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

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 := "01.2"

EID := concat("PATE_", TID) EID = "PATE_01.2"

'Constants'

\[ D_p := 7.05 \cdot m \]
\[ h_S := 3.85 \cdot m \]
diameter of propeller
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

\[ H_{Wave} := 3.3 \cdot m \]
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 of plausibility.

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

<table>
<thead>
<tr>
<th>Day time</th>
<th>Heading</th>
<th>Rel. wind velocity</th>
<th>Rel. wind direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 21</td>
<td>180</td>
<td>35</td>
<td>5</td>
</tr>
<tr>
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<td>0</td>
<td>11</td>
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</tr>
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<tr>
<td>8 41</td>
<td>0</td>
<td>7</td>
<td>160</td>
</tr>
<tr>
<td>9 5</td>
<td>180</td>
<td>45</td>
<td>0</td>
</tr>
</tbody>
</table>

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 Numerical Recipes subroutine package. Thus the possible change of the standard, resulting in intransparent code, is not a viable choice.
'Duration' of measurements

\[ s_{\text{mean}} := \frac{1 \text{ nm}}{m} \quad s_{\text{mean}} := \frac{s_{\text{mean}}}{m} \]

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

\[ V_{HA} := V_{HA} \frac{\text{sec}}{m}, \quad N_S := N_S \text{sec}, \quad P_S := P_S \times \frac{1}{\text{MW}}, \quad V_{HG} := V_{HG} \frac{\text{sec}}{m} \]

Times of measurements

\[ n_i := \text{last}(\text{time}<0>) \quad i := 0..n_i \]

\[ \text{dur}_i := \frac{s_{\text{mean}}}{V_{HG_i}}, \quad t := \text{time}<0> + \text{time}<1> \times \frac{\text{min}}{\text{hr}} + \frac{\text{dur}_i \times \text{sec}}{2 \times \text{hr}} \]

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

Normalise data

At this stage for preliminary check of consistency only!

\[ J_{HG_i} := J(D_P, V_{HG_i}, N_{S_i}), \quad K_{P,o_i} := KP(D_P, P_S, N_{S_i}) \]

Sort runs

\[ S := \text{Sort}\_\text{runs}(J_{HG}, K_{P,o}, \psi_{HG}) \]

\[ J_{G,up} := S^{<0>}, \quad K_{P,up} := S^{<1>}, \quad J_{G,do} := S^{<2>}, \quad K_{P,do} := S^{<3>} \]

\[
\begin{align*}
J_{G,up} &= \begin{bmatrix} 0.555 \\ 0.524 \\ 0.609 \\ 0.602 \\ 0.607 \\ 0.593 \end{bmatrix} & K_{P,up} &= \begin{bmatrix} 0.161 \\ 0.149 \\ 0.138 \\ 0.138 \\ 0.139 \end{bmatrix} & J_{G,do} &= \begin{bmatrix} 0.685 \\ 0.726 \\ 0.746 \\ 0.729 \\ 0.725 \end{bmatrix} & K_{P,do} &= \begin{bmatrix} 0.147 \\ 0.133 \\ 0.131 \\ 0.131 \\ 0.134 \end{bmatrix}
\end{align*}
\]
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 is being used here.

Outlying data eliminated

\[
\begin{align*}
\Delta t_{red_i} & := \Delta t_{i+ne} \\
\psi_{HG,red_i} & := \psi_{HG,i+ne} \\
V_{HA,red_i} & := V_{HA,i+ne} \\
\Delta t & := \Delta t_{red} \\
\psi_{HG} & := \psi_{HG,red} \\
V_{HA} & := V_{HA,red} \\
N_{S,red_i} & := N_{S_i+ne} \\
P_{S,red_i} & := P_{S_i+ne} \\
V_{HG,red_i} & := V_{HG_i+ne} \\
N_S & := N_{S,red} \\
P_S & := P_{S,red} \\
V_{HG} & := V_{HG,red}
\end{align*}
\]

