Prof. Dr.-Ing. M.Schmiechen

MS 0306011630
0310091100
1107121300

1205131500
1207201330

1301051100
1305081300

To whom it may concern

Powering performance of a bulk carrier during speed trials in ballast condition at two trim settings reduced to the nominal no wind and waves condition

As first evaluated data at the second, at the larger trim, i. e. at the larger nominal propeller submergence

Title of the file and title of a plot corrected on
1306171630

Units, constants, routines

Reference:C:\ANONYMA_5\routines .mcd

Trials identification

TID = "ANONYMA"

Trials condition $trim := 2$

The data of the second, the later trials at the larger trim have been evaluated first, after the preliminary evaluation of the data of the first trials resulted in an unrealistic propeller power characteristic, indicating that something was 'wrong' with the data. Reasons to be revealed subsequently, when the data of the first, the earlier trials at the smaller trim are being evaluated next.

Constants

Trim at trials $\Delta T_{nom} := 3.64 \cdot m$ $\Delta T_{nom} := \frac{\Delta T_{nom}}{m}$

Draught aft $T_{aft} := 7.15 \cdot m$ $T_{aft} := \frac{T_{aft}}{m}$

Propeller tip below undisturbed surface, estimated $\Delta T_{Tip} := 1.35\ m$

Input of mean data

means := READPRN("Means_2.prn")

rstdevs := READPRN("rSdvM_2.prn")

$nr := rows(means)$ $run := 0 .. nr - 1$ $nr = 6.000$

$nc := cols(means)$ $mag := 0 .. nc - 1$ $nc = 17.000$

Assign data reported

Time	$t := means^{\langle 0 \rangle} \cdot hr$	$t := \frac{t}{hr}$	
Shaft frequency	$N_S := means^{\langle 2 \rangle} \cdot Hz$	$N_S := \frac{N_S}{Hz}$	$N_{S.rsdm} := rstdevs^{\langle 2 \rangle}$
Shaft power	$P_S := means^{\langle 1 \rangle} \cdot W$	$P_S := \frac{P_S}{MW}$	$P_{S.rsdm} := rstdevs^{\langle 1 \rangle}$
Speed over ground	$V_G := means^{\langle 3 \rangle} \cdot \frac{m}{s}$	$V_G := \frac{V_G \cdot s}{m}$	$V_{G.rsdm} := rstdevs^{\langle 3 \rangle}$
Wind speed	$V_W := means^{\langle 7 \rangle} \frac{m}{s}$	$V_W := \frac{V_W \cdot s}{m}$	$V_{W.rsdm} := rstdevs^{\langle 7 \rangle}$
Wind direction	$\psi_W := means^{\langle 6 \rangle} \cdot \frac{deg}{rad}$		$\psi_{W.rsdm} := rstdevs^{\langle 6 \rangle}$
Trim	$\Delta T := means^{\langle 5 \rangle} \; m$	$\Delta T := \frac{\Delta T}{m}$	$\Delta T_{rsdm} := rstdevs^{\langle 5 \rangle}$
Ship speed in water	$V_{H.rep} := means^{\langle 15 \rangle} \frac{m}{s}$	$V_{H.rep} := \frac{V_{H.rep} \cdot s}{m}$	$V_{H.rep.rsdm} := rstdevs^{\langle 15 \rangle}$

Data in SI-Units non-dimensionalized in view of further use in some mathematical subroutines, which by definition cannot handle arguments with (different) physical dimensions!

Mean values, intermediate results

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

$$t = \begin{bmatrix} -1.004 \\ -0.638 \\ -0.142 \\ 0.227 \\ 0.571 \\ 0.986 \end{bmatrix} \quad N_S = \begin{bmatrix} 1.748 \\ 1.748 \\ 1.900 \\ 1.587 \\ 1.587 \\ 1.898 \end{bmatrix} \quad P_S = \begin{bmatrix} 4.824 \\ 5.547 \\ 6.924 \\ 4.143 \\ 3.621 \\ 6.281 \end{bmatrix} \quad V_G = \begin{bmatrix} 7.203 \\ 5.725 \\ 6.637 \\ 4.970 \\ 6.675 \\ 7.796 \end{bmatrix}$$

$$V_W = \begin{bmatrix} 7.742 \\ 21.690 \\ 20.870 \\ 20.550 \\ 7.871 \\ 6.565 \end{bmatrix} \quad \psi_W = \begin{bmatrix} 3.759 \\ 0.617 \\ 0.250 \\ 0.244 \\ 3.808 \\ 3.852 \end{bmatrix} \quad \Delta T = \begin{bmatrix} 4.020 \\ 3.850 \\ 3.845 \\ 3.754 \\ 3.791 \\ 3.839 \end{bmatrix} \quad V_{H.rep} = \begin{bmatrix} 7.203 \\ 5.725 \\ 6.637 \\ 4.970 \\ 6.675 \\ 7.796 \end{bmatrix}$$

$\psi_{W_1} := 0.256$ The value reported does not fit 'into the pattern'

