Nominal mean currents in kts

Rational

$V_{WG.mean} \cdot \frac{m}{kts \cdot sec} = -0.420$

Traditional

$v_{trad} := X_{WG.trad}$

$V_{WG.mean.trad} := v_{trad_0}$

$V_{WG.mean.trad} \cdot \frac{m}{kts \cdot sec} = -1.140$

Nominal tidal amplitudes in kts

$V_{WG.ampl} \cdot \frac{m}{kts \cdot sec} = 0.699$

$V_{WG.ampl.trad} := \sqrt{\left(v_{trad_1}\right)^2 + \left(v_{trad_2}\right)^2}$

$V_{WG.ampl.trad} \cdot \frac{m}{kts \cdot sec} = 0.813$

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.

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

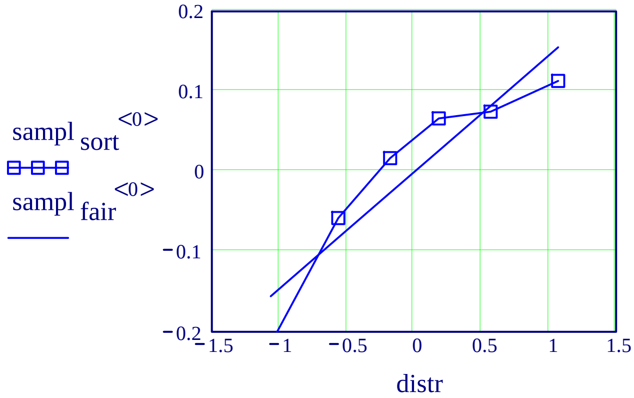
$\Delta V_{WG.mean} := \text{mean}\left(\Delta V_{WG}\right)$

$\Delta V_{WG.mean} \cdot \frac{m}{kts \cdot sec} = -0.398$ kts

Check distribution of differences in current

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

$\left[distr \;\; sampl_{sort} \;\; sampl_{fair} \;\; distr_{par} \right] := \text{norm\_distr}\left(\Delta\Delta V_{WG}\right)$



$distr_{par} = \begin{bmatrix} 0.000 \\ 0.146 \\ 0.059 \end{bmatrix}$

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 $f := n_s - n_p$

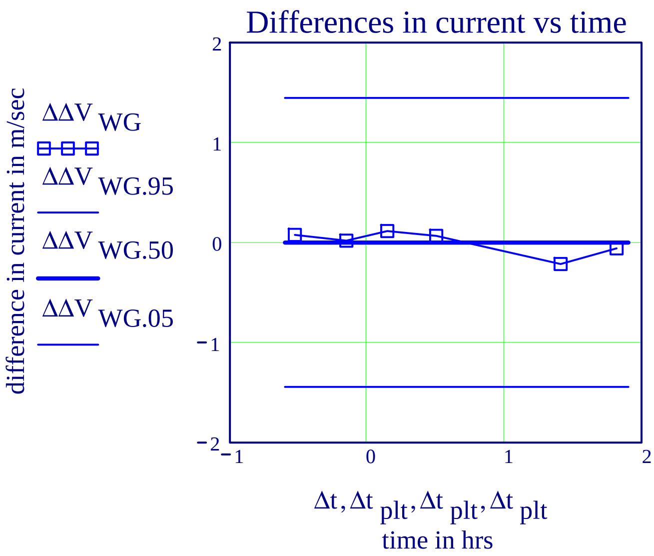
$\Delta\Delta V_{WG.95.rad} := C_{95}\left(\Delta\Delta V_{WG}, f\right)$

$\Delta\Delta V_{WG.95.rad} \cdot \frac{m}{kts \cdot sec} = 2.810$ kts

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

$\Delta\Delta V_{WG.50_k} := 0$

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



Shaft power ratios vs hull advance ratios

$$V_{HW.trad.corr_i} := V_{HW_i} - \Delta V_{WG.mean} \cdot dir\left(\psi_{HG_i}\right)$$