Normalise reduced data

\[
\begin{align*}
J_{HG} & := J(D, P, V_{HG_i}, N_{S_i}) \\
K_P & := K(P, D, P_{S_i}, N_{S_i}) \\
S & := \text{Sort}_\text{runs}(J_{HG}, K_P, \psi_{HG}) \\
J_{HG,up} & := S^{<0>} \\
K_{P,up} & := S^{<1>} \\
J_{HG,do} & := S^{<2>} \\
K_{P,do} & := S^{<3>}
\end{align*}
\]

\[
\begin{align*}
J_{HG,up} & = \begin{bmatrix} 0.609 \\ 0.602 \\ 0.607 \\ 0.593 \end{bmatrix} \\
K_{P,up} & = \begin{bmatrix} 0.138 \\ 0.138 \\ 0.138 \\ 0.139 \end{bmatrix} \\
J_{HG,do} & = \begin{bmatrix} 0.746 \\ 0.729 \\ 0.730 \\ 0.725 \end{bmatrix} \\
K_{P,do} & = \begin{bmatrix} 0.131 \\ 0.132 \\ 0.134 \\ 0.134 \end{bmatrix}
\end{align*}
\]
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!

Record 01.1 := READPRN("Results_PATE_01.1")

[Internal rat.01.1 Final rat.01.1 Internal trad.01.1 Final trad.01.1 ] := Record 01.1
[Res sup.01.1 Res req.01.1 ] := Internal rat.01.1

[ΔP S.sup.01.1 V 01.1 V WG.01.1 ]
[V HW.01.1 P 01.1 P S.sup.01.1 ] := Res sup.01.1
[J HW.01.1 P n.01.1 K P.sup.01.1 ]

[ΔP S.req.01.1 Q 01.1 P S.req.01.1 A req.01.1 X req.01.1 ] := Res req.01.1

[Run 01.1 Δt 01.1 V HW.rat.trial.01.1 P S.rat.trial.01.1 N S.rat.trial.01.1 ] := Final rat.01.1
[ V WG.trad.corr.01.1 J HW.trad.corr.01.1 K P.sup.trad.01.1 ] := Internal trad.01.1

[Run Δt trad.01.1 V HW.trad.ref.01.1 P S.trad.ref.01.1 N S.trad.ref.01.1 ] := Final trad.01.1
**Analyse power supplied**

including identification of tidal current

**Conventions adopted**

**Propeller power convention**

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

**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**

\[ \text{Res}_{\text{sup}} := \text{Supplied} \cdot \left( \rho, D, p, \Delta t, V_{HG}, \psi_{HG}, N_S, P_S \right) \]

\[ \left[ \begin{array}{c} \Delta P_{S,\text{sup}} \\ V_{HW} \\ P \end{array} \right] = \text{Res}_{\text{sup}} \]

\[ \left[ \begin{array}{c} K_{P,\text{sup}} \\ K_{P,\text{up}} \\ K_{P,\text{do}} \end{array} \right] \]

\[ p = \begin{bmatrix} 3.744 \\ -0.281 \\ 1.306 \times 10^{-3} \end{bmatrix} \]

\[ p_n = \begin{bmatrix} 0.210 \\ -0.111 \end{bmatrix} \]

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

**95 % confidence radius**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of samples of parameters ( n_s )</td>
<td>( n_i + 1 )</td>
</tr>
<tr>
<td>Number of parameters ( n_p )</td>
<td>4</td>
</tr>
<tr>
<td>Degrees of freedom ( f )</td>
<td>( n_s - n_p )</td>
</tr>
<tr>
<td>Supplied power residua ( P_{S.sup} )</td>
<td>38.1 kW</td>
</tr>
</tbody>
</table>

\[
P_{S.sup.95} := C \, \Delta P_{S.sup} \cdot f
\]

\[
\Delta P_{S.sup.05} := -P_{S.sup.95}
\]

\[
\Delta P_{S.sup.95} := P_{S.sup.50}
\]

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

**Current velocity vs time**

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

\[ V_{WG,\text{mean}} := v_0 \]

\[ V_{WG,\text{ampl}} := \sqrt{(v_1)^2 + (v_2)^2} \]

Nominal mean current in kts

\[ V_{WG,\text{ampl}} \frac{m}{\text{kts} \cdot \text{sec}} = 0.669 \]

