**Prof. Dr.-Ing. M.Schmiechen**

MS 1305081300
1401221400
1404011700

**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 **a second of my 'post-ANONYMA trial evaluations'** using the same sub-set of data as in the undisclosed traditional evaluation. **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 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, thus permitting to demonstrate the inherent deficiencies of the traditional procedure.

### '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 reamarks
Concepts
- Names
- Symbols
- Remarks

Units
Routines

## Identify trial and evaluation

TID := "02.2"

EID := concat("PATE_" , TID) EID = "PATE_02.2"

## '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

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

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

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

### Water depth

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

**Mean values**

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

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

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**

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

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

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

**Normalise data**

At this stage for preliminary check of consistency only!

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

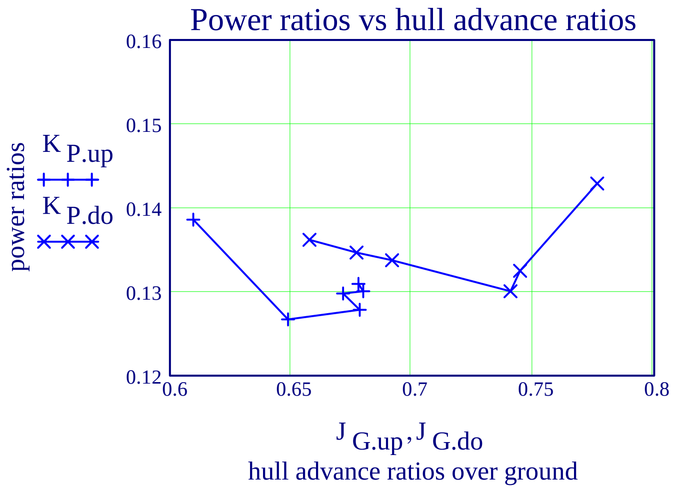
**Sort runs**

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

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

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

### 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.

## Outlying data eliminated

$ne := 4$ $\qquad ni := last(t) - ne$

$i := 0 .. ni$

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

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

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

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

### Normalise reduced data

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

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

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

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

**Read results of PATE_02.1**
**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!**

$Record_{02.1} := READPRN(\text{"Results\_PATE\_02.1"})$

$\left[ Internal_{rat.02.1} \;\; Final_{rat.02.1} \;\; Internal_{trad.02.1} \;\; Final_{trad.02.1} \right] := Record_{02.1}$

$\left[ Res_{sup.02.1} \;\; Res_{req.02.1} \right] := Internal_{rat.02.1}$

$$\begin{bmatrix} \Delta P_{S.sup.02.1} & v_{02.1} & V_{WG.02.1} \\ V_{HW.02.1} & p_{02.1} & P_{S.sup.02.1} \\ J_{HW.02.1} & p_{n.02.1} & K_{P.sup.02.1} \end{bmatrix} := Res_{sup.02.1}$$

$\left[ \Delta P_{S.req.02.1} \;\; q_{02.1} \;\; P_{S.req.02.1} \;\; A_{req.02.1} \;\; X_{req.02.1} \right] := Res_{req.02.1}$

$\left[ Run_{02.1} \;\; \Delta t_{02.1} \;\; V_{HW.rat.trial.02.1} \;\; P_{S.rat.trial.02.1} \;\; N_{S.rat.trial.02.1} \right] := Final_{rat.02.1}$

$\left[ V_{WG.trad.corr.02.1} \;\; J_{HW.trad.corr.02.1} \;\; K_{P.sup.trad.02.1} \right] := Internal_{trad.02.1}$

$\left[ Run \;\; \Delta t_{trad.02.1} \;\; V_{HW.trad.ref.02.1} \;\; P_{S.trad.ref.02.1} \;\; N_{S.trad.ref.02.1} \right] := Final_{trad.02.1}$

**Read results of PATE_01.2**

**for ready comparison with the results**
**of the following analysis of the trial**
**with a sister ship a fornight earlier**

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

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

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

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

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

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

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

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

# Analyse power supplied
### including identification of tidal current

## Conventions adopted

### Propeller power convention

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

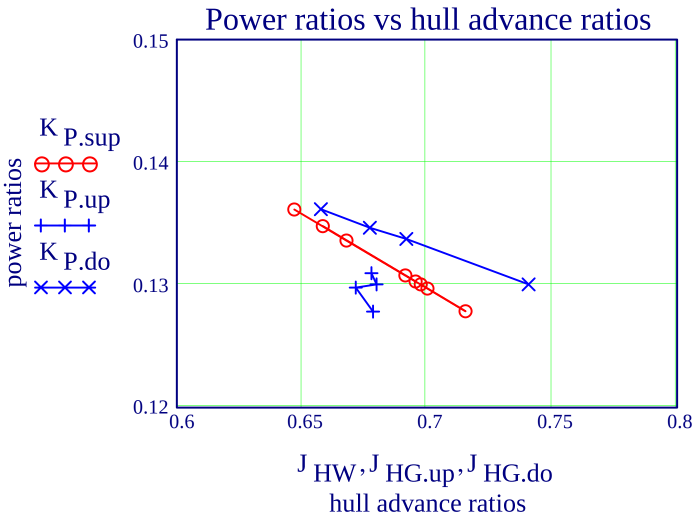
### Tidal current velocity convention

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

## Evaluate

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

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




$$p = \begin{bmatrix} 3.832 \\ -0.307 \\ 0.012 \\ 2.862 \cdot 10^{-3} \end{bmatrix}$$

$$p_n = \begin{bmatrix} 0.215 \\ -0.121 \end{bmatrix}$$

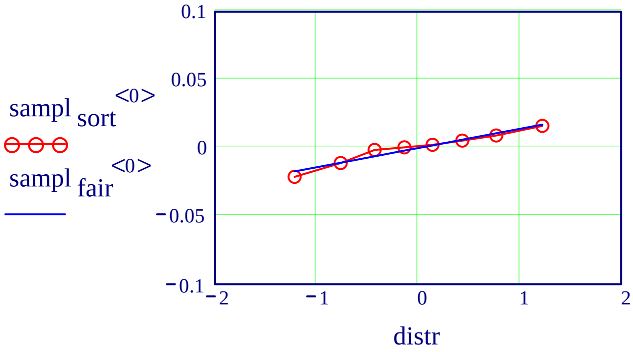
**Nota bene:** The propeller performance in the behind condition identified is that at the hull condition, the loading condition and the sea condition prevailing at the trials!