Relative (!) standard deviations of mean (!) values

For ready reference the matrices of the relative (!) standard deviations of mean values of the measured magnitudes are also printed here, conveniently in %. Multiplied by the factor 2 these values are estimates of the relative 95% confidence radii of the mean values.

$$\frac{N_{S.rsdm}}{\%} = \begin{bmatrix} 0.019 \\ 0.016 \\ 0.016 \\ 0.051 \\ 0.019 \\ 0.016 \end{bmatrix} \quad \frac{P_{S.rsdm}}{\%} = \begin{bmatrix} 0.099 \\ 0.077 \\ 0.071 \\ 0.102 \\ 0.110 \\ 0.080 \end{bmatrix} \quad \frac{V_{G.rsdm}}{\%} = \begin{bmatrix} 0.030 \\ 0.058 \\ 0.061 \\ 0.160 \\ 0.034 \\ 0.032 \end{bmatrix}$$

$$\frac{V_{W.rsdm}}{\%} = \begin{bmatrix} 0.604 \\ 0.249 \\ 0.233 \\ 0.366 \\ 0.565 \\ 0.687 \end{bmatrix} \quad \frac{\psi_{W.rsdm}}{\%} = \begin{bmatrix} 0.145 \\ 5.662 \\ 7.374 \\ 11.270 \\ 0.136 \\ 0.181 \end{bmatrix} \quad \frac{\Delta T_{rsdm}}{\%} = \begin{bmatrix} 0.381 \\ 0.732 \\ 0.695 \\ 1.888 \\ 0.413 \\ 0.318 \end{bmatrix} \quad \frac{V_{H.rep.rsdm}}{\%} = \begin{bmatrix} 0.030 \\ 0.058 \\ 0.061 \\ 0.160 \\ 0.034 \\ 0.032 \end{bmatrix}$$

At the up-wind conditions, runs 2, 3, 4 (indices 1, 2, 3), the wind direction is varying considerably. The variations in the trim are also noteworthy.

Normalise data

for preliminary check of consistency only!

$n_i := \mathrm{last}(t)$

$i := 0 .. n_i$

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

$J_G = \begin{bmatrix} 0.710 \\ 0.565 \\ 0.602 \\ 0.540 \\ 0.725 \\ 0.708 \end{bmatrix}$ $\qquad$ $K_P = \begin{bmatrix} 0.134 \\ 0.154 \\ 0.150 \\ 0.154 \\ 0.135 \\ 0.137 \end{bmatrix}$

Sort data in down and up-wind

$S := \mathrm{Sort\_runs}\left(J_G, K_P, \psi_H\right)$

$J_{G.do} := S^{\langle 0 \rangle}$ $\qquad$ $J_{G.do} = \begin{bmatrix} 0.710 \\ 0.725 \\ 0.708 \end{bmatrix}$ $\qquad$ $K_{P.do.or} := S^{\langle 1 \rangle}$ $\qquad$ $K_{P.do.or} = \begin{bmatrix} 0.134 \\ 0.135 \\ 0.137 \end{bmatrix}$

$J_{G.up} := S^{\langle 2 \rangle}$ $\qquad$ $J_{G.up} = \begin{bmatrix} 0.565 \\ 0.602 \\ 0.540 \end{bmatrix}$ $\qquad$ $K_{P.up.or} := S^{\langle 3 \rangle}$ $\qquad$ $K_{P.up.or} = \begin{bmatrix} 0.154 \\ 0.150 \\ 0.154 \end{bmatrix}$