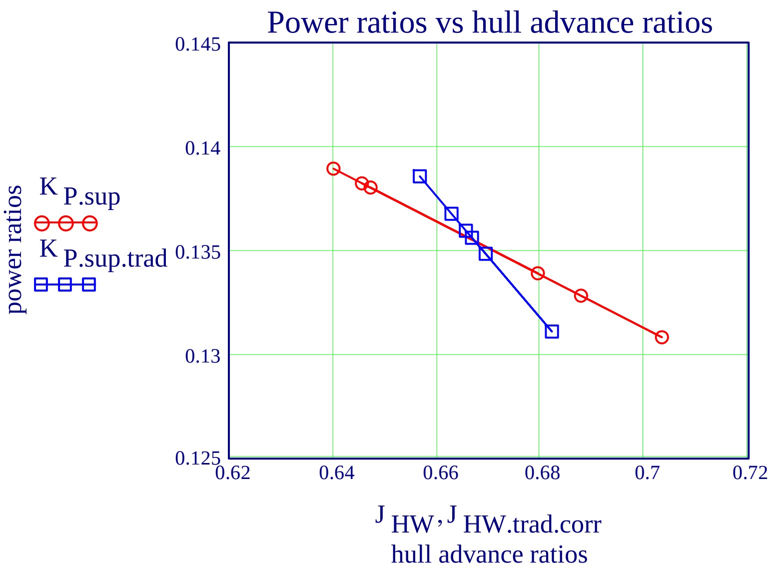
$$J_{HW.trad.corr_i} := \frac{V_{HW.trad.corr_i}}{D_P \cdot N_{S_i}}$$

Fairing power ratios

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

$$X_{KP} := geninv\left(A_{KP}\right) \cdot K_P$$

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



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

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

$$V_{HA.x} = \begin{bmatrix} 21.012 \\ -4.834 \\ -4.834 \\ 21.524 \\ 3.587 \\ -21.754 \end{bmatrix}$$

Check wind speed over ground

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

Approximate quadratically

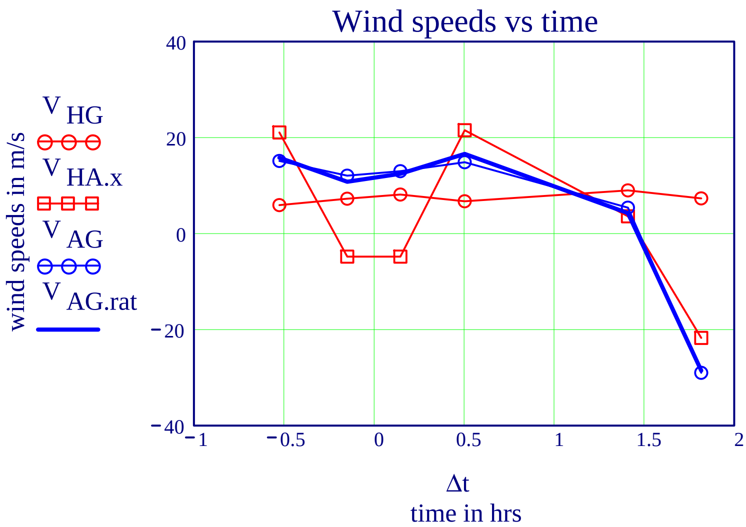
$k := 0..3$

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

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

$$X_{AG} = \begin{bmatrix} 11.237 \\ 6.226 \\ 18.211 \\ -18.599 \end{bmatrix}$$

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



$$V_{AG.rat} = \begin{bmatrix} 15.752 \\ 10.777 \\ 12.454 \\ 16.583 \\ 4.217 \\ -28.556 \end{bmatrix}$$

Relative wind speed corrected

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

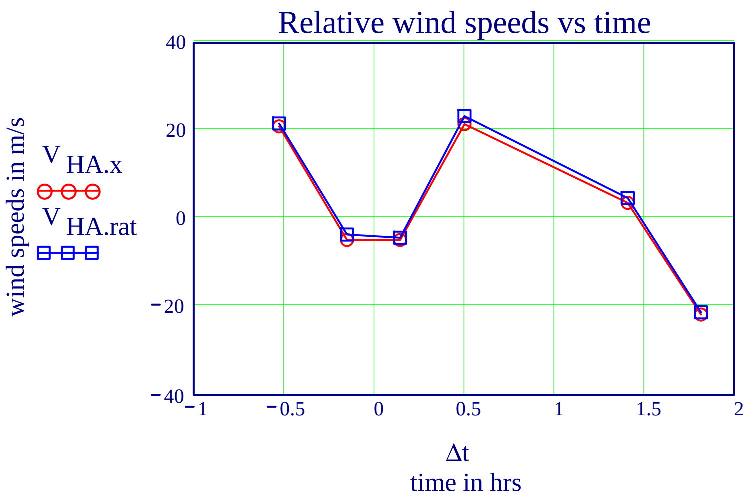
$$\Delta V_{AG} = \begin{bmatrix} 0.626 \\ -1.269 \\ -0.501 \\ 1.771 \\ -1.137 \\ 0.509 \end{bmatrix}$$

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

But 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!

