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Rational Ship Speed Trial Evaluation

Rational method proposed
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Results of rational evaluation only!
Results of traditional evaluation not being disclosed!

Note! All data in coherent SI units, except time in hr,
as stored in the corresponding program TID_data.mcd

Units $kn := \frac{1852 \cdot m}{3600 \cdot sec}$ $MW := 10^6 \cdot watt$

Trial identification TID := "05010"

File_const := concat(TID , "_const.prn")

$Const := READPRN(File\_const)^T$

$Const_0 := TID$ TID = "05010" $\rho := Const_1$ $D := Const_2$

Measured data: Physical data for traditional runs as provided by the yard

File_meas_trad := concat(TID , "_meas_trad.prn")

$Data_{meas.trad} := READPRN(File\_meas\_trad)$

$t := Data_{meas.trad}^{\langle 0 \rangle}$ $\phi := Data_{meas.trad}^{\langle 1 \rangle}$ $V_{Grd} := Data_{meas.trad}^{\langle 2 \rangle}$

$N_{Shaft} := Data_{meas.trad}^{\langle 3 \rangle}$ $P_{Shaft} := Data_{meas.trad}^{\langle 4 \rangle}$

$V_{W.rel.abs} := Data_{meas.trad}^{\langle 5 \rangle}$ $V_{W.rel.dir} := Data_{meas.trad}^{\langle 6 \rangle}$

Convention: Speed over ground is assumed to be given in the direction of the course!

Identification of models

$n := rows(t)$ $n = 8$ Size of sample

$i := 0 .. n - 1$

Power charcteristic in the behind condition

$A_{rat_{i,0}} := \left(N_{Shaft_i}\right)^3$

$A_{rat_{i,1}} := -\left(N_{Shaft_i}\right)^2 \cdot V_{Grd_i}$

Convention: This model is introduced as sufficient approximation in the range of the data available.

Current velocity

Harmonic current model

$T := 12 \cdot hr + 25 \cdot min$ Average cycle of tides

$\omega := \frac{2 \cdot \pi}{T}$ $\omega = 1.406 \cdot 10^{-4}\ sec^{-1}$

$\omega := \omega \cdot hr$ $\omega = 0.506$

$D_{Curr_i} := \mathrm{if}(\phi_i < \pi, -1, 1)$ Direction of current

$A_{rat_{i,2}} := (N_{Shaft_i})^2 \cdot D_{Curr_i}$

$A_{rat_{i,3}} := A_{rat_{i,2}} \cdot \cos(\omega \cdot t_i)$

$A_{rat_{i,4}} := A_{rat_{i,2}} \cdot \sin(\omega \cdot t_i)$

Least square fit

$X_{rat} := LI(A_{rat}) \cdot P_{Shaft}$

Residua in terms of power

$E := P_{Shaft} - A_{rat} \cdot X_{rat}$

Relative residua

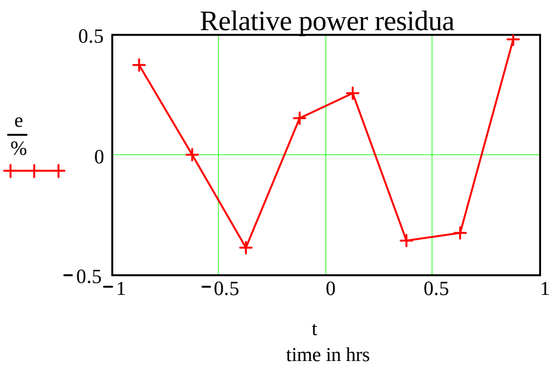
$$e_i := \frac{E_i}{P_{Shaft_i}}$$

Quality of approximation

$$\frac{|E|}{|P_{Shaft}|} = 0.305 \circ \%$$

Left-inverse

$$LI(A) := \left| \begin{array}{l} r \leftarrow rows(A) \\ c \leftarrow cols(A) \\ s \leftarrow svds(A) \\ \text{for } i \in 0..c-1 \\ \quad ISV_{i,i} \leftarrow (s_i)^{-1} \\ UV \leftarrow svd(A) \\ U \leftarrow submatrix(UV, 0, r-1, 0, c-1) \\ V \leftarrow submatrix(UV, r, r+c-1, 0, c-1) \\ A_{inv.left} \leftarrow V \cdot ISV \cdot U^T \\ A_{inv.left} \end{array} \right.$$