Nominal tidal amplitude in kts

\[ V_{WG,\text{ampl}} \frac{m}{\text{kts} \cdot \text{sec}} = 0.466 \]

Mean velocity over ground and mean power

\[ n_j := \frac{n_i - 1}{2} \]

\[ j := 0 \ldots n_j \]

\[ \Delta t_{\text{mean}} := \frac{\Delta t_{2j} + \Delta t_{2j+1}}{2} \]

\[ V_{HG,\text{mean}} := \frac{V_{HG,2j} + V_{HG,2j+1}}{2} \]

\[ P_{S,\text{sup,mean}} := \frac{P_{S,\text{sup,2j}} + P_{S,\text{sup,2j+1}}}{2} \]

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

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

Currents

The currents identified for the two different data sets are also slightly differing.
Scrutinise results of an undisclosed traditional evaluation
Part 1 concerning the speed through the water

Hull speed thru water reported

\[
\begin{align*}
V_{\text{HW.trad}} &= [12.38, 12.85, 14.72, 14.29, 15.46, 15.84, 16.23, 15.80] \text{kts} \\
\frac{V_{\text{HW.trad}} \cdot \text{sec}}{m} \\
J_{\text{HW.trad}_i} &= \frac{V_{\text{HW.trad}_i}}{D \cdot P \cdot N \cdot S_i}
\end{align*}
\]

Mean hull speed thru water vs time

\[
\begin{align*}
\text{speed thru water in m/sec} \\
\Delta t \quad \text{time in hrs}
\end{align*}
\]
Current velocity identified by traditional procedure

\[ V_{WG.trad.1} := (V_{HG.1} - V_{HW.trad.1}) \cdot \text{dir}(\psi_{HG.1}) \]

Tidal approximation as in the rational evaluation

\[ A_{WG.trad.1,0} := 1 \]
\[ A_{WG.trad.1,1} := \cos(\omega T \cdot \Delta t_i) \]
\[ A_{WG.trad.1,2} := \sin(\omega T \cdot \Delta t_i) \]
\[ X_{WG.trad} := \text{geninv}(A_{WG.trad}) \cdot V_{WG.trad} \]
\[ V_{WG.trad.corr} := A_{WG.trad} \cdot X_{WG.trad} \]
\[ \Delta V_{WG.trad} := V_{WG.trad} - V_{WG.trad.corr} \]
\[ V_{HW.trad.corr.1} := V_{HG.1} + V_{WG.trad.corr.1} \cdot \text{dir}(\psi_{HG.1}) \]

Current velocities vs time

Graph showing current velocities vs time with different velocities labeled and a table showing time in hours and current velocities.
Nominal mean currents and tidal amplitudes compared

Rational

\[
V_{WG\text{.mean}}\frac{m}{kts\cdot sec} = -0.669
\]

\[
V_{WG\text{.ampl}}\frac{m}{kts\cdot sec} = 0.466
\]

Traditional

\[
v_{\text{trad}} := X_{WG\text{.trad}}
\]

\[
V_{WG\text{.mean.trad}} := v_{\text{trad}}^0
\]

\[
V_{WG\text{.ampl.trad}} := \sqrt{(v_{\text{trad}}_1)^2 + (v_{\text{trad}}_2)^2}
\]

\[
V_{WG\text{.mean.trad}}\frac{m}{kts\cdot sec} = -1.586
\]

\[
V_{WG\text{.ampl.trad}}\frac{m}{kts\cdot sec} = 0.566
\]

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.

\[
\Delta V_{WG} := V_{WG\text{.trad}} - V_{WG}
\]

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

\[
\Delta V_{WG\text{.mean}}\frac{m}{kts\cdot sec} = -0.325 \quad \text{kts}
\]

