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To whom it may concern

including the reduction to the no-wind and no-waves condition based on the **added resistance due to waves identified according to the rational method**

including the VWS results

Sub: **New ISO/CD 15016 Example**
here: **Re-evaluation according to the proposed rational method**
Ref.: Evaluations of August 10, 24, 29, 1999,
Discussion by the German Trials Group at DIN/NSMT on September 01. 1999

The present re-evaluation of the new example published in the ISO/CD 15016, circulated 1999.07.29, is including the reduction to the no wind condition.

Concerning the resistance due to waves the author has not yet seriously thought about an adequate, sufficiently simple model, the parameters of which can be identified from the data simultaneously with the parameters of the wind and water resistance models. Consequently, in order to avoid lengthly discussions at this stage, he is taking the crude values provided in the ISO example. The first tests with various, even accepted models of added resistance in waves provided mostly unplausible results, the problems still to be studied.

The change to the one-file organisation without intermediate storage of the data in 'standard format and the change to the symbols of ISO/CD 15016 have been made to improve the readability and direct comparability, respectively, and thus hopefully the acceptability.

The values taken from ISO/CD 15016 are plotted in blue and denoted by o's, while the values computed according to the rational procedure are plotted in red and denoted by +'s.

Units $kN := 10^3 \cdot newton$ $N := newton$ $W := watt$

Test identification TID := "23010" New ISO/CD 15016 example

Constants

Length of ship

$L := 318 \cdot m$

$L := \frac{L}{m}$

Diameter of propeller

$D := 9.5 \cdot m$

$D := \frac{D}{m}$

Density of sea water

$\rho := 1.024 \cdot 10^{3} \cdot kg \cdot m^{-3}$

$\rho := \dfrac{\rho}{kg \cdot m^{-3}}$

Density of air

$\rho_A := 1.225 \cdot kg \cdot m^{-3}$

$\rho_A := \dfrac{\rho_A}{kg \cdot m^{-3}}$

Data reported from traditional trial measurements

time:
row 48

$$t := \begin{bmatrix} 16.792 \\ 18.830 \\ 20.826 \\ 23.053 \\ 24.986 \\ 26.682 \\ 30.597 \\ 32.433 \\ 34.231 \\ 35.849 \end{bmatrix} \cdot hr$$

course:
row 3

$$\psi_0 := \begin{bmatrix} 5.901 \\ 2.909 \\ 5.901 \\ 2.909 \\ 5.901 \\ 2.909 \\ 2.909 \\ 5.901 \\ 2.909 \\ 5.901 \end{bmatrix} \cdot rad$$

speed over ground:
row 4

$$V_G := \begin{bmatrix} 4.409 \\ 5.561 \\ 6.050 \\ 7.182 \\ 7.218 \\ 8.082 \\ 8.416 \\ 7.773 \\ 8.437 \\ 7.922 \end{bmatrix} \cdot \frac{m}{sec}$$

frequency of revolution:
row 5

$$n := \begin{bmatrix} 0.7317 \\ 0.7300 \\ 0.9267 \\ 0.9267 \\ 1.0467 \\ 1.0467 \\ 1.0933 \\ 1.0950 \\ 1.1167 \\ 1.1133 \end{bmatrix} \cdot Hz$$

brake power measured:
row 6

$$P_B := \begin{bmatrix} 5711 \\ 5533 \\ 11349 \\ 11140 \\ 16200 \\ 16190 \\ 18500 \\ 18330 \\ 19450 \\ 19756 \end{bmatrix} \cdot kW$$

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

$t := \dfrac{t}{hr}$ $\quad \psi_0 := \dfrac{\psi_0}{rad}$ $\quad V_G := \dfrac{V_G}{m \cdot sec^{-1}}$ $\quad n := \dfrac{n}{Hz}$ $\quad P_B := \dfrac{P_B}{W}$