Analyse power supplied

Confidence range of mean powers

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

$P_{S.sdv_i} := P_{S.rsdm_i} \cdot P_{S_i}$

$P_{S.Conf_i} := 2 \cdot \text{mean}(P_{S.sdv})$

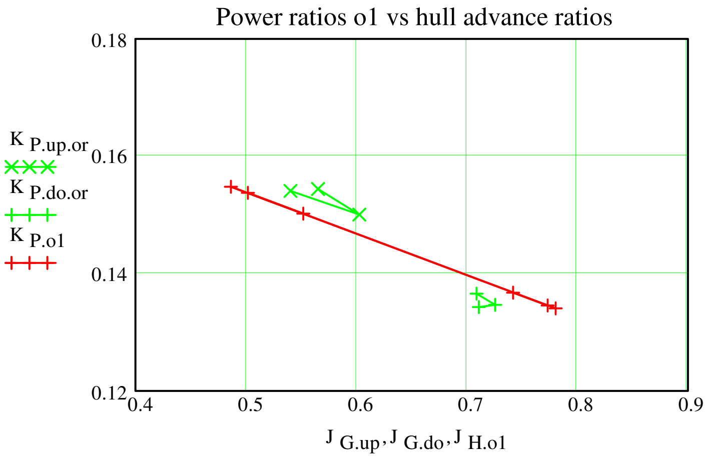
Identify current

Linear current convention

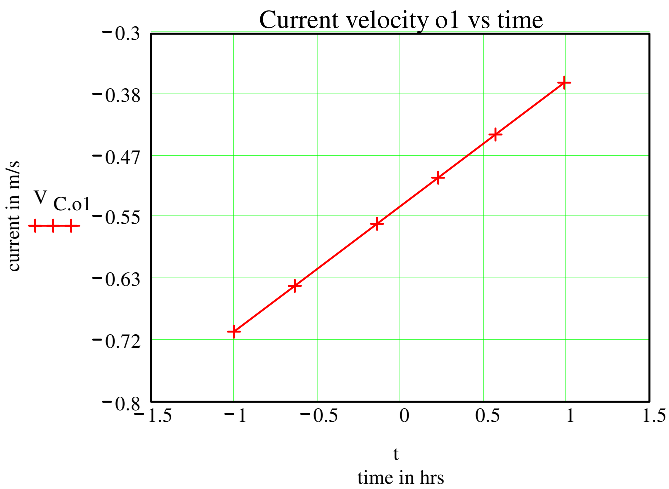
$o := 1$

$Res_{sup.o1} := \text{Polyn\_current}(o, \rho, D, t, \psi_H, V_G, N_S, P_S)$

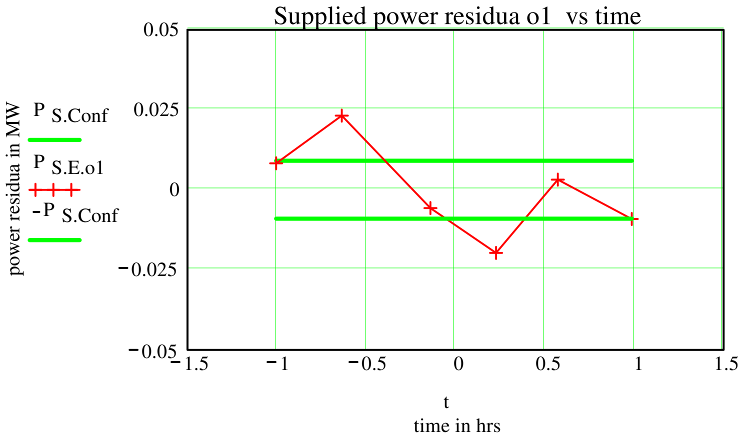
$\left[P_{S.E.o1} \;\; v_{o1} \;\; V_{C.o1} \;\; p_{o1} \;\; V_{H.o1} \;\; P_{S.o1} \;\; p_{nor.o1} \;\; J_{H.o1} \;\; K_{P.o1} \right] := Res_{sup.o1}$