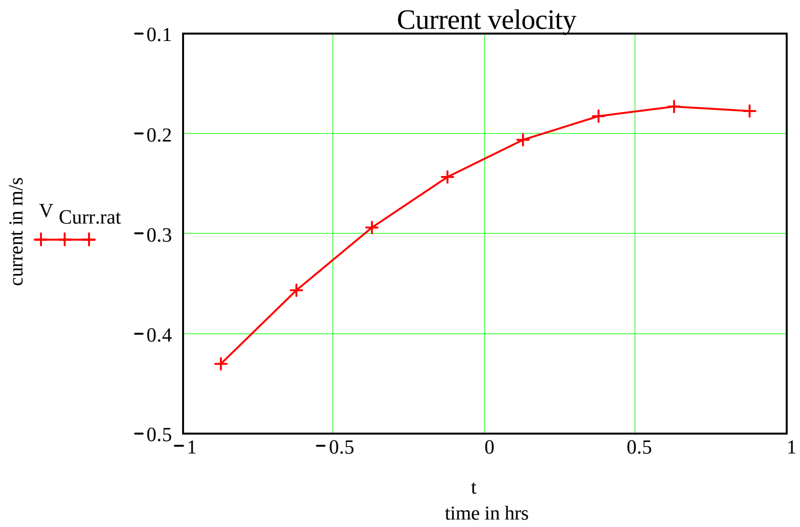
Current velocity

$j := 0..2$

$$v_j := \frac{X_{rat_{2+j}}}{X_{rat_1}}$$

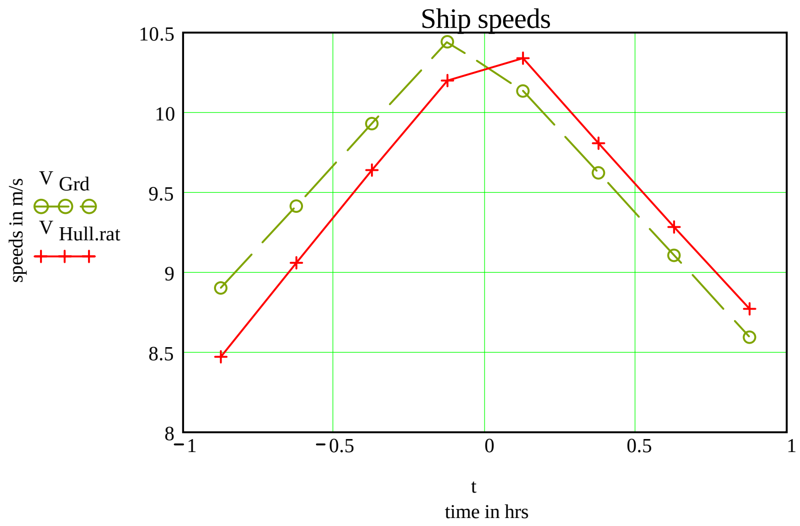
$V_{Curr.rat_i} := v_0 + v_1 \cdot \cos(\omega \cdot t_i) + v_2 \cdot \sin(\omega \cdot t_i)$

Convention: The current is assumed to be in the direction of the ship's axis, the propeller is assumed not to notice cross flow.