Data normalized for check of consistency

$i := 0 .. \mathrm{last}(t)$

$$J_{H_i} := \frac{V_{G_i}}{D \cdot n_i}$$

$$K_{P_i} := \frac{P_{B_i}}{\rho \cdot D^5 \cdot (n_i)^3}$$

$J_{H.0} := \mathrm{Sort}(J_H, K_P, \psi_0)^{<0>}$

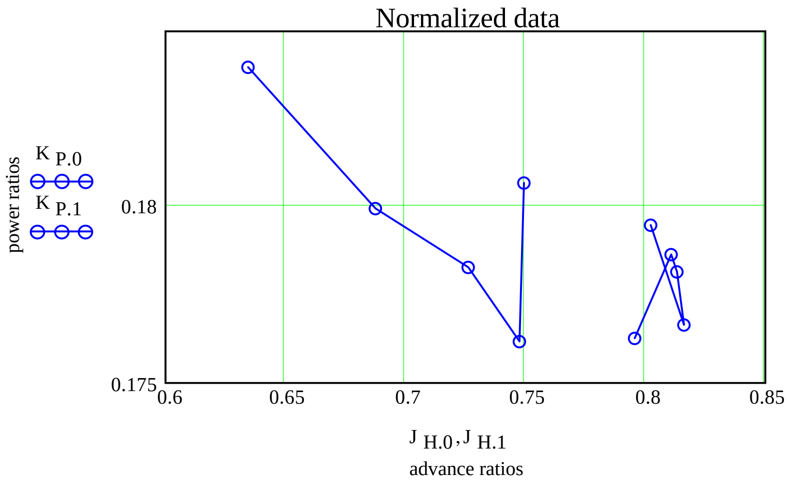
$K_{P.0} := \mathrm{Sort}(J_H, K_P, \psi_0)^{<1>}$

$J_{H.1} := \mathrm{Sort}(J_H, K_P, \psi_0)^{<2>}$

$K_{P.1} := \mathrm{Sort}(J_H, K_P, \psi_0)^{<3>}$

Sort

```
Sort(J_H, K_P, ψ) := | j_0 ← 0
                     | j_1 ← 0
                     | for i ∈ 0 .. last(J_H)
                     |   | if ψ_i > π
                     |   |   | S_(j_0,0) ← J_H_i
                     |   |   | S_(j_0,1) ← K_P_i
                     |   |   | j_0 ← j_0 + 1
                     |   | otherwise
                     |   |   | S_(j_1,2) ← J_H_i
                     |   |   | S_(j_1,3) ← K_P_i
                     |   |   | j_1 ← j_1 + 1
                     | S
```



$$J_{H.0} = \begin{bmatrix} 0.634 \\ 0.687 \\ 0.726 \\ 0.747 \\ 0.749 \end{bmatrix}$$

$$J_{H.1} = \begin{bmatrix} 0.802 \\ 0.816 \\ 0.813 \\ 0.81 \\ 0.795 \end{bmatrix}$$

Data reduced in view of inconsistencies at runs 9 and 10

$i := 0 .. \mathrm{last}(t) - 2$

$temp1_i := t_i$ $\qquad t := temp1$

$temp1_i := \psi_{0_i}$ $\qquad \psi_0 := temp1$

$temp1_i := V_{G_i}$ $\qquad V_G := temp1$

$temp1_i := n_i$ $\qquad n := temp1$

$temp1_i := P_{B_i}$ $\qquad P_B := temp1$

$i := 0 .. \mathrm{last}\left(J_{H.0}\right) - 1$ $\quad j := 0 .. \mathrm{last}\left(J_{H.1}\right) - 1$

$temp2_i := J_{H.0_i}$ $\quad J_{H.0} := temp2$ $\quad temp3_j := J_{H.1_j}$ $\quad J_{H.1} := temp3$

$temp2_i := K_{P.0_i}$ $\quad K_{P.0} := temp2$ $\quad temp3_j := K_{P.1_j}$ $\quad K_{P.1} := temp3$

Reduced data set evaluated for current velocity and powering characteristic in behind at the trials conditions.

Power supplied

$i := 0 .. \mathrm{last}(t)$

$A_{sup_{i,0}} := \left(n_i\right)^3$ $\quad A_{sup_{i,1}} := -\left(n_i\right)^2 \cdot V_{G_i}$

Current velocity

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

$\omega := \dfrac{2 \cdot \pi}{T_T}$ $\quad \omega := \omega \cdot hr$ $\quad \omega = 0.506$

$d_{FM_i} := \mathrm{if}\left(\psi_{0_i} < \pi, 1, -1\right)$ Direction of current

$A_{sup_{i,2}} := \left(n_i\right)^2 \cdot d_{FM_i}$

$A_{sup_{i,3}} := A_{sup_{i,2}} \cdot t_i$ Linear term finally included in view of the weather condition

$A_{sup_{i,4}} := A_{sup_{i,2}} \cdot \cos\left(\omega \cdot t_i\right)$

$A_{sup_{i,5}} := A_{sup_{i,2}} \cdot \sin\left(\omega \cdot t_i\right)$

$A_{sup_{i,4}} := A_{sup_{i,2}} \cdot \left(t_i\right)^2$ Disabled!