Current velocity



Power residua

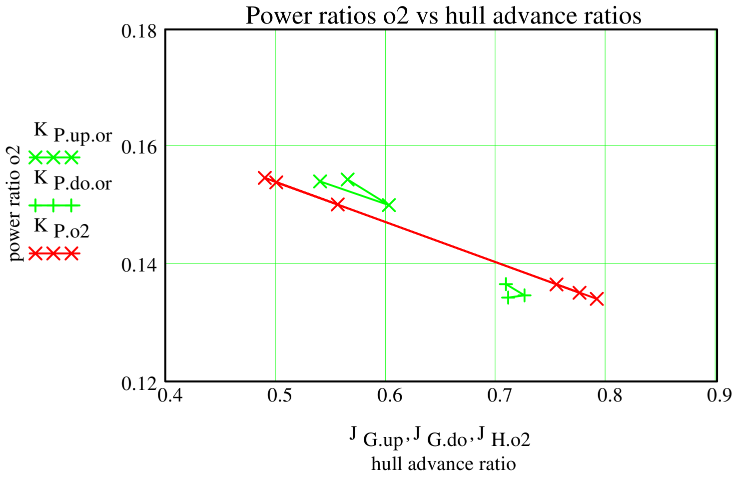


Quadratic current convention

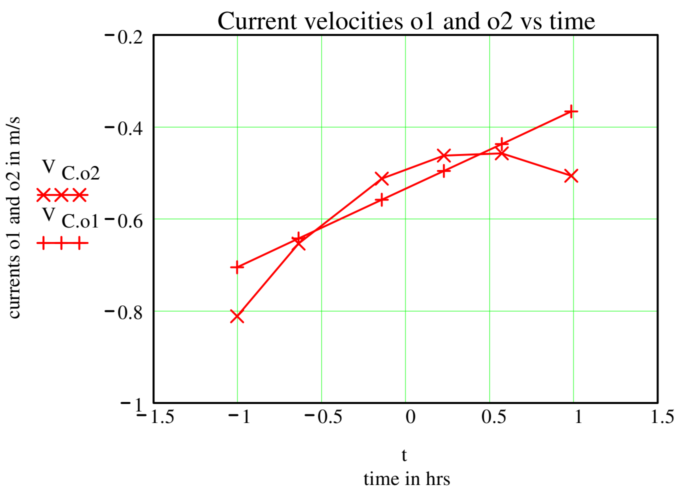
$o := 2$

$Res_{sup.o2} := Polyn\_current(o, \rho, D, t, \psi_H, V_G, N_S, P_S)$

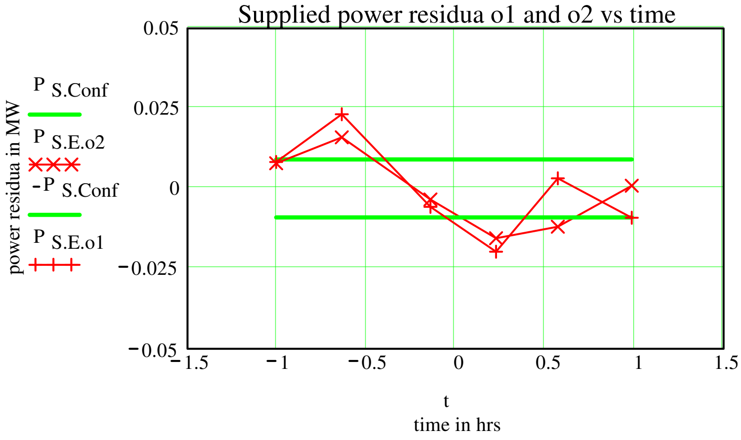
$[P_{S.E.o2}\ v_{o2}\ V_{C.o2}\ p_{o2}\ V_{H.2}\ P_{S.o2}\ p_{nor.n2}\ J_{H.o2}\ K_{P.o2}] := Res_{sup.o2}$



Current velocity



Compare power residua



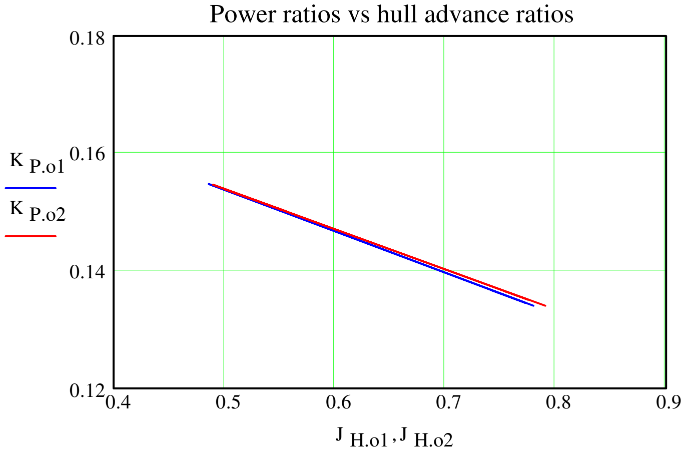
According to this detailed analysis **the linear law for the current may be considered as optimal, as most acceptable in the range of observations, as the quadratic law does not improve the quality of the approximation.**
This criterion has been used earlier for optimal estimates of spectra as described e. g. in the paper:
Schmiechen, M.: Estimation of Spectra of Truncated Transient Functions. Schiffstechnik/Ship Technology Research 46 (1999) No. 2, pp. 111/127.

And as shown in the following it happens accidentally (!) that the linear law results in nearly exactly the same current as a simple tidal law, a constant current super-imposed by a harmonic tidal current, the latter permitting extraplolation to the earlier trial at smaller trim.

An interesting observation

concerning the propeller characteristic

According to the above evaluations the propeller characteristic does not change significantly with changing order of approximation, but the small differences matter.

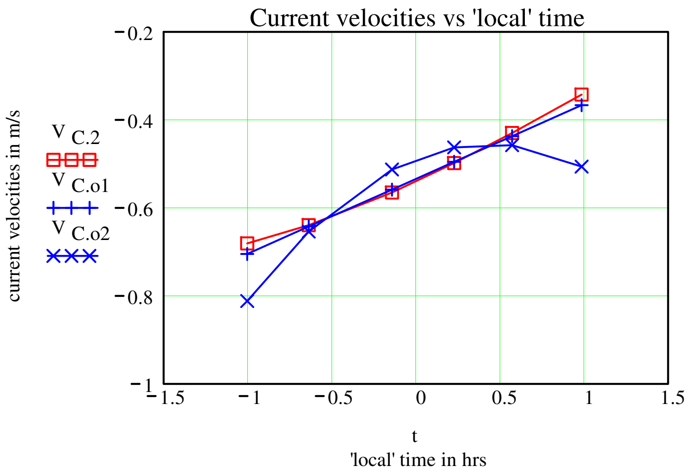


Identification of current at the larger trim

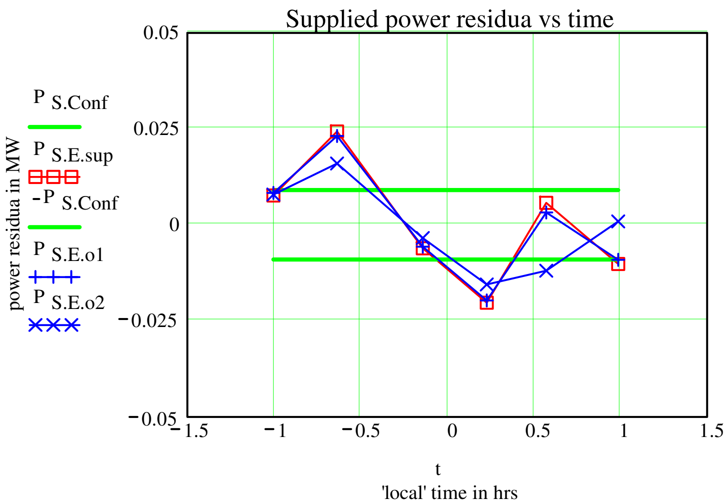
$Res_{sup} := Tidal\_current(\omega_T, t_T - t_{2.m}, \rho, D, t, \psi_H, V_G, N_S, P_S)$