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

$$V_{HA.rat} = \begin{bmatrix} 21.638 \\ -3.566 \\ -4.334 \\ 23.296 \\ 4.724 \\ -21.245 \end{bmatrix}$$



Conventions adopted

First power' convention

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

Second power convention

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

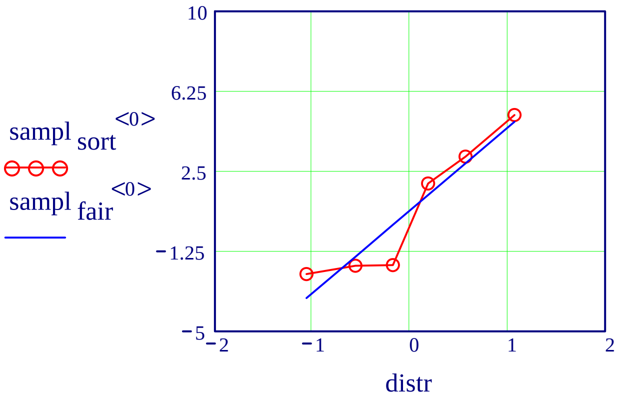
Evaluation

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

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

Check distribtution

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



$$distr_{par} = \begin{bmatrix} 0.699 \\ 3.872 \\ 1.581 \end{bmatrix}$$

Evidently the first value is an outlier as is also shown in the following plot. The following estimate of confidence is thus not quite justified.

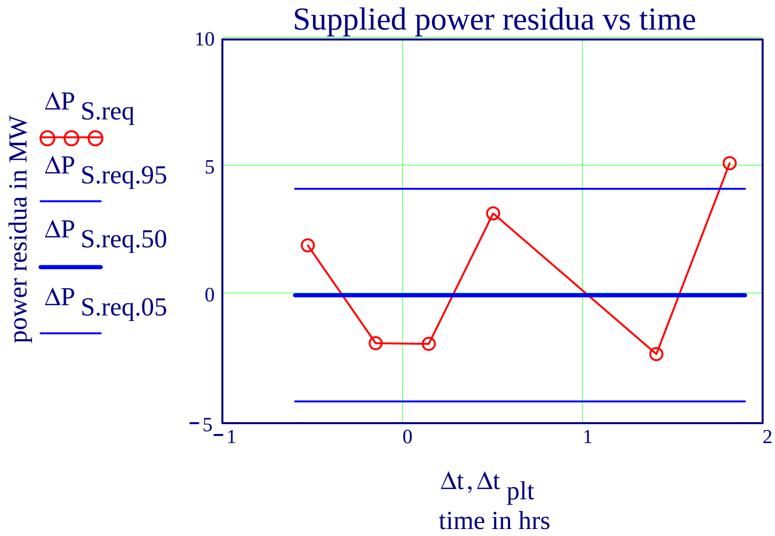
95 % confidence radius

number of samples $n_s := ni + 1$ — of parameters $n_p := 2$ — of degrees of freedom $f := n_s - n_p$

$$P_{S.req.95} := C_{95}(\Delta P_{S.req}, f) \qquad P_{S.req.95} = 4.155$$

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

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



$$q = \begin{bmatrix} 0.0211 \\ 4.4130 \cdot 10^{-5} \\ 3.1656 \\ 0.1957 \end{bmatrix}$$

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.

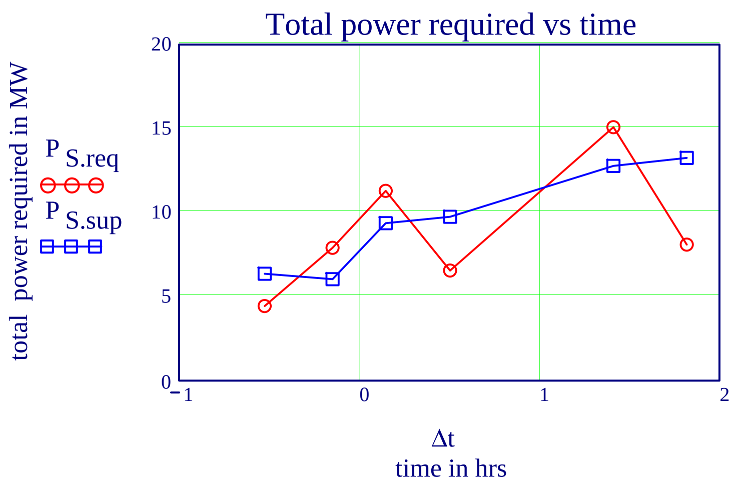
In view of the values of the powers measured the value of the confidence radius is felt to be quite realistic, the relative values ranging from 7.0 to 3.3 %.