Check distribution of differences in current

\[
\Delta \Delta V_{WG_i} := \Delta V_{WG_i} - \Delta V_{WG\text{.mean}}
\]

\[
[\text{distr sampl sort sampl fair distr par}] := \text{norm_distr}\left(\Delta \Delta V_{WG}\right)
\]
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**

\[
\Delta \Delta V_{WG,95,\text{rad}} := C_{95}(\Delta \Delta V_{WG} \cdot \hat{f})
\]

\[
k := 0..1 \quad \Delta t_{\text{plt}_0} := -0.6
\]

\[
\Delta \Delta V_{WG,50} := 0
\]

\[
\Delta \Delta V_{WG,95} := \Delta \Delta V_{WG,95,\text{rad}}
\]

\[
\Delta \Delta V_{WG,95,\text{rad}} := -\Delta \Delta V_{WG,95,\text{rad}}
\]

\[
\frac{\Delta \Delta V_{WG,95,\text{rad}} \cdot m}{\text{kts} \cdot \text{sec}} = 0.215 \text{ kts}
\]

\[
\Delta t_{\text{plt}_1} := 1.9
\]
Shaft power ratios vs hull advance ratios

\[ V_{HW,trad.corr_i} := V_{HW_i} - \Delta V_{WG,mean \cdot dir}^{\psi \cdot HG_i} \]

\[ J_{HW,trad.corr_i} := \frac{V_{HW,trad.corr_i}}{D \cdot P \cdot N \cdot S_i} \]

Fairing power ratios

\[ A_{KP_i,k} := (J_{HW,trad.corr_i})^k \]

\[ X_{KP} := \text{geninv}(A_{KP}) \cdot K_P \]

\[ K_{P,\text{sup.trad}} := A_{KP} \cdot X_{KP} \]

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

\[ V_{HA,x_i} := V_{HA_i} \cdot \cos(\psi_{HA_i}) \]

Check wind speed over ground

\[ V_{AG_i} := \left( V_{HA,x_i} - V_{HG_i} \right) \cdot \text{dir}(\psi_{HG_i}) \]

Approximate quadratically

\[ k := 0..3 \]

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

\[ X_{AG} := \text{geninv}(A_{AG}) \cdot V_{AG} \]

\[ V_{AG,\text{rat}} := A_{AG} \cdot X_{AG} \]

Wind speeds vs time

Relative wind speed corrected

\[ \Delta V_{AG} := V_{AG,\text{rat}} - V_{AG} \]
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!

\[
\Delta V_{AG} = \begin{bmatrix}
-0.888 \\
1.732 \\
0.559 \\
-1.462 \\
-1.803 \\
0.988 \\
1.761 \\
-0.887
\end{bmatrix}
\]

\[V_{HA.rat_i} = V_{HG_i} + V_{AG.rat_i} \cdot \text{dir} \left( \psi_{HG_i} \right)\]

\[
V_{HA.rat} = \begin{bmatrix}
20.124 \\
-6.566 \\
-5.394 \\
20.062 \\
20.746 \\
-4.856 \\
-5.025 \\
22.175
\end{bmatrix}
\]
Conventions adopted

First power' convention

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

Second power convention

\[ P_{S\text{.req.1}}(q, V_{HW}, V_{HA}) := q_1 \cdot V_{HA} \cdot V_{HW} \]

Evaluation

\[ \text{Res req} := \text{Required}(V_{HG}, P_{S\text{.sup}}, V_{HA\text{.rat}}) \]

\[ \left[ \Delta P_{S\text{.req}} q P_{S\text{.req}} A_{\text{req}} X_{\text{req}} \right] := \text{Res}_{\text{req}} \]

Check distribution

\[ \left[ \text{distr sampl sort sampl fair distr par} \right] := \text{norm_distr}(\Delta P_{S\text{.req}}) \]

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 of parameters of degrees of freedom
\[ n_s := n_i + 1 \quad n_p := 2 \quad f := n_s - n_p \]

\[ P_{S\text{.req.95}} := C_{95}(\Delta P_{S\text{.req}}, f) \]

\[ k := 0 \ldots 1 \quad \Delta t_{\text{plt}_0} := -0.6 \quad \Delta t_{\text{plt}_1} := 1.9 \]

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

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MS 01.04.2014 17:34 h
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 %.

\[
P_{S,\text{req.95 rel}}_i = \frac{P_{S,\text{req.95}}}{P_{S_i}}
\]

\[
P_{S,\text{req.95 rel}} = \begin{bmatrix}
0.069 \\
0.073 \\
0.047 \\
0.045 \\
0.035 \\
0.036 \\
0.034 \\
0.033
\end{bmatrix}
\]
First partial power required

\[ P_{S.\text{req.1}} = A_{\text{req}^<0>} \cdot X_{\text{req}_0} \]