$[P_{S.E.sup}\ v_2\ V_{C.2}\ p_2\ V_{H.2}\ P_{S.sup.2}\ p_{n.2}\ J_{H.2}\ K_{P.2}] := Res_{sup}$

Accounting for the 'uinversal' tidal period and the tidal phase, known from the table of tides, the constant current velocity and the tidal current amplitude are identified.



$$V_{C.2} = \begin{bmatrix} -0.681 \\ -0.640 \\ -0.565 \\ -0.499 \\ -0.430 \\ -0.343 \end{bmatrix}$$



$V_{C.2.mean} := v_{2_0}$ $V_{C.2.mean} = -0.298$ The **mean** northerly **current** is **0.58 kn**

$V_{C.2.ampl} := v_{2_1}$ $V_{C.2.ampl} = 0.427$ The **tidal current amplitude** is **0.83 kn**

Results stored

WRITEPRN("Res_sup_2.prn") := Res_{sup}

Extrapolate to current at the smaller trim

As has been mentioned earlier the identification of the current at the first trials with the smaller trim is not possible. Thus its values are determined by extrapolation based on the current and tide identified from data recorded at the second trials.

Due to the very high length of the tidal wave crudely estimated from a source readily at hand* there is no need to account for tidal phases due to the different locations of the runs in the two sets of trials, but only for a mean phase shift between the two sets of runs.

* Albert Defant: Ebbe und Flut des Meeres, der Atmosphäre und der Erdfeste. Berlin: Springer, 1953; p. 86.

The location of the first set of runs was north of second set, the rotating tide in the North Atlantic is also moving north at the location of the trials. Thus the tide at the first trials was later than that at the first trials.

$t_2 := t + t_{2.m}$ — 'Global' or day time at the second trial

$\Delta t := \frac{\Delta s_{12}}{c_T}$ $\quad \Delta t = 0.125$ — Evidently the global phase correction is quite small.

$k := 0..21$

$V_{C.2.m_k} := v_{2_0}$

$t_{exp_k} := -9.0 + 0.5 \cdot k$

$V_{C.2.exp_k} := VC\left(v_2, t_{exp_k} + t_{2.m}, \omega_T, t_T\right)$

Time at first trials

$means_1 := READPRN("Means\_1.prn")$

$\Delta t_1 := means_1^{<0>}$

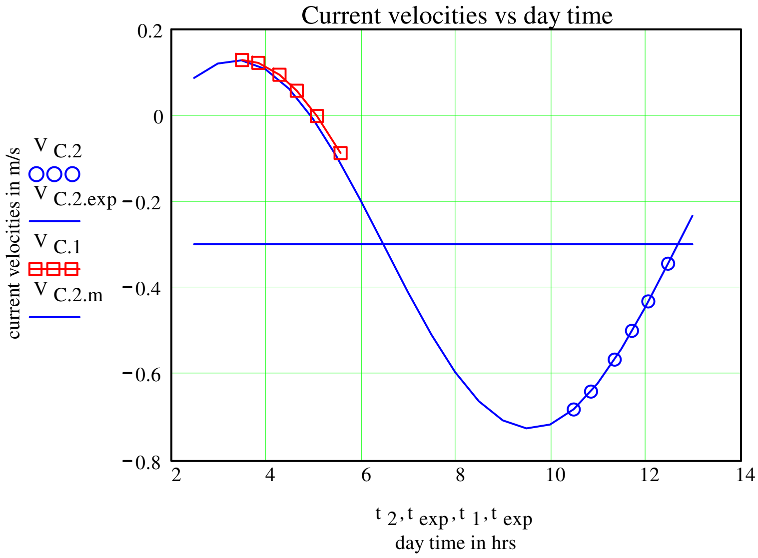
$t_1 := t_{1.m} + \Delta t_1$

$V_{C.1_i} := VC\left(v_2, t_{1_i} - \Delta t, \omega_T, t_T\right)$

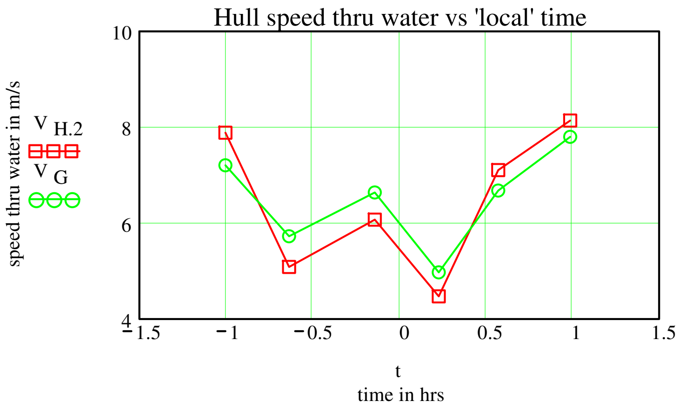
$WRITEPRN("V.C.1.prn") := V_{C.1}$ — Store for the analysis of the data at the smaller trim.