## 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.

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




$$distr_{par} = \begin{bmatrix} 1.043 \cdot 10^{-4} \\ 0.014 \\ 5.001 \cdot 10^{-3} \end{bmatrix}$$

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

**95 % confidence radius**

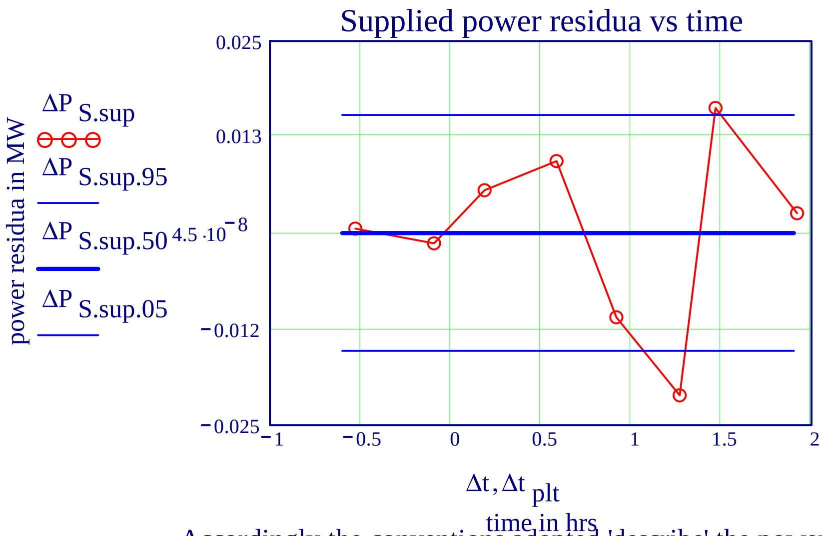
number of samples | of parameters | of degrees of freedom

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

$P_{S.sup.95} := C_{95}\left(\Delta P_{S.sup}, f\right)$ $\qquad P_{S.sup.95} \cdot \frac{MW}{kW} = 15.362$ kW

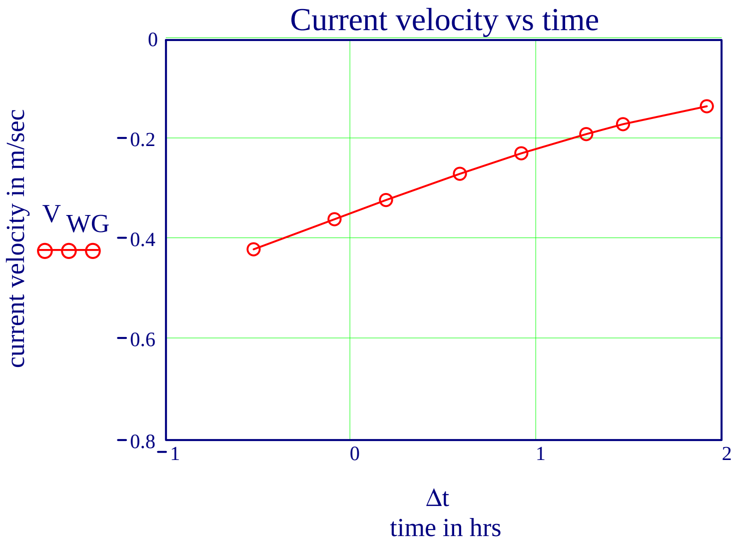
$k := 0..1$ $\qquad \Delta t_{plt_0} := -0.6$ $\qquad \Delta t_{plt_1} := 1.9$

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




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**




$$V_{WG} \cdot \frac{m}{kts \cdot sec} = \begin{bmatrix} -0.815 \\ -0.697 \\ -0.623 \\ -0.520 \\ -0.441 \\ -0.366 \\ -0.328 \\ -0.258 \end{bmatrix} kts$$

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

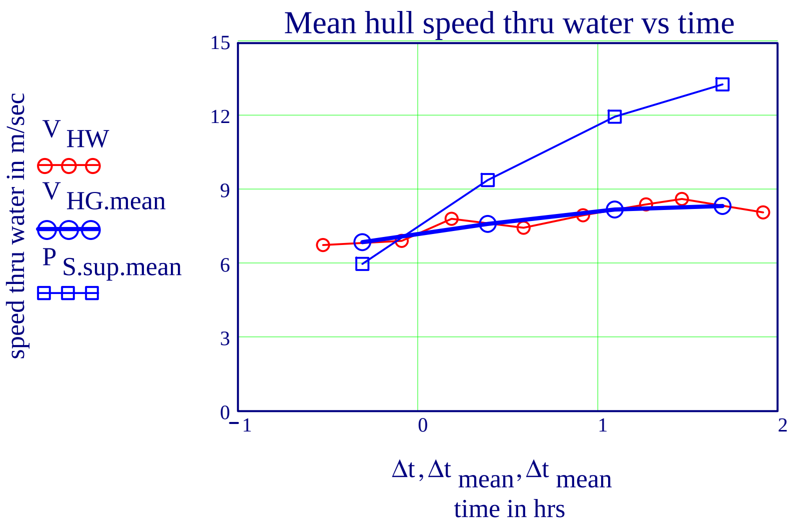
$V_{WG.mean} := v_0$ $\quad V_{WG.mean} \cdot \frac{m}{kts \cdot sec} = -0.725$ Nominal mean current in kts

$V_{WG.ampl} := \sqrt{(v_1)^2 + (v_2)^2}$ $\quad V_{WG.ampl} \cdot \frac{m}{kts \cdot sec} = 0.533$ Nominal tidal amplitude in kts

**Mean velocity over ground and mean power**

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

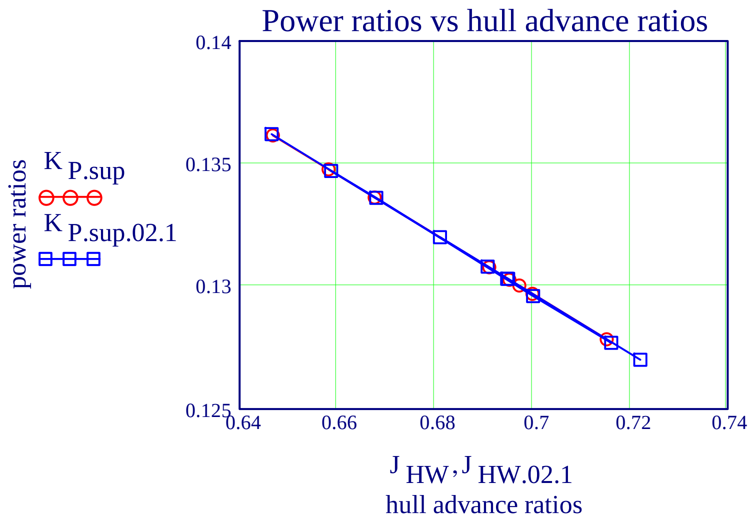
$V_{HG.mean_j} := \frac{V_{HG_{2 \cdot j}} + V_{HG_{2 \cdot j + 1}}}{2}$ $\quad P_{S.sup.mean_j} := \frac{P_{S.sup_{2 \cdot j}} + P_{S.sup_{2 \cdot j + 1}}}{2}$