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

$$P_{S.req.95.rel} = \begin{bmatrix} 0.653 \\ 0.688 \\ 0.445 \\ 0.427 \\ 0.325 \\ 0.314 \end{bmatrix}$$

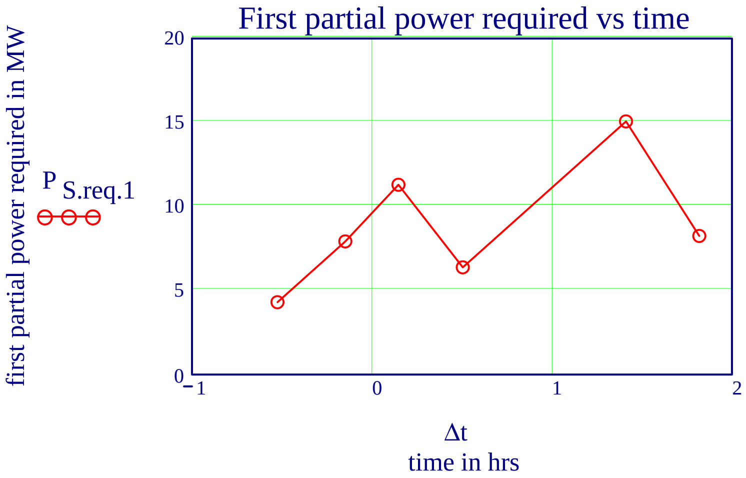
Powers required

Total power required



First partial power required

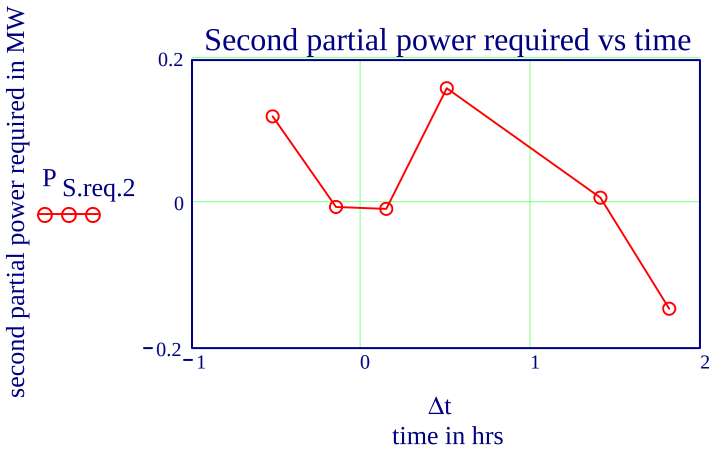
$P_{S.req.1} := A_{req}^{\langle 0 \rangle} \cdot X_{req_0}$



$P_{S.req.1} = \begin{bmatrix} 4.299 \\ 7.905 \\ 11.285 \\ 6.377 \\ 15.066 \\ 8.236 \end{bmatrix}$

Second partial power required

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



$P_{S.req.2} = \begin{bmatrix} 0.122 \\ -4.046 \cdot 10^{-3} \\ -6.730 \cdot 10^{-3} \\ 0.161 \\ 8.807 \cdot 10^{-3} \\ -0.146 \end{bmatrix}$

Re-order runs

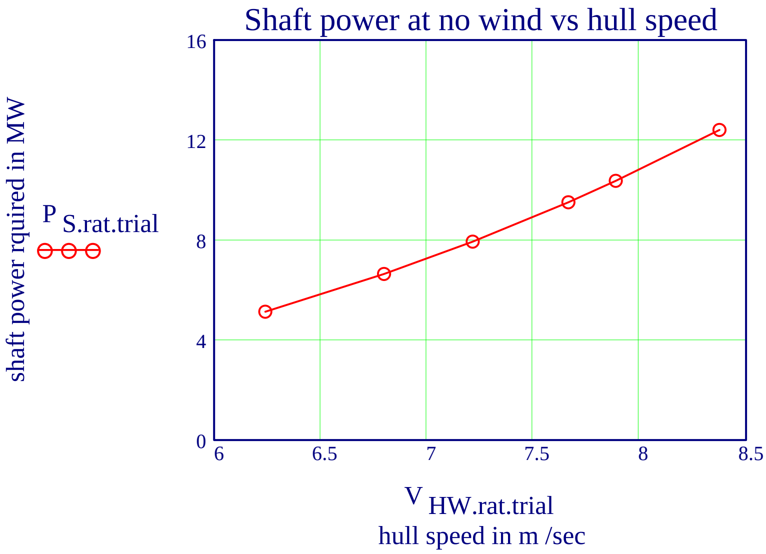
$R_{i,0} := run_i$ $\quad R^{\langle 1 \rangle} := V_{HW}$ $\quad R := csort(R, 1)$ $\quad Run := R^{\langle 0 \rangle}$

Run number re-ordered
according to increasing hull speed through speed
The natural count of runs is coveniently reduced by 1!