$t_{exp} := t_{exp} + t_{2.m}$ — 'Local' time at second trim

Plot current velocities at both locations



Ship speed thru water



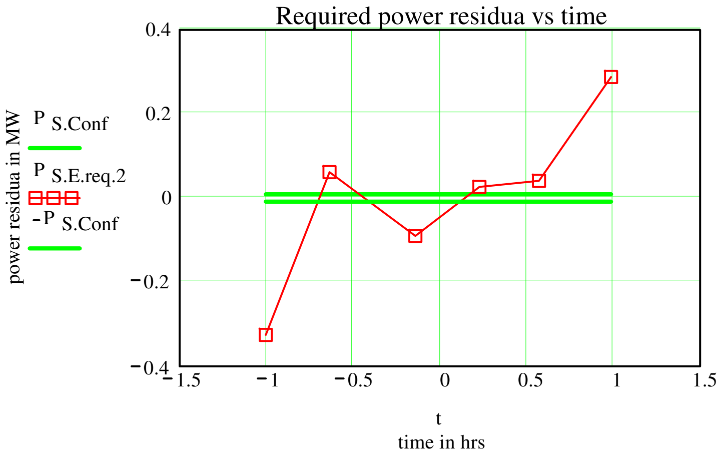
Analyse power required

Identify power (!) 'coefficients' of environment convention

$Res_{req.2} := Required(V_{H.2}, \psi_H, V_{C.2}, P_S, V_W, \psi_W)$

$[P_{S.E.req.2} \;\; q_2 \;\; P_{S.req.2} \;\; P_{S.req.2.0} \;\; P_{S.req.2.1}] := Res_{req.2}$

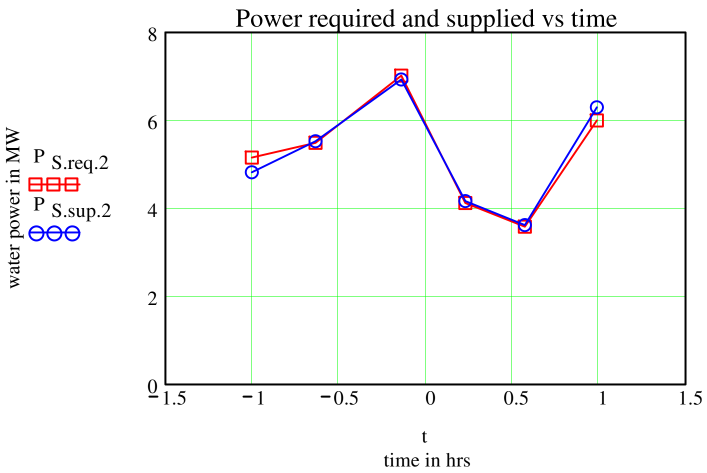
Required power residua



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

The residua can be considered as a measure of changes of the inviroment

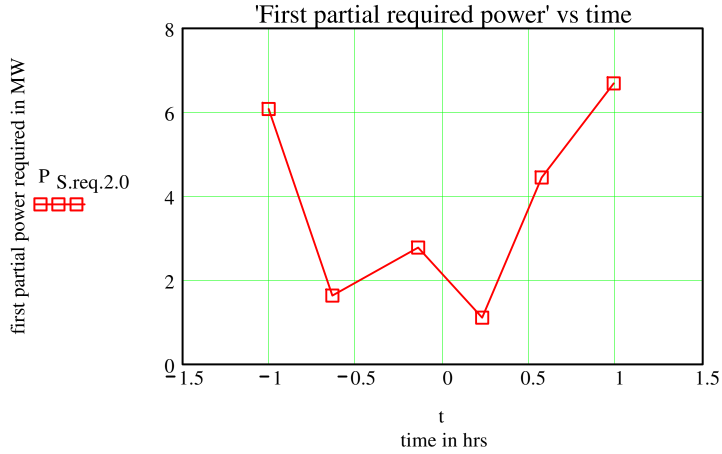
Power required



$$P_{S.req.2} = \begin{bmatrix} 5.150 \\ 5.486 \\ 7.014 \\ 4.116 \\ 3.581 \\ 5.993 \end{bmatrix}$$