Ship hull speed, i. e. relative to the water

$$V_{Hull.rat_i} := V_{Grd_i} - V_{Curr.rat_i} \cdot D_{Curr_i}$$



Power parameters, rational

$$p_{rat_0} := X_{rat_0} \qquad p_{rat_1} := X_{rat_1}$$

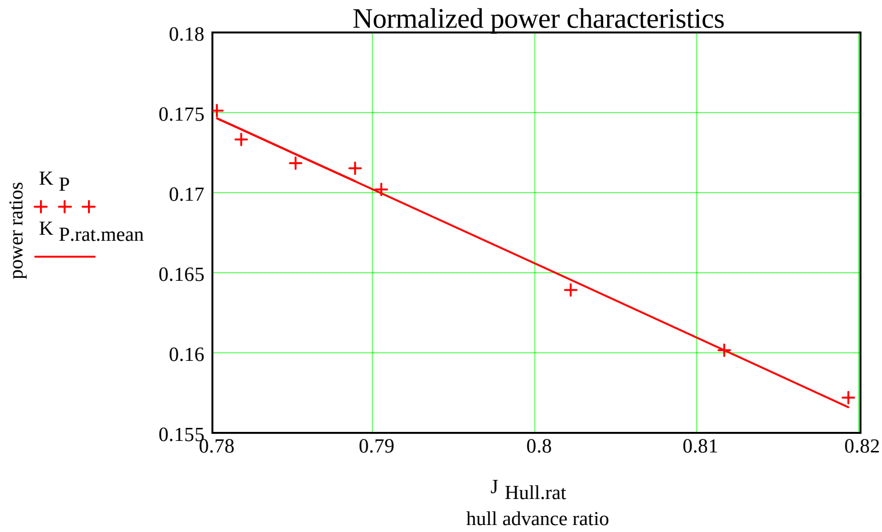
Normalised values

$$J_{Hull.rat_i} := \frac{V_{Hull.rat_i}}{D \cdot N_{Shaft_i}} \qquad K_{P.rat_0} := \frac{p_{rat_0}}{\rho \cdot D^5} \qquad K_{P.rat_1} := \frac{p_{rat_1}}{\rho \cdot D^4}$$

Power characteristic

$$K_{P.rat.mean_i} := K_{P.rat_0} - K_{P.rat_1} \cdot J_{Hull.rat_i}$$

$$K_{P_i} := \frac{P_{Shaft_i}}{\rho \cdot D^5 \cdot \left(N_{Shaft_i}\right)^3}$$



'Resistance' characteristic

$i := 0 .. n-1$ $\qquad V_{W.rel.x_i} := V_{W.rel.abs_i} \cdot \cos\left(V_{W.rel.dir_i}\right)$

$k := 0 .. 2$ $\qquad A_{req_{i,k}} := \left(V_{Hull.rat_i}\right)^{k+1}$ $\qquad A_{req_{i,3}} := \left(V_{W.rel.x_i}\right)^3$

Convention: This model is introduced as sufficient approximation

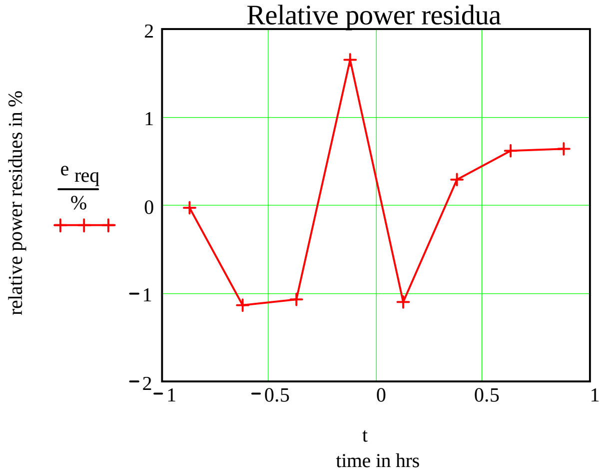
$X_{req} := LI\left(A_{req}\right) \cdot P_{Shaft}$ of the data available.

$E_{req} := P_{Shaft} - A_{req} \cdot X_{req}$

$e_{req_i} := \frac{E_{req_i}}{P_{Shaft_i}}$

Quality of approximation

$\frac{\left|E_{req}\right|}{\left|P_{Shaft}\right|} = 1.049 \circ \%$



Final rational power

$V_{W.red.x} := -V_{Hull.rat}$

$A_{red.3_i} := \left(V_{W.red.x_i}\right)^3$

$P_{Shaft.rat.fin} := A_{req} \cdot X_{req} - X_{req_3} \cdot A_{req}^{\langle 3 \rangle} + X_{req_3} \cdot A_{red.3}$