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_02.1

### Powering performances



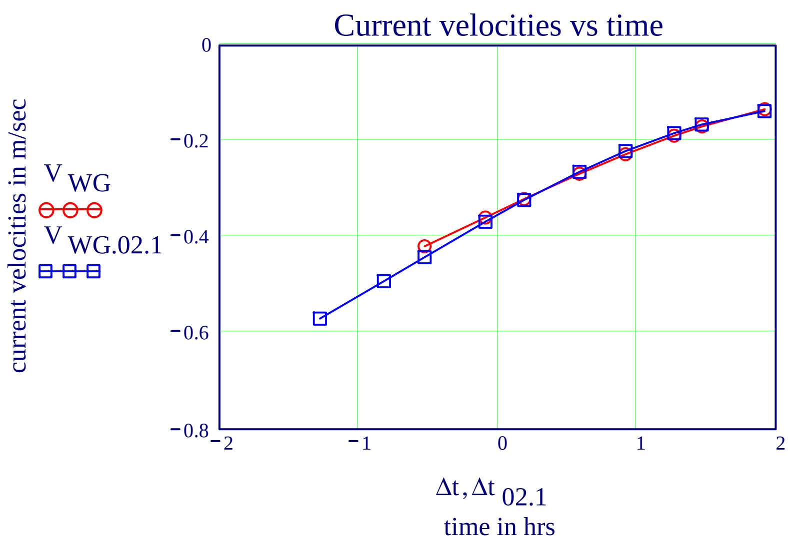

$$p_{02.1} = \begin{bmatrix} 3.841 \\ -0.309 \\ 0.013 \\ 3.014 \cdot 10^{-3} \end{bmatrix}$$

$$p = \begin{bmatrix} 3.832 \\ -0.307 \\ 0.012 \\ 2.862 \cdot 10^{-3} \end{bmatrix}$$

$$\Delta K_P := p_{n.02.1} - p_n \qquad \Delta K_P = \begin{bmatrix} 5.161 \cdot 10^{-4} \\ -7.797 \cdot 10^{-4} \end{bmatrix}$$

The powering performances in the behind conditon identified for the two different data sets are in perfect agrrement.

### Currents



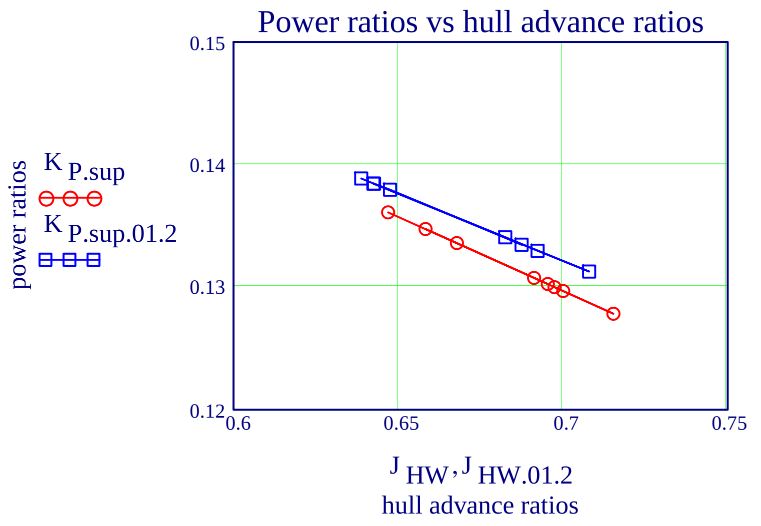

$$V_{WG.02.1.red_i} := V_{WG.02.1_{i+2}}$$

$$\Delta V_{WG} := V_{WG.02.1.red} - V_{WG} \qquad \text{mean}\left(\Delta V_{WG}\right) = -2.146 \cdot 10^{-3}$$

The currents identified for the two different data sets are also in perfect agrrement .

# Compare with results of PATE_01.2

## Powering performance




$\Delta K_P := p_{n.01.2} - p_n$

$\Delta K_P = \begin{bmatrix} -4.984 \cdot 10^{-3} \\ 0.011 \end{bmatrix}$

The powering performances in the behind conditon identified for both ships are differing slightly in value and in tendency.

## Curent

Identified

$V_{WG.mean} \cdot \frac{m}{kts \cdot sec} = -0.725$ Nominal mean current in kts

$V_{WG.ampl} \cdot \frac{m}{kts \cdot sec} = 0.533$ Nominal tidal amplitude in kts

Identified for the trial a fortnight later

$V_{WG.mean.01.2} := v_{01.2_0}$

$V_{WG.ampl.01.2} := \sqrt{\left(v_{01.2_1}\right)^2 + \left(v_{01.2_2}\right)^2}$

$V_{WG.mean.01.2} \cdot \frac{m}{kts \cdot sec} = -0.669$ Nominal mean current in kts

$V_{WG.ampl.01.2} \cdot \frac{m}{kts \cdot sec} = 0.467$ Nominal tidal amplitude in kts

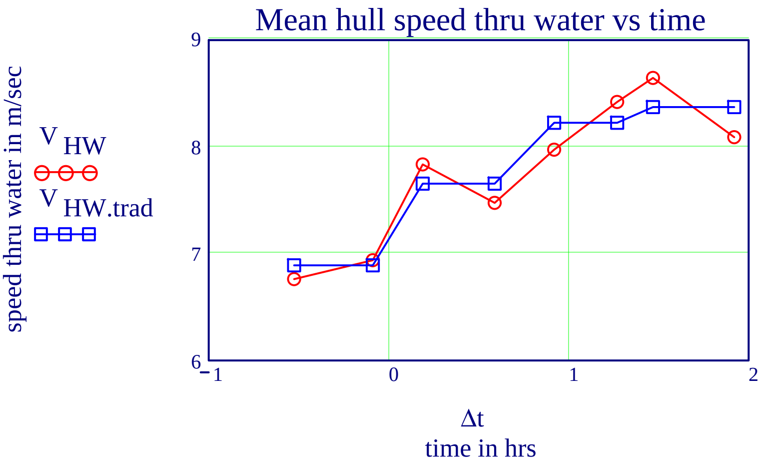
## Scrutinise results of an undisclosed traditional evaluation