First partial power required

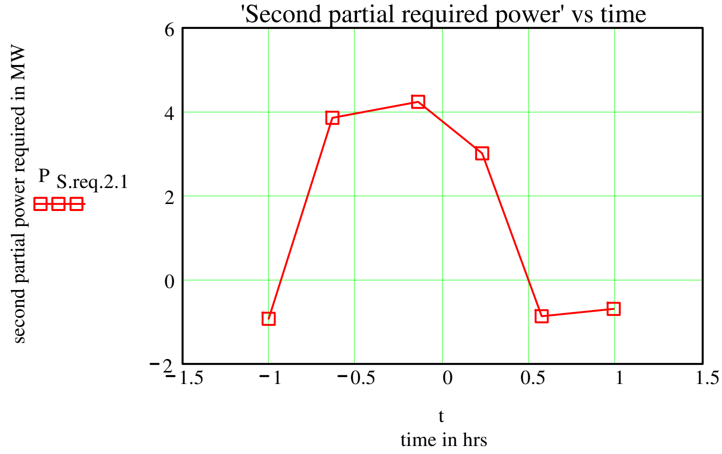
This concept has formerly, *misleadingly* been called 'water' power.



$$P_{S.req.2.0} = \begin{bmatrix} 6.076 \\ 1.631 \\ 2.776 \\ 1.108 \\ 4.448 \\ 6.685 \end{bmatrix}$$

Second partial power required

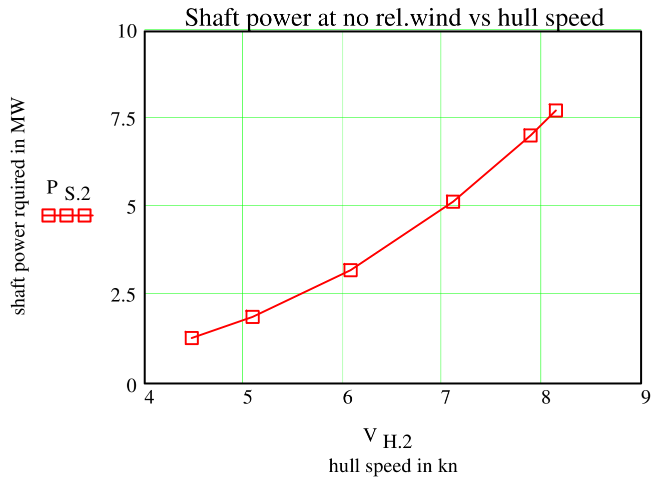
This concept has formerly, *misleadingly* been called 'wind and wave' power. both concepts include additional powes due the seastate.



$$P_{S.req.2.0} = \begin{bmatrix} 6.076 \\ 1.631 \\ 2.776 \\ 1.108 \\ 4.448 \\ 6.685 \end{bmatrix}$$

Power vs hull speed
at the nominal no wind and waves condition

$C_{PV.2} := q_{2_0} + q_{2_1}$ $\quad C_{PV.2} = 0.01437$ $\quad V_{H.2} := \mathrm{sort}(V_{H.2})$ $\quad P_{S.2} := C_{PV.2} \cdot V_{H.2}^{\ 3}$



$$P_{S.2} = \begin{bmatrix} 1.285 \\ 1.890 \\ 3.217 \\ 5.155 \\ 7.042 \\ 7.748 \end{bmatrix}$$

Powering performance

at the nominal no wind and waves condition

Power coefficient normalised

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

Identify equilibrium

$J := 1 \qquad K := 1$

Given

$K = p_{n.2_0} + p_{n.2_1} \cdot J$

$K = C_{PV.2.n} \cdot J^3$

Solve

$$\begin{bmatrix} J_{H.equil.2} \\ K_{P.equil.2} \end{bmatrix} := \text{Find}(J, K)$$