Nominal power vs hull speed
at the nominal no wind condition

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

$C_{PV} := q_0 + q_1$ $\qquad C_{PV} = 0.02112$ $\qquad P_{S.rat.trial_i} := C_{PV} \cdot \left(V_{HW.rat.trial_i}\right)^3$



$$P_{S.rat.trial} = \begin{bmatrix} 5.131 \\ 6.636 \\ 7.928 \\ 9.508 \\ 10.361 \\ 12.396 \end{bmatrix}$$

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

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

Given

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

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

Solve

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

$J_{HW.noVAW} = 0.685$ $\qquad K_{P.noVAW} = 0.133$

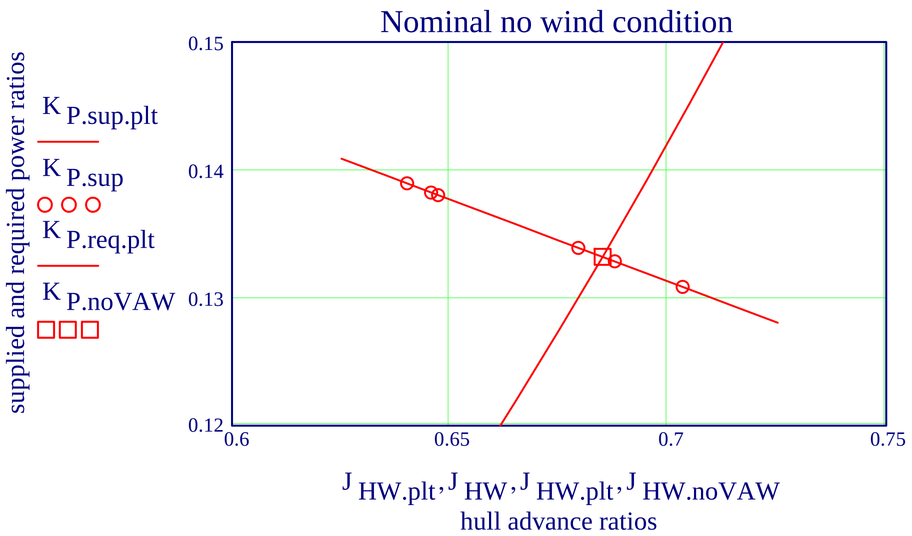
Results plotted

$k := 0 .. 10$

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

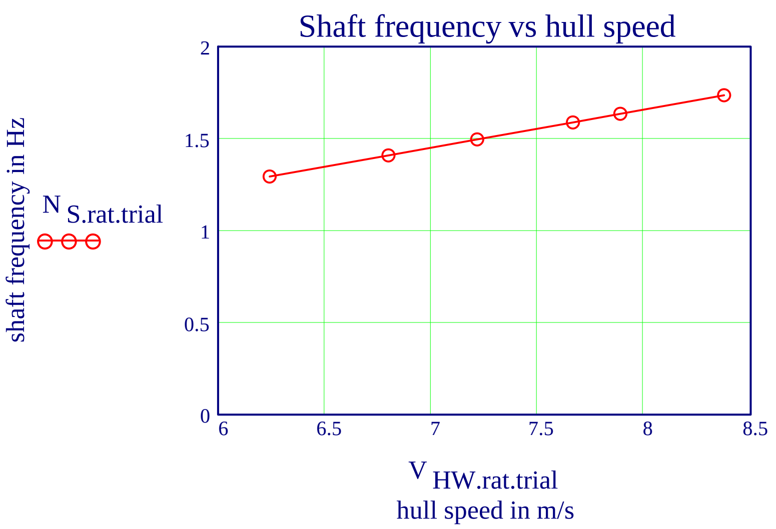
$K_{P.sup.plt_k} := p_{n_0} + p_{n_1} \cdot J_{HW.plt_k}$