**Part 1** concerning the speed through the water

### Hull speed thru water reported

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

$$J_{HW.trad_i} := \frac{V_{HW.trad_i}}{D_P \cdot N_{S_i}} \qquad J_{HW.trad} = \begin{bmatrix} 0.710 \\ 0.710 \\ 0.684 \\ 0.684 \\ 0.679 \\ 0.679 \\ 0.669 \\ 0.669 \end{bmatrix}$$



**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**

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

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

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

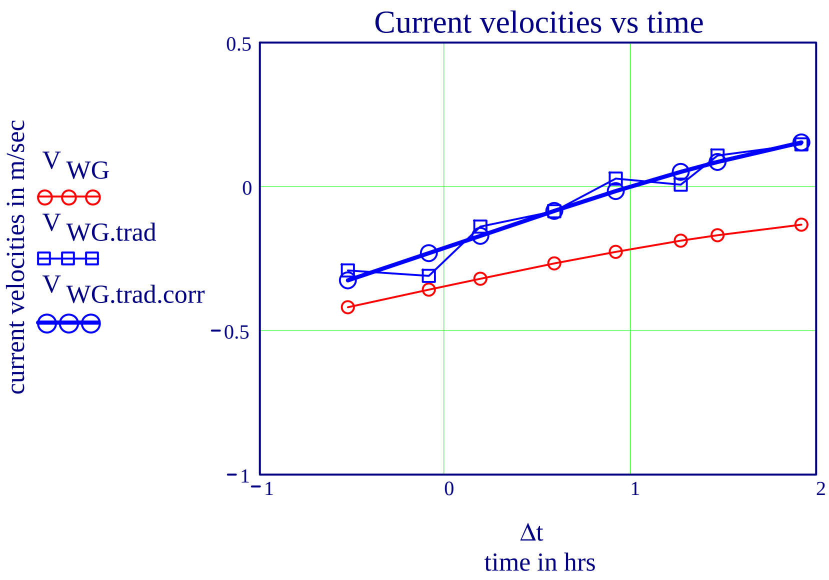
$$X_{WG.trad} := geninv\left(A_{WG.trad}\right) \cdot V_{WG.trad}$$

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

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

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

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



## Nominal mean currents and tidal amplitudes compared

**Nominal mean currents in kts**

**Rational**

$$V_{WG.mean} \cdot \frac{m}{kts \cdot sec} = -0.725$$

**Nominal tidal amplitudes in kts**

$$V_{WG.ampl} \cdot \frac{m}{kts \cdot sec} = 0.533$$

**Traditional**

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

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

$$V_{WG.mean} \cdot \frac{m}{kts \cdot sec} = -0.725$$

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

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

**Difference of traditionally identified current**

In view of the intricate current conditions in the East China Sea the comparison of the nominal tidal currents may be not particularly meaningful, but different from the evaluation PATE_01the mean difference in the currents identified is as meannigless in the present context.

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

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

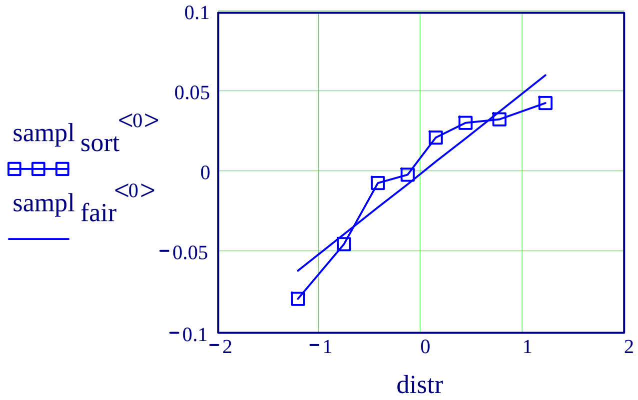
$$\Delta V_{WG.mean} \cdot \frac{m}{kts \cdot sec} = 0.374 \quad kts$$

Thus the traditional evaluation results in a mean difference of 0.374 kts in the current identified, while in case of PATE_01 this value has been $-0.27$, i. e. of opposite sign, indicating an inconsistency in the traditional evaluation.

**Check distribution of randon errors in current identified traditionally**

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

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




$$distr_{par} = \begin{bmatrix} 0.000 \\ 0.050 \\ 0.018 \end{bmatrix}$$

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

**95 % confidence radius**

number of samples — of parameters — of degrees of freedom

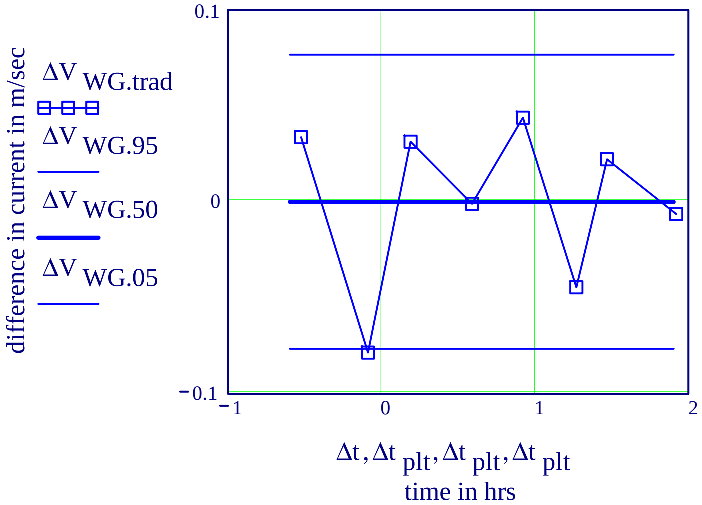
$n_s := ni - 1$ $\quad n_p := 3$ $\quad f := n_s - n_p$

$\Delta V_{WG.95.rad} := C_{95}(\Delta V_{WG.trad}, f)$ $\quad \Delta V_{WG.95.rad} \cdot \frac{m}{kts \cdot sec} = 0.149$ kts