$A_{sup_{i,5}} := A_{sup_{i,2}} \cdot \left(t_i\right)^3$ Disabled!

Left-inverse

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

Least square fit

$X_{sup} := LI\left(A_{sup}\right) \cdot P_B$

Residua in terms of power

$E_{sup} := P_B - A_{sup} \cdot X_{sup}$

Quality of approximation

$\dfrac{\left|E_{sup}\right|}{\left|P_B\right|} = 0.169 \circ\%$

These residua do not look quite random, but they are so small that changes of the models are not warranted.

$$\mathrm{Stdev}\left(\frac{E_{sup}}{10^3}\right) = 24.8$$

Current velocity

Rational evaluation

$j := 0 .. 3$

$$v_j := \frac{X_{sup_{2+j}}}{X_{sup_1}} \qquad \sqrt{(v_2)^2 + (v_3)^2} = 0.081$$

Tidal current amplitude in m/sec

$$V_{F.rat_i} := v_0 + v_1 \cdot t_i + v_2 \cdot \cos(\omega \cdot t_i) + v_3 \cdot \sin(\omega \cdot t_i)$$

$$V_{F.rat_i} := \sum_j v_j \cdot (t_i)^j$$

Disabled!

Interpolation

$$m := 100 \qquad k := 0 .. m \qquad T_k := t_0 - 1 + \frac{t_{last(t)} - t_0 + 2}{m} \cdot k$$

$$V_{F.int_k} := v_0 + v_1 \cdot T_k + v_2 \cdot \cos(\omega \cdot T_k) + v_3 \cdot \sin(\omega \cdot T_k)$$

$$V_{F.int_k} := \sum_j v_j \cdot (T_k)^j$$

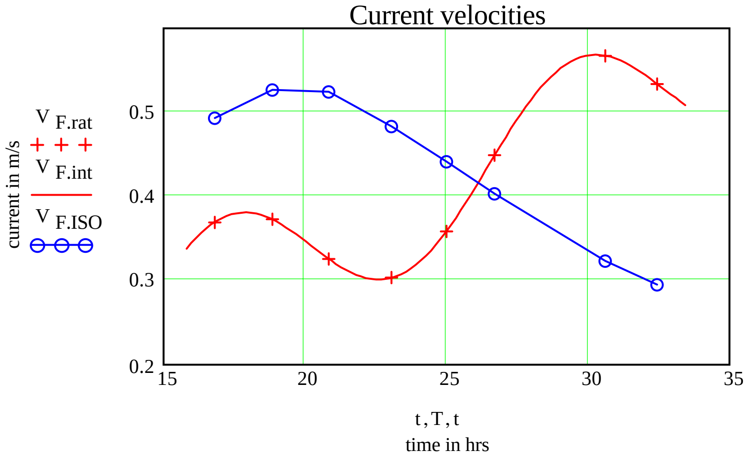
Disabled!

ISO/CD evaluation:

current at each run:
row 52

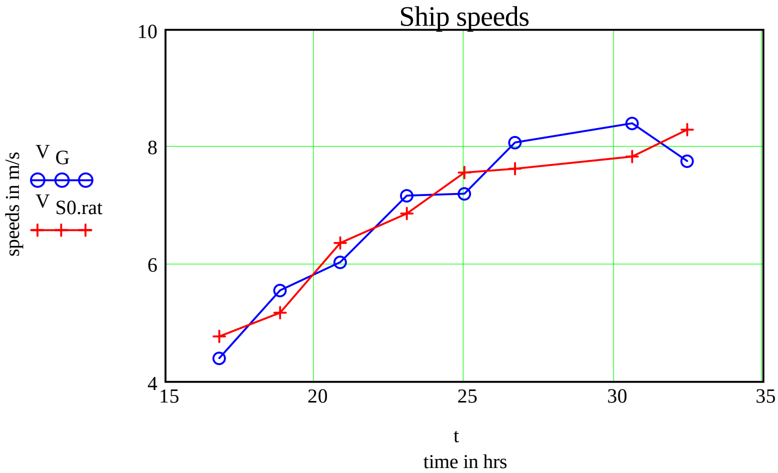
$$V_{F.ISO} := \begin{bmatrix} 0.494 \\ 0.527 \\ 0.525 \\ 0.484 \\ 0.442 \\ 0.404 \\ 0.324 \\ 0.296 \end{bmatrix} \cdot \frac{m}{sec}$$