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



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

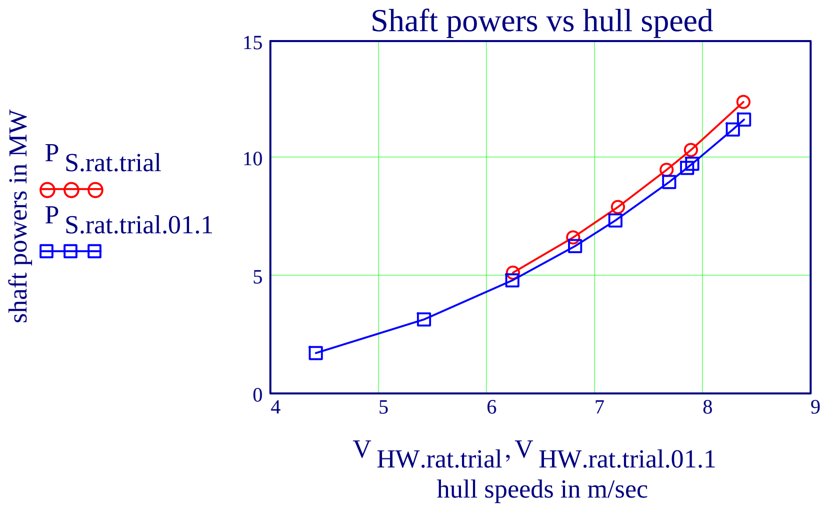
$$N_{S.rat.trial_i} := \frac{V_{HW.rat.trial_i}}{J_{HW.noVAW} \cdot D_P}$$

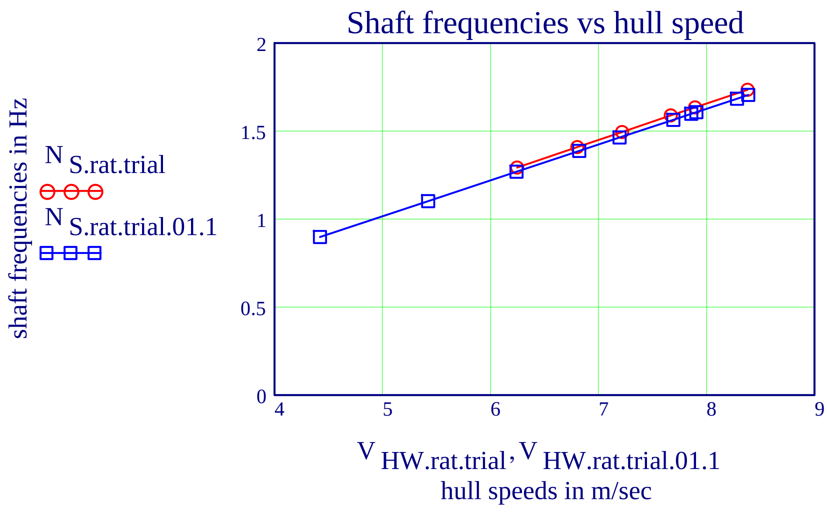


$$N_{S.rat.trial} = \begin{bmatrix} 1.292 \\ 1.408 \\ 1.494 \\ 1.587 \\ 1.633 \\ 1.734 \end{bmatrix}$$