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

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

Differences in current vs time



**Shaft power ratios vs hull advance ratios**

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

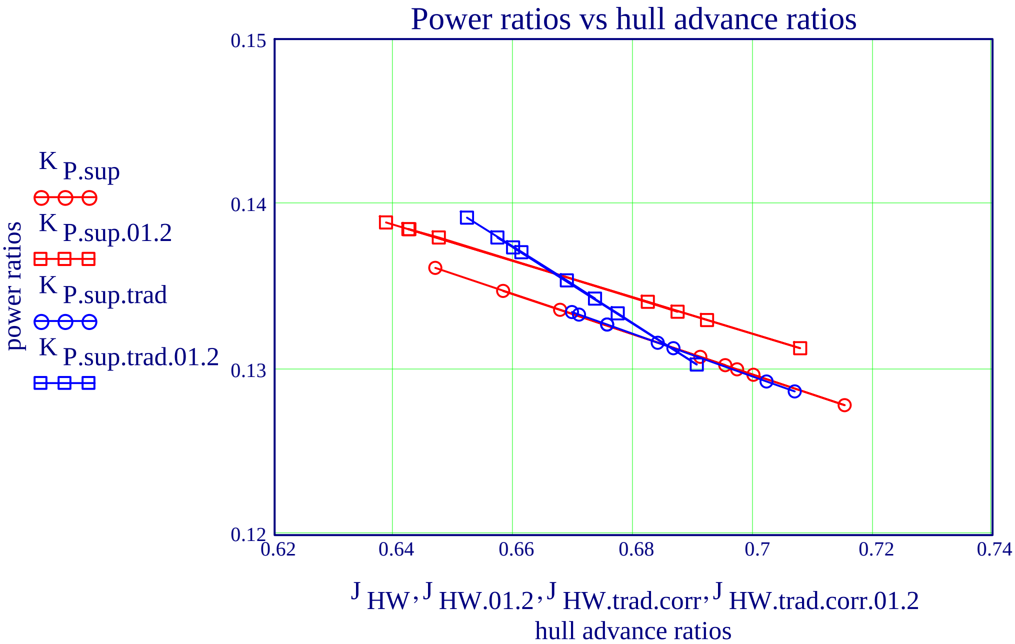
$$J_{HW.trad.corr_i} := \frac{V_{HW.trad.corr_i}}{D_P \cdot N_{S_i}}$$

**Fairing power ratios**

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

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

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




In this case the hull speeds through the water identified differ only very little and thus the powering performance in the behind condition identifiied by the rational and traditional procedures 'coincide'!

While the rational procedure results nearly in the same powering performance for the sister ships at the same conditions except for the wave height, the traditional procedure results show considerable differences in tendency.

## 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

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

$V_{HA.x} = \begin{bmatrix} 8.019 \\ 8.670 \\ 9.852 \\ 7.094 \\ 5.952 \\ 9.458 \\ 10.693 \\ 6.283 \end{bmatrix}$

### Wind speed over ground

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

### Approximate wind speed

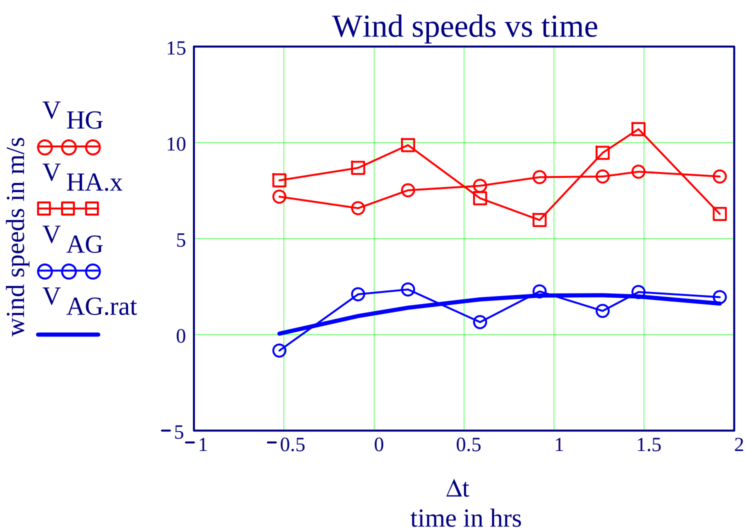
$k := 0 .. 2$

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

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

$X_{AG} = \begin{bmatrix} 1.113 \\ 1.653 \\ -0.726 \end{bmatrix}$

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




$V_{AG.rat} = \begin{bmatrix} 0.037 \\ 0.955 \\ 1.396 \\ 1.832 \\ 2.018 \\ 2.041 \\ 1.975 \\ 1.612 \end{bmatrix}$

### Relative wind speed corrected

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

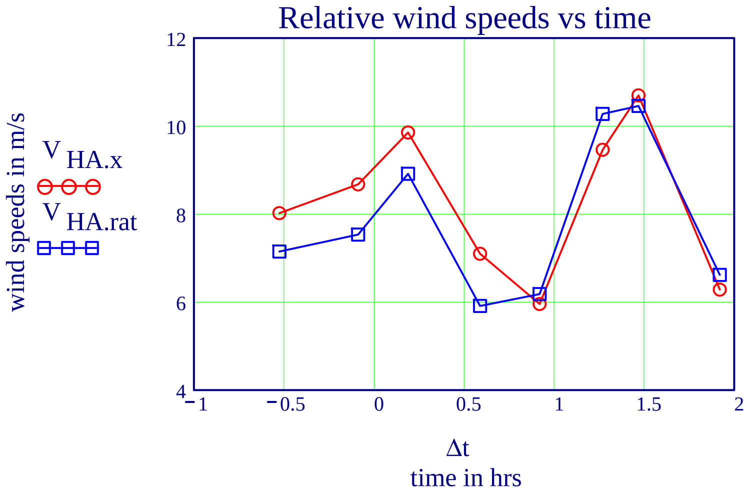
$$\Delta V_{AG} = \begin{bmatrix} 0.876 \\ -1.137 \\ -0.941 \\ 1.185 \\ -0.229 \\ 0.815 \\ -0.240 \\ -0.329 \end{bmatrix}$$

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!

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

$$V_{HA.rat} = \begin{bmatrix} 7.143 \\ 7.533 \\ 8.911 \\ 5.909 \\ 6.181 \\ 10.273 \\ 10.452 \\ 6.611 \end{bmatrix}$$



## Conventions adopted

### First power' convention

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

### Second power convention

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

## Evaluate power required

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

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

$$q = \begin{bmatrix} 0.023 \\ -1.078 \cdot 10^{-3} \\ 0.942 \\ 0.193 \end{bmatrix} \qquad q_{01.2} = \begin{bmatrix} 0.0182 \\ 1.5770 \cdot 10^{-3} \\ 0.4726 \\ 0.2040 \end{bmatrix}$$