Second partial power required

\[ P_{S.\text{req.2}} = A_{\text{req}^<1>} \cdot X_{\text{req}_1} \]

Re-order runs

\[ R_{1,0} = i + 4 \quad R^{<1>} := V_{\text{HW}} \quad R := \text{csort}(R, 1) \quad \text{Run} := R^{<0>} \]

Run number re-ordered according to increasing hull speed through speed
The natural count of runs is conveniently reduced by 1!
Nominal power vs hull speed at the nominal no wind condition

\[ V_{\text{HW.trial}} := R^{<1>} \]

\[ P_{S \text{.rat.trial}i} := C_{PV} \left( V_{\text{HW.trial}} \right)^3 \]

 Shaft power at no wind vs hull speed

**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

\[ C_{PV,n} := \frac{C_{PV} \cdot 10^6}{\rho \cdot D^2} \]

Identify equilibrium

\[ J := 0.5 \quad K := 0.15 \quad \text{Initial values} \]

Given

\[ K = \rho_0 + \rho_1 \cdot J \]

\[ K = C_{PV,n} \cdot J^3 \]

Solve

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

\[ J_{\text{HW.noVAW}} = 0.699 \quad K_{P \text{.noVAW}} = 0.132 \]
Results plotted

\[ k := 0 \ldots 10 \]
\[ J_{HW,plt}^k := 0.625 + 0.01 \cdot k \]
\[ K_{P,\text{sup,plt}}^k := p_n^0 + p_n^1 \cdot J_{HW,plt}^k \]
\[ K_{P,\text{req,plt}}^k := C \cdot PV_n \cdot (J_{HW,plt}^k)^3 \]

Nominal no wind condition

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

\[ N_{S,\text{rat.trial}} := \frac{V_{HW,\text{rat.trial}}}{J_{HW,\text{noVAW}}^D \cdot P} \]

Shaft frequency vs hull speed

\[ N_{S,\text{rat.trial}} = [1.261, 1.389, 1.453, 1.566, 1.587, 1.597, 1.686, 1.707] \]
Compare with results of PATE_01.1

Power

Shaft powers vs hull speed

<table>
<thead>
<tr>
<th>Hull speeds in m/sec</th>
<th>Shaft powers in MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>15</td>
</tr>
</tbody>
</table>

V_{HW.rat.trial}, V_{HW.rat.trial.01.1}

hull speeds in m/sec

Shaft frequencies vs hull speed

<table>
<thead>
<tr>
<th>Hull speeds in m/sec</th>
<th>Shaft frequencies in Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>0.5</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>1.5</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
</tr>
</tbody>
</table>

V_{HW.rat.trial}, V_{HW.rat.trial.01.1}

hull speeds in m/sec

Evidently the final results do not differ for the two different data sets!
Scrubinise 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 differs only slightly from the trials condition.

<table>
<thead>
<tr>
<th>Trials condition</th>
<th>Reference condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_{\text{aft.trial}} := 7.42 \cdot \text{m}$</td>
<td>$T_{\text{aft.ref}} := 7.60 \cdot \text{m}$</td>
</tr>
<tr>
<td>$T_{\text{fore.trial}} := 6.12 \cdot \text{m}$</td>
<td>$T_{\text{fore.ref}} := 6.10 \cdot \text{m}$</td>
</tr>
<tr>
<td>$D_{\text{Vol.trial}} := 58894.1 \cdot \text{m}^3$</td>
<td>$D_{\text{Vol.ref}} := 59649.0 \cdot \text{m}^3$</td>
</tr>
</tbody>
</table>