Compare with results of PATE_01.1

Power

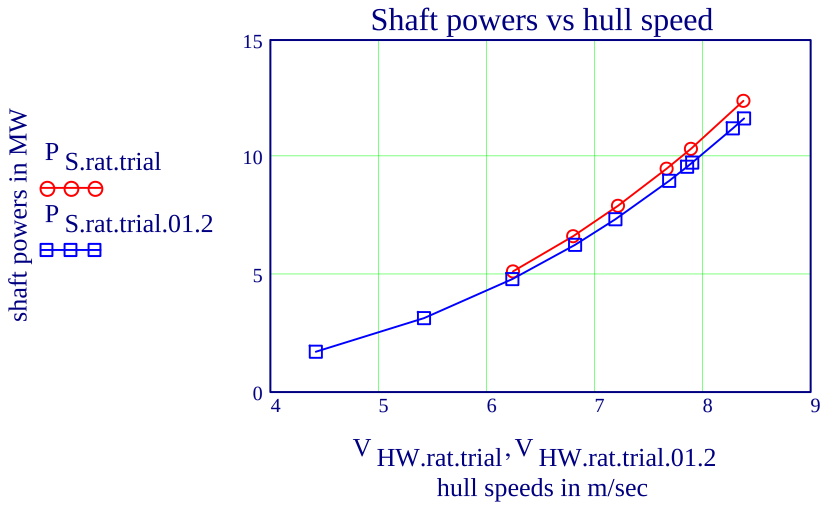


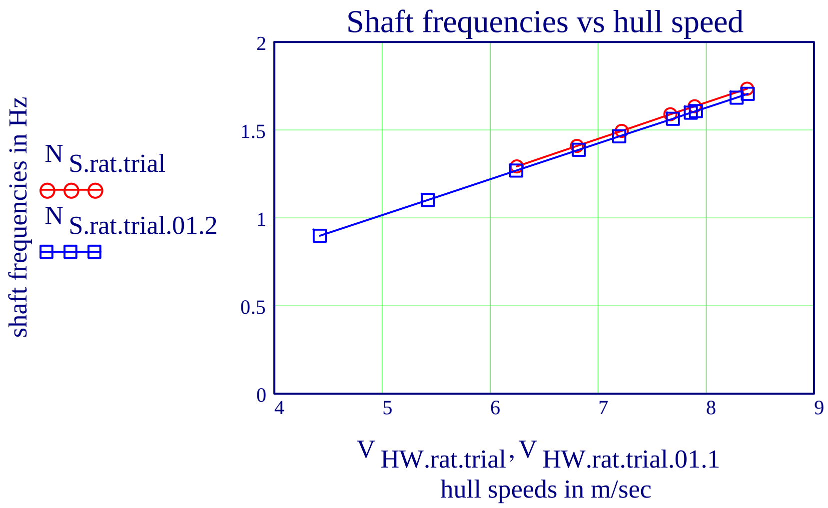


Evidently the final results do not differ for the two different data sets!

Compare with results of PATE_01.2

Power





Evidently the final results do not differ for the two different data sets!

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

$$V_{HW.trad} = \begin{bmatrix} 6.369 \\ 6.611 \\ 7.573 \\ 7.351 \\ 7.953 \\ 8.149 \\ 8.349 \\ 8.128 \end{bmatrix} \quad P_{S.trad} := \begin{bmatrix} 4.4224 \\ 5.8975 \\ 9.2628 \\ 7.4969 \\ 9.8683 \\ 12.0176 \\ 12.7595 \\ 10.5436 \end{bmatrix} \cdot MW \quad N_{S.trad} := \begin{bmatrix} 75.8 \\ 81.8 \\ 94.6 \\ 89.4 \\ 97.5 \\ 102.7 \\ 105.0 \\ 99.7 \end{bmatrix} \cdot rpm \quad \eta_D := \begin{bmatrix} 0.828 \\ 0.824 \\ 0.801 \\ 0.808 \\ 0.788 \\ 0.780 \\ 0.770 \\ 0.781 \end{bmatrix}$$

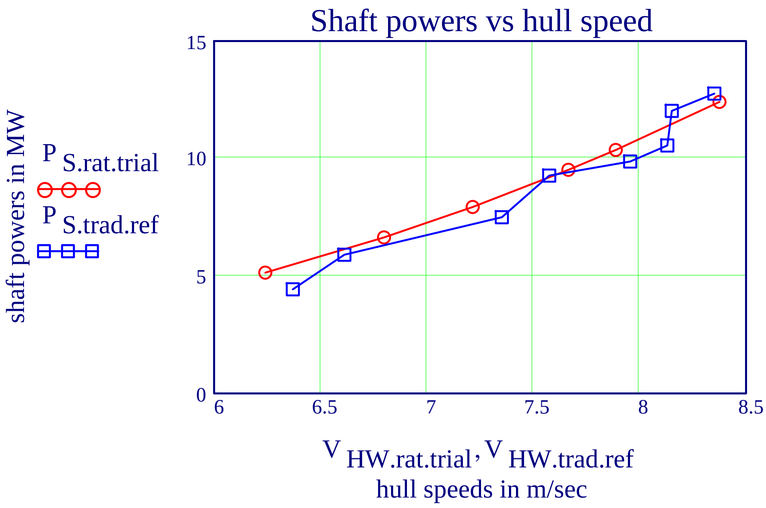
$$P_{S.trad} := \frac{P_{S.trad}}{MW} \qquad N_{S.trad} := \frac{N_{S.trad}}{Hz}$$