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

$$X_{req.0} := q_{01.2_0} \qquad X_{req.0} = 0.0182$$

### Evaluation

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

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

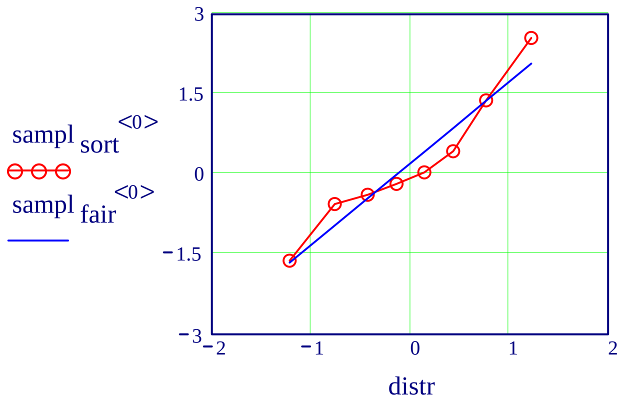
$$q = \begin{bmatrix} 0.0182 \\ 0.0026 \\ 1.2774 \\ 0.1927 \end{bmatrix} \qquad q_{01.2} = \begin{bmatrix} 0.0182 \\ 0.0016 \\ 0.4726 \\ 0.2040 \end{bmatrix}$$

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

**Check distribtution**

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




$$\text{distr}_{\text{par}} = \begin{bmatrix} 0.211 \\ 1.529 \\ 0.541 \end{bmatrix}$$

Evidently the distribution is not normal as is also shown in the following plot.
The following estimate of confidence is thus not quite justified.

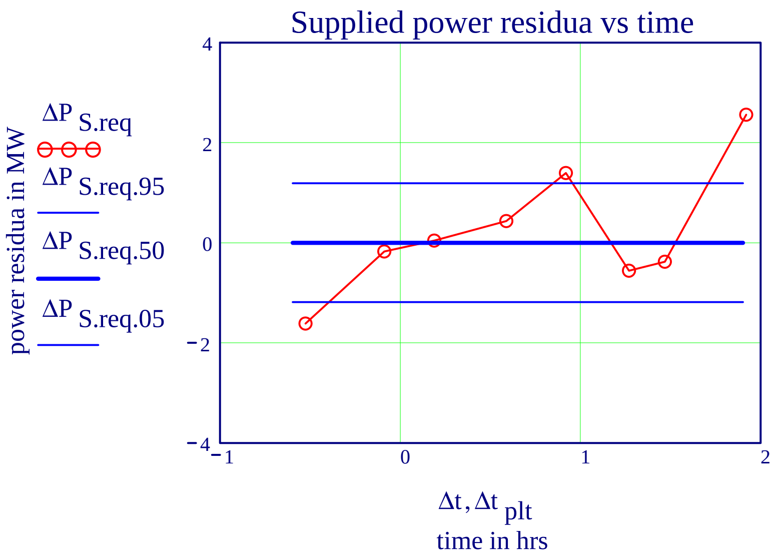
**95 % confidence radius**

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

$P_{\text{S.req.95}} := C_{95}\left(\Delta P_{\text{S.req}}, f\right)$ $\qquad P_{\text{S.req.95}} = 1.188$ MW

$k := 0 .. 1 \qquad \Delta t_{\text{plt}_0} := -0.6 \qquad \Delta t_{\text{plt}_1} := 1.9$

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



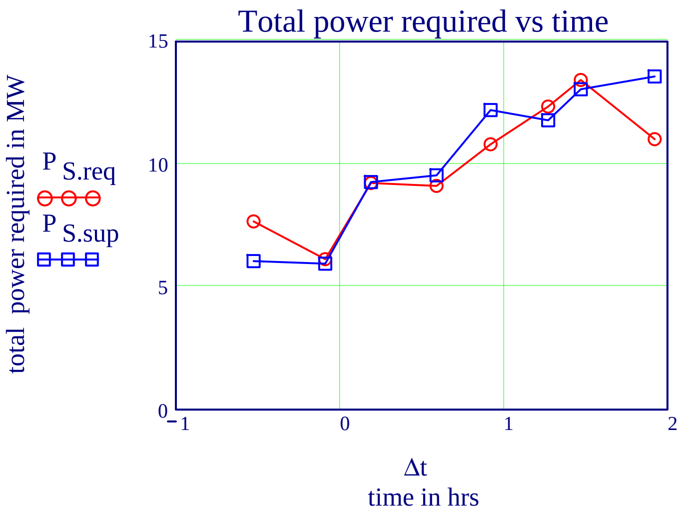
As usual the required power residua are much larger than in case of the supplied power due to the uncertainties in the wind measurements and the crude wave observations.

In view of the outliers the value of the relative confidence radius from 20 to 10 % is felt to be quite grossly distorted.

$$P_{S.req.95.rel_i} := \frac{P_{S.req.95}}{P_{S_i}} \qquad P_{S.req.95.rel} = \begin{bmatrix} 0.197 \\ 0.200 \\ 0.128 \\ 0.124 \\ 0.097 \\ 0.101 \\ 0.091 \\ 0.087 \end{bmatrix}$$

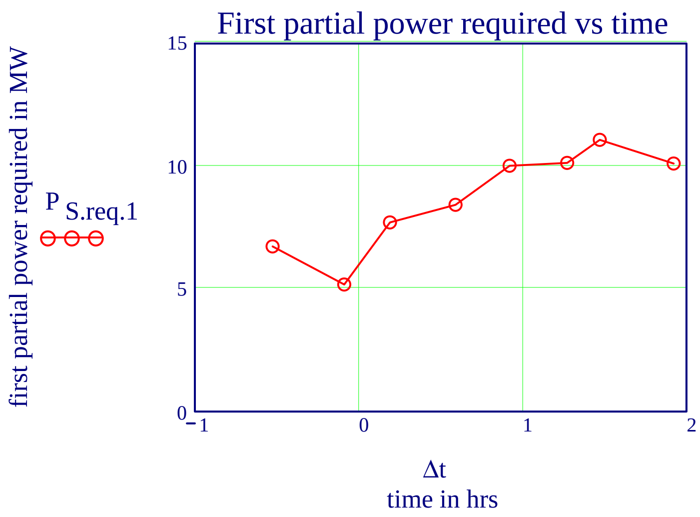
**Powers required**

**Total power required**



**First partial power required**

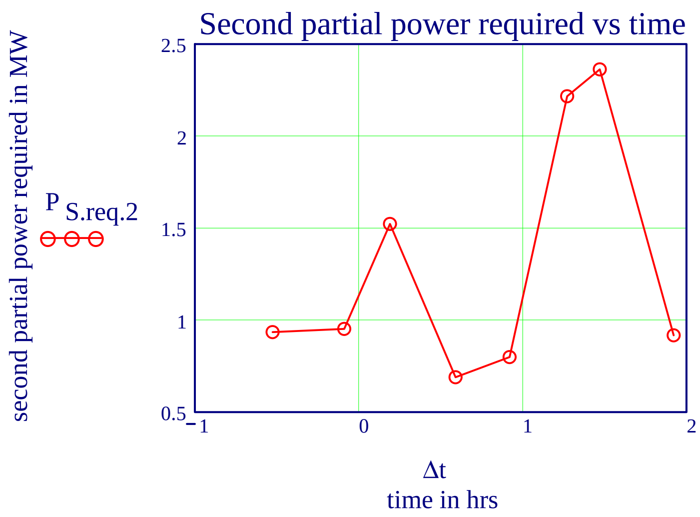
$P_{S.req.1} := A_{req}^{\langle 0 \rangle} \cdot X_{req_0}$




$$P_{S.req.1} = \begin{bmatrix} 6.724 \\ 5.168 \\ 7.707 \\ 8.423 \\ 10.008 \\ 10.129 \\ 11.062 \\ 10.101 \end{bmatrix}$$