Propeller power supplied (delivered) and shaft frequency

at reference condition reported

\[
\begin{align*}
V_{\text{HW.trad}} &= \begin{bmatrix} 6.369 \\ 6.611 \\ 7.573 \\ 7.351 \\ 7.953 \\ 8.149 \\ 8.349 \\ 8.128 \end{bmatrix}, \\
P_{\text{S.trad}} &= \begin{bmatrix} 4.4224 \\ 5.8975 \\ 9.2628 \\ 7.4969 \\ 9.8683 \\ 12.0176 \\ 12.7595 \\ 10.5436 \end{bmatrix} \cdot \text{MW}, \\
N_{\text{S.trad}} &= \begin{bmatrix} 75.8 \\ 81.8 \\ 94.6 \\ 89.4 \\ 97.5 \\ 102.7 \\ 105.0 \\ 99.7 \end{bmatrix} \cdot \text{rpm}, \\
\eta_{\text{D.ref}} &= \begin{bmatrix} 0.828 \\ 0.824 \\ 0.801 \\ 0.808 \\ 0.788 \\ 0.780 \\ 0.770 \\ 0.781 \end{bmatrix}.
\]

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

\[ k := 0 \ldots 1 \]

\[ A_{\text{eta},k} := \left( V \text{ HW.trad.ref}_i \right)^k \]

\[ X_{\text{eta}} := \text{geninv} \left( A_{\text{eta}} \right) \cdot \eta D \]

\[ \eta D\text{.trad} := A_{\text{eta}} \cdot X_{\text{eta}} \]

\[ \eta D\text{.trad.mean} := \text{mean} \left( \eta D\text{.trad} \right) \]

\[ \eta D\text{.trad.mean} := \eta D\text{.trad.mean} \]

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.

\[ C_{\text{RV.tot}} := \eta D\text{.trad.mean} \cdot C PV \]

\[ R_{\text{HW.trad.tot}} := C_{\text{RV.tot}} \left( V \text{ HW.trad.ref}_j \right)^2 \]

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

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

\[ \Delta t_{trad} := \Delta t \]

Record :=
\[
\begin{align*}
\text{Internal}_\text{rat} & \leftarrow [\text{Res}_{\text{sup}} \quad \text{Res}_{\text{req}}] \\
\text{Final}_\text{rat} & \leftarrow [\text{Run} \quad \Delta t \quad V_{\text{HW.rat.trial}} \quad P_{\text{S.rat.trial}} \quad N_{\text{S.rat.trial}}] \\
\text{Internal}_\text{trad} & \leftarrow [V_{\text{WG.trad.scorr}} \quad J_{\text{HW.trad.scorr}} \quad K_{\text{P.sup.trad}}] \\
\text{Final}_\text{trad} & \leftarrow [\text{Run} \quad \Delta t_{\text{trad}} \quad V_{\text{HW.trad.ref}} \quad P_{\text{S.trad.ref}} \quad N_{\text{S.trad.ref}}] \\
\text{record} & \leftarrow [\text{Internal}_\text{rat} \quad \text{Final}_\text{rat} \quad \text{Internal}_\text{trad} \quad \text{Final}_\text{trad}] \\
\text{record} & \leftarrow [\text{Internal}_\text{rat} \quad \text{Final}_\text{rat} \quad \text{Internal}_\text{trad} \quad \text{Final}_\text{trad}] \\
\end{align*}
\]

File := concat(“Results_”. , EID)

WRITEPRN(File) := Record

Print final rational results

final \( \text{rat}^{<0>} \) := Run

final \( \text{rat}^{<1>} \) := V\( \frac{m}{\text{kts} \cdot \text{sec}} \)

final \( \text{rat}^{<2>} \) := P_{\text{S.rat.trial}}

final \( \text{rat}^{<3>} \) := N\( \frac{\text{min}}{\text{sec}} \)

\[
\text{final}_\text{rat} = \begin{bmatrix}
4.000 & 12.072 & 4.729 & 75.632 \\
5.000 & 13.299 & 6.322 & 83.317 \\
7.000 & 13.915 & 7.242 & 87.178 \\
6.000 & 14.997 & 9.064 & 93.951 \\
8.000 & 15.203 & 9.443 & 95.243 \\
11.000 & 15.296 & 9.618 & 95.826 \\
9.000 & 16.150 & 11.321 & 101.177 \\
10.000 & 16.347 & 11.740 & 102.410
\end{bmatrix}
\]
Conclusions

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

The rational evaluation produces nearly the same results for the two data sets analysed. In the near future a data set further reduced, to include only the data of three double runs as usually performed, will be analysed in PATE_01.3.

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