$J_{H.equil.2} = 0.695$

$K_{P.equil.2} = 0.140$

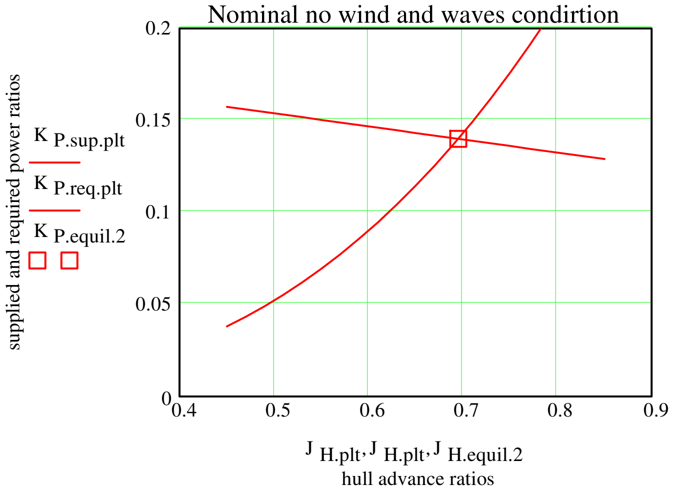
Results plotted

$k := 0 .. 20$

$J_{H.plt_k} := 0.45 + 0.02 \cdot k$

$K_{P.sup.plt_k} := p_{n.2_0} + p_{n.2_1} \cdot J_{H.plt_k}$

$K_{P.req.plt_k} := C_{PV.2.n} \cdot \left(J_{H.plt_k}\right)^3$



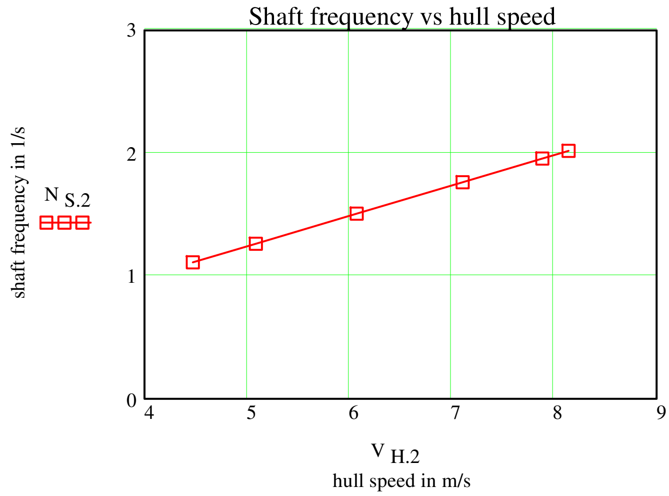
Due to the model adopted in this case the propeller is permanently operating at the same normalised condition.

Check of consistency

Frequency of shaft rev's vs hull speed
at the nominal no wind and waves condition

$N_{S.2_i} := 1$ initial values

$N_{S.2} := \text{Identify\_freq}\left(p_2, V_{H.2}, P_{S.2}, N_{S.2}\right)$



$N_{S.2} = \begin{bmatrix} 1.109 \\ 1.262 \\ 1.506 \\ 1.763 \\ 1.956 \\ 2.019 \end{bmatrix}$

Linear approximation

$A_{N.2_{i,0}} := 1 \quad A_{N.2_{i,1}} := V_{H.2_i} \quad X_{N.2} := \text{geninv}\left(A_{N.2}\right) \cdot N_{S.2} \quad X_{N.2} = \begin{bmatrix} -3.1677 \cdot 10^{-5} \\ 0.2481 \end{bmatrix}$

$N_{S.E.2} := N_{S.2} - A_{N.2} \cdot X_{N.2} \quad N_{S.E.2.Conf} := 2 \cdot \text{stdev}\left(N_{S.E.2}\right) \quad N_{S.E.2.Conf} = 7.225 \cdot 10^{-5}$

Per definition this result is in accordance
with the nominal no wind and waves condition derived:
the frequency of shaft rotation is directly
proportional to the hull advance speed.

$C_{NV.2} := \dfrac{1}{D \cdot J_{H.equil.2}} \quad C_{NV.2} = 0.2481 \quad N_{S.2} := C_{NV.2} \cdot V_{H.2} \quad N_{S.2} = \begin{bmatrix} 1.109 \\ 1.262 \\ 1.506 \\ 1.763 \\ 1.956 \\ 2.019 \end{bmatrix}$

Required power results

$Res_{req} := \left[P_{S.E.req.2} \;\; q_2 \;\; V_{H.2} \;\; P_{S.req.2.0} \;\; P_{S.req.2.1} \;\; P_{S.2} \;\; N_{S.2} \right]$

Store results

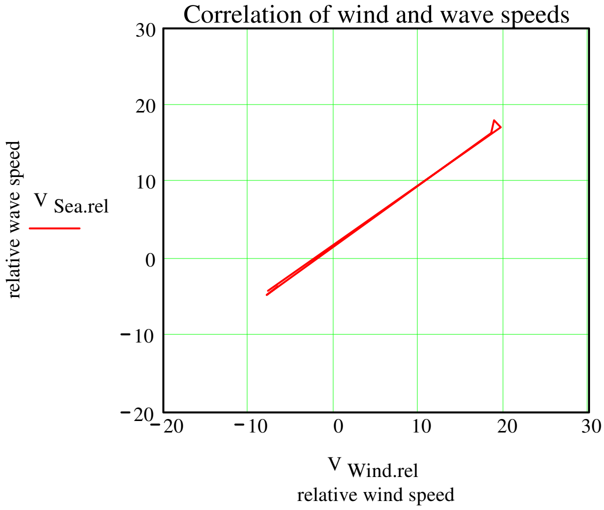
WRITEPRN("Res_req_2.prn") := Res_{req}

Appendix

Check correlation of relative speeds of wind and hypothetical waves

$$V_{Wind.rel_i} := -V_{W_i} \cdot \cos\left(\psi_{W_i} - \psi_{H_i}\right) \cdot dir\left(\psi_{H_i}\right) \qquad V_{Sea.rel_i} := -\left(V_S \cdot dir\left(\psi_{H_i}\right) - V_{G_i}\right)$$

$$V_{Wind.rel} = \begin{bmatrix} -7.717 \\ 19.606 \\ 18.815 \\ 18.470 \\ -7.867 \\ -6.565 \end{bmatrix} \qquad V_{Sea.rel} = \begin{bmatrix} -4.195 \\ 17.123 \\ 18.035 \\ 16.368 \\ -4.723 \\ -3.602 \end{bmatrix}$$



END

As first evaluated data at the second, at the larger trim, i. e. at the larger propeller submergence