**Second partial power required**

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




$$P_{S.req.2} = \begin{bmatrix} 0.935 \\ 0.952 \\ 1.522 \\ 0.689 \\ 0.799 \\ 2.216 \\ 2.362 \\ 0.917 \end{bmatrix}$$

**Re-order runs**

$R_{i,0} := i + 4 \qquad R^{\langle 1 \rangle} := V_{HW} \qquad R := \mathrm{csort}(R, 1) \qquad Run := R^{\langle 0 \rangle}$

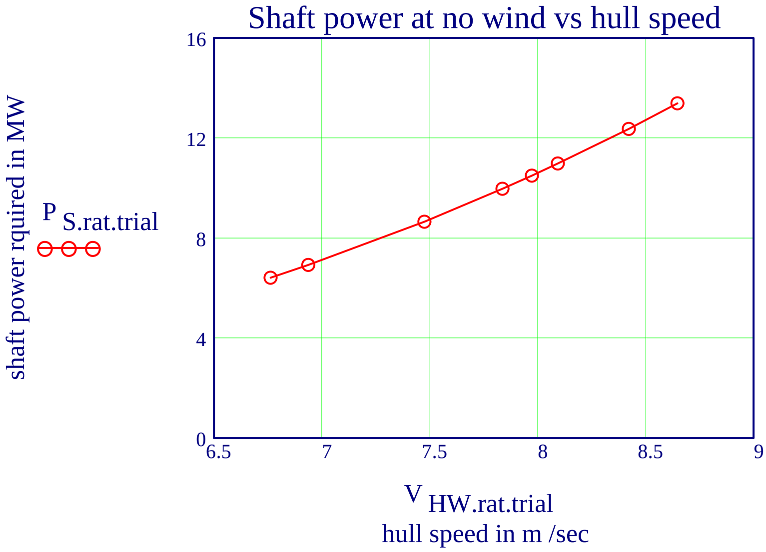
**Nominal power vs hull speed**
**at the nominal no wind condition**

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

$C_{PV} := q_0 + q_1$

$C_{PV} = 0.02071$

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




$$P_{S.rat.trial} = \begin{bmatrix} 6.402 \\ 6.912 \\ 8.644 \\ 9.963 \\ 10.492 \\ 10.970 \\ 12.363 \\ 13.386 \end{bmatrix}$$

**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**

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

Given

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

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

Solve

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

$J_{HW.noVAW} = 0.686$  $K_{P.noVAW} = 0.131$

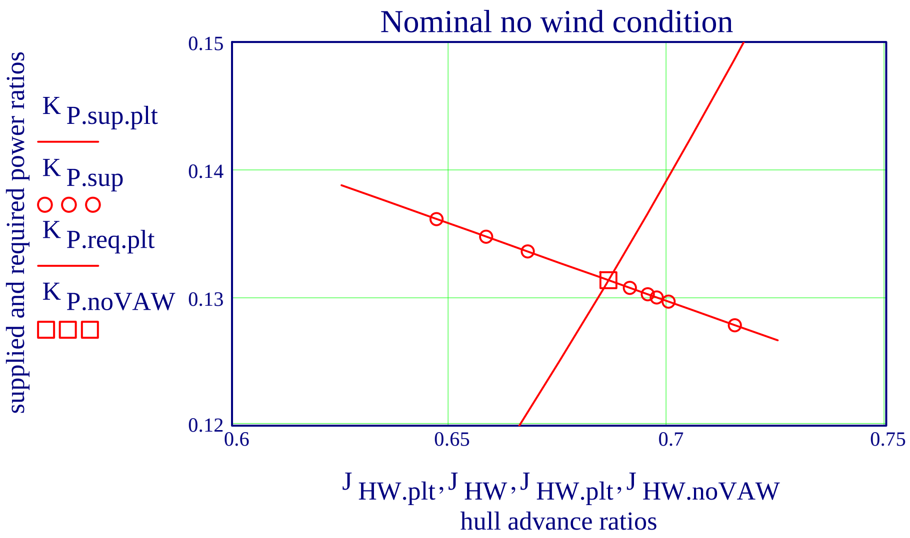
**Results plotted**

$k := 0 .. 10$

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

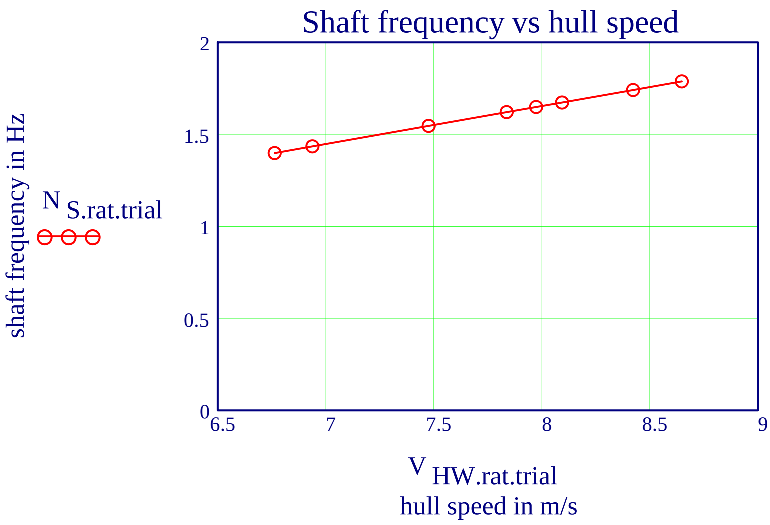
$K_{P.sup.plt_k} := p_{n_0} + p_{n_1} \cdot J_{HW.plt_k}$

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




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

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




$$N_{S.rat.trial} = \begin{bmatrix} 1.398 \\ 1.434 \\ 1.545 \\ 1.620 \\ 1.648 \\ 1.672 \\ 1.740 \\ 1.787 \end{bmatrix}$$