Table of values

Speed $\qquad Speed\_Power_{0,0} :=$ "Speed in kn"

$Speed_i := (16.5 + 0.5 \cdot i) \cdot kn$ $\qquad Speed\_Power_{i+1,0} := \frac{Speed_i}{kn}$

Power $\qquad Speed\_Power_{0,1} :=$ "Power in MW"

$$A_{red_{i,k}} := \left(\frac{Speed_i}{m \cdot sec^{-1}}\right)^{k+1} \qquad A_{red_{i,3}} := \left(\frac{-Speed_i}{m \cdot sec^{-1}}\right)^{3}$$

$$Power := A_{red} \cdot X_{req} \qquad Speed\_Power_{i+1,1} := \frac{Power_i}{10^6}$$

Speed_Power =

"Speed in kn"	"Power in MW"
16.50	6.56
17.00	7.35
17.50	8.22
18.00	9.18
18.50	10.22
19.00	11.36
19.50	12.59
20.00	13.91

Rates of revolution

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Revs(p, V, P, N) := | n_i ← last(V)
                    | for i ∈ 0 .. n_i
                    |   | q_0 ← P_i
                    |   | q_1 ← V_i
                    |   | n ← N_i
                    |   | N rat_i ← root(q_0 − p_0·n^3 + p_1·n^2·q_1 , n)
                    | N rat
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$N_{Shaft.rat.fin} := Revs\left(p_{rat}, V_{Hull.rat}, P_{Shaft.rat.fin}, N_{Shaft}\right)$

Table of values

Speed $Speed\_Revs_{0,0}$:= "Speed in kn" $Speed\_Revs_{i+1,0} := \frac{Speed_i}{kn}$

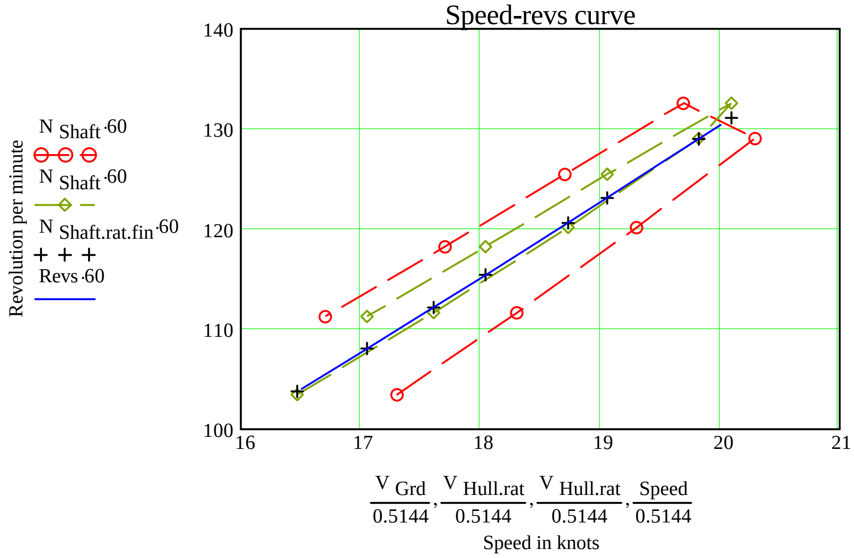
Revolutions $Speed\_Revs_{0,1}$:= "Revs per min"

$Revs := Revs\left(p_{rat}, Speed, Power, N_{Shaft}\right)$

$Speed\_Revs_{i+1,1} := Revs_i \cdot 60$

Speed_Revs =

"Speed in kn"	"Revs per min"
16.50	104.00
17.00	107.65
17.50	111.34
18.00	115.07
18.50	118.84
19.00	122.64
19.50	126.47
20.00	130.32



Remarks: All conventions are open for discussion.
The sea state has not yet been taken into account
for lack of an adequate model,
that may be identified from the few data at hand
due to the traditional trials procedure.
Errors due to incorrect interpretation of the traditional conventions may still have to be corrected!!!

END Rational Ship Speed Trial Evaluation

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