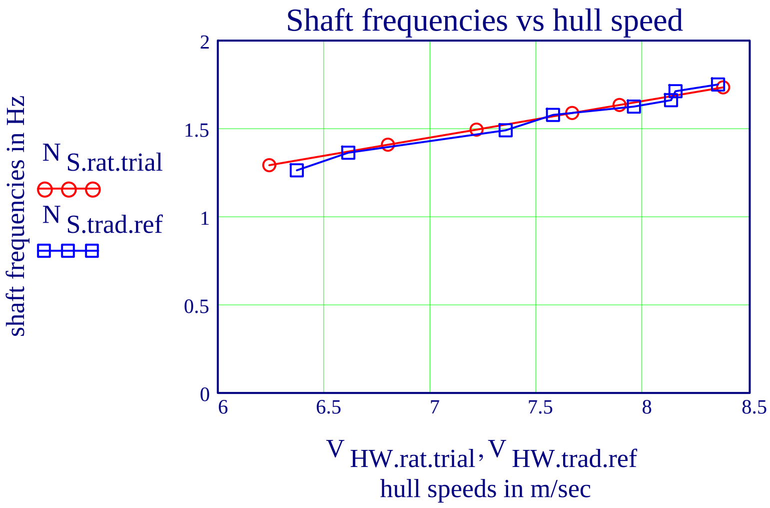
$ref^{\langle 0 \rangle} := V_{HW.trad}$ $\quad ref^{\langle 1 \rangle} := P_{S.trad}$ $\quad ref^{\langle 2 \rangle} := N_{S.trad}$ $\quad ref^{\langle 3 \rangle} := \eta_D$

$ref := csort(ref, 0)$

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

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

$i := 0 .. \text{last}(\eta_D)$

$k := 0 .. 1$

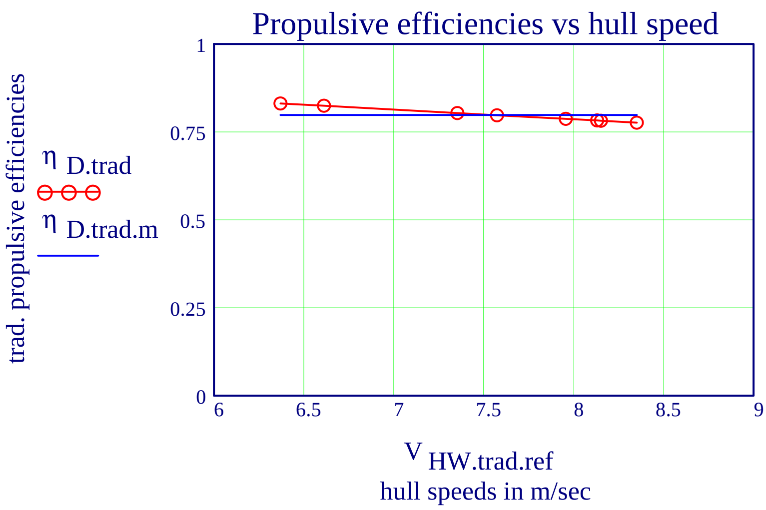
$A_{eta_{i,k}} := \left(V_{HW.trad.ref_i}\right)^k$

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

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

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

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



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

$\Delta t_{trad} := \Delta t$

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

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

$WRITEPRN(File) := Record$

Print final rational results

$final_{rat}^{\langle 0 \rangle} := Run$

$final_{rat}^{\langle 1 \rangle} := V_{HW.rat.trial} \cdot \frac{m}{kts \cdot sec}$

$final_{rat}^{\langle 2 \rangle} := P_{S.rat.trial}$

$final_{rat}^{\langle 3 \rangle} := N_{S.rat.trial} \cdot \frac{min}{sec}$

$$final_{rat} = \begin{bmatrix} 4.000 & 12.129 & 5.131 & 77.536 \\ 5.000 & 13.214 & 6.636 & 84.477 \\ 7.000 & 14.022 & 7.928 & 89.638 \\ 6.000 & 14.897 & 9.508 & 95.237 \\ 11.000 & 15.330 & 10.361 & 98.005 \\ 10.000 & 16.275 & 12.396 & 104.042 \end{bmatrix}$$

Conclusions

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

The rational evaluation produced nearly the same results for the two data sets 01.1 and 01.2 analysed. Now a data set further reduced to include only the data of three double runs as usually performed has been analysed.

This analysis PATE_01.3 shows that even based on the data of only three double runs the rational evaluation results in perfectly acceptable values.

For the rational evaluation the change from the trials condition to the reference condition results in an increase in the resistance due to the change in the displacement volume, and in an increase in the propulsive efficiency due to the larger nominal submergence of the propeller, maybe compensating each other.

But the result of the rational evaluation still includes the relatively small power required for moving in the sea state reported. **Thus the strictly accidental coincidence of the results in powers remains as unexplained as the whole undisclosed traditional procedure. In fact any traditional procedure is doomed to fail in any cases where no prior experience and data are available.**

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