## 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**

$$V_{HW.trad} = \begin{bmatrix} 6.888 \\ 6.888 \\ 7.655 \\ 7.655 \\ 8.226 \\ 8.226 \\ 8.370 \\ 8.370 \end{bmatrix} \quad P_{S.trad} := \begin{bmatrix} 5.9284 \\ 5.9191 \\ 9.1332 \\ 9.4898 \\ 12.1716 \\ 11.7092 \\ 13.0222 \\ 13.5097 \end{bmatrix} \cdot MW \quad N_{S.trad} := \begin{bmatrix} 83.1 \\ 83.1 \\ 94.5 \\ 95.3 \\ 103.1 \\ 102.3 \\ 105.3 \\ 106.1 \end{bmatrix} \cdot rpm \quad \eta_D := \begin{bmatrix} 0.818 \\ 0.818 \\ 0.798 \\ 0.798 \\ 0.776 \\ 0.776 \\ 0.769 \\ 0.769 \end{bmatrix}$$

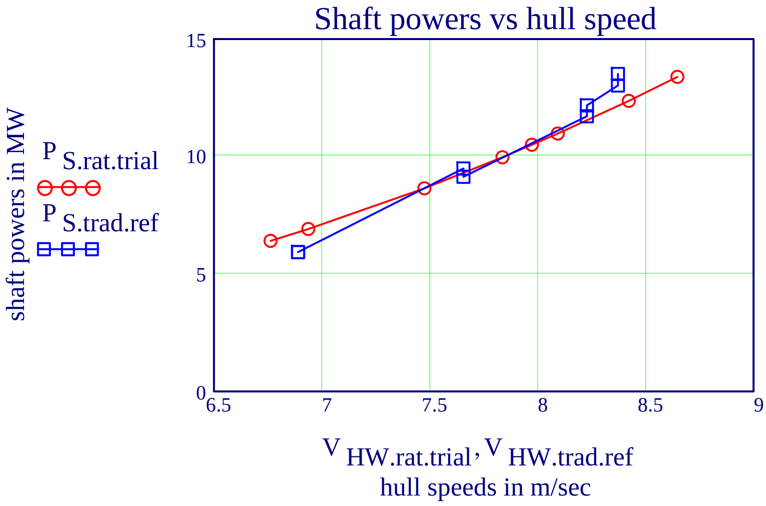
$$P_{S.trad} := \frac{P_{S.trad}}{MW} \qquad N_{S.trad} := \frac{N_{S.trad}}{Hz}$$

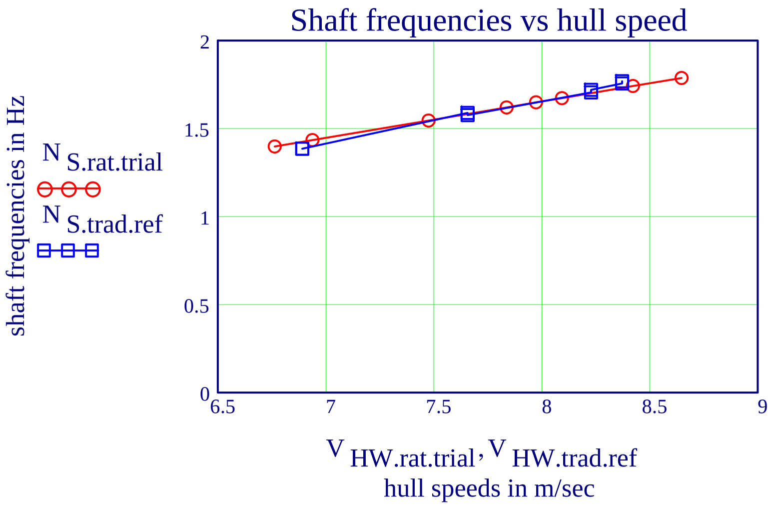
$$ref^{\langle 0 \rangle} := V_{HW.trad} \qquad ref^{\langle 1 \rangle} := P_{S.trad} \qquad ref^{\langle 2 \rangle} := N_{S.trad} \qquad ref^{\langle 3 \rangle} := \eta_D$$

$$ref := csort(ref, 0)$$

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

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'.

For the rational evaluation the change from the trials condition to the reference condition results in an increase in 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 power required for moving in the sea state reported. **Thus the strictly accidental coincidence of the results remains as unexplained as the whole undisclosed traditional procedure. In fact any traditional procedure is doomed to fail in any case where no prior experience and data are available.**

**Computed values of the propulsive efficiency analysed**

$k := 0 .. 1$

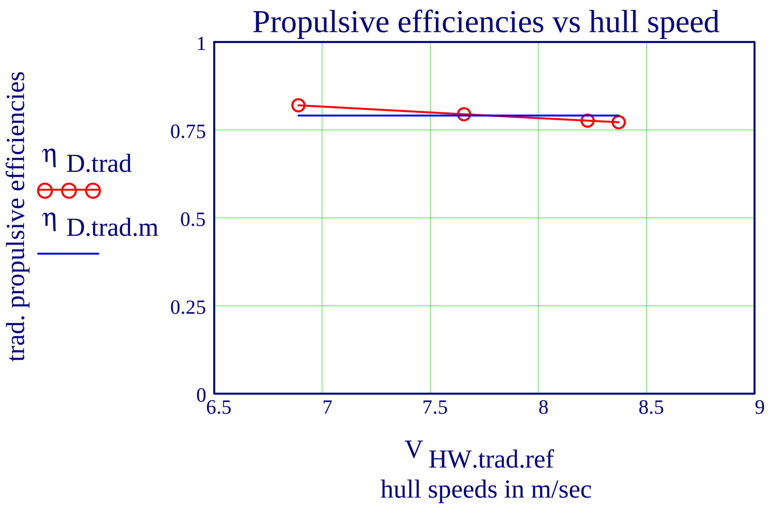
$A_{eta_{i,k}} := \left(V_{HW.trad.ref_i}\right)^k$

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

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

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

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




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

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

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

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

$WRITEPRN(File) := Record$

### Print final rational results

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

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

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

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

$$final_{rat} = \begin{bmatrix} 4.000 & 13.143 & 6.402 & 83.859 \\ 5.000 & 13.483 & 6.912 & 86.028 \\ 7.000 & 14.527 & 8.644 & 92.685 \\ 6.000 & 15.231 & 9.963 & 97.178 \\ 8.000 & 15.496 & 10.492 & 98.869 \\ 11.000 & 15.728 & 10.970 & 100.347 \\ 9.000 & 16.367 & 12.363 & 104.427 \\ 10.000 & 16.806 & 13.386 & 107.230 \end{bmatrix}$$

## Conclusions

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 propeller powering performance in the behind condition 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