$$V_{F.ISO} := \frac{V_{F.ISO}}{m \cdot sec^{-1}}$$



Ship speed relative to water

$$V_{S0.rat_i} := V_{G_i} - V_{F.rat_i} \cdot d_{FM_i}$$



Power parameters, rational

$$p_{rat_0} := X_{sup_0} \qquad p_{rat_1} := X_{sup_1}$$

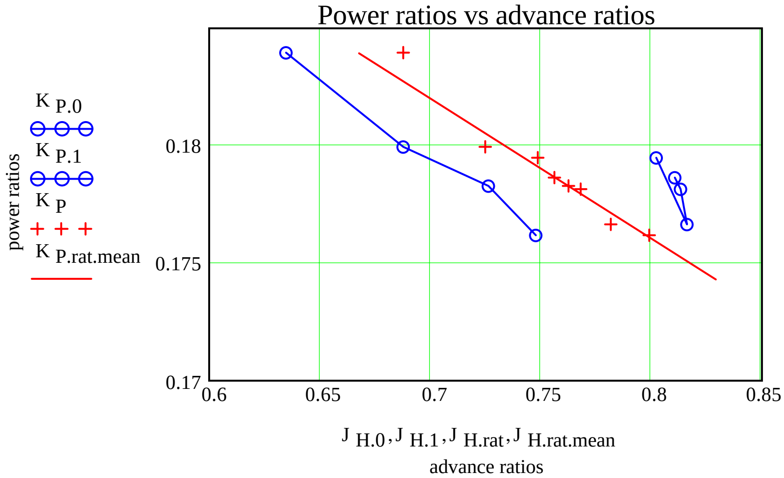
$$P_{B.rat_i} := p_{rat_0} \cdot \left(n_i\right)^3 - p_{rat_1} \cdot \left(n_i\right)^2 \cdot V_{S0.rat_i}$$

Normalised values

$$J_{H.rat_i} := \frac{V_{S0.rat_i}}{D \cdot n_i} \qquad k_{P.rat_0} := \frac{p_{rat_0}}{\rho \cdot D^5} \qquad k_{P.rat_1} := \frac{p_{rat_1}}{\rho \cdot D^4}$$

$$k := 0 .. 1 \qquad J_{H.rat.mean_k} := J_{H.rat_0} - 0.02 + \left(J_{H.rat_{last(t)}} - J_{H.rat_0} + 0.05\right) \cdot k$$

$$K_{P.rat.mean_k} := k_{P.rat_0} - k_{P.rat_1} \cdot J_{H.rat.mean_k}$$



Power required

Power required due to water resistance

$p := 2$ $\qquad$ $q := 1$

$k := 0 .. p$ $\qquad$ $A_{req_{i,k}} := \left(V_{S0.rat_i}\right)^{k+q}$

Additional power required due to wind resistance

Relative wind measured

relative wind velocity:
row 7

relative wind direction:
row 8

$$V_{WindR} := \begin{bmatrix} 13.5 \\ 4.0 \\ 15.0 \\ 2.8 \\ 16.0 \\ 0.7 \\ 0.4 \\ 16.5 \end{bmatrix} \cdot \frac{m}{sec} \qquad \psi_{WindR} := \begin{bmatrix} -0.1745 \\ 2.5307 \\ -0.1745 \\ 2.3562 \\ 0.0873 \\ 2.6180 \\ 2.3562 \\ 0.0873 \end{bmatrix} \cdot rad$$

Non-dimensional values, not normalized(!), in coherent units

$$V_{WindR} := \frac{V_{WindR}}{m \cdot sec^{-1}} \qquad \psi_{WindR} := \frac{\psi_{WindR}}{rad}$$

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

$$A_{req_{i,3}} := V_{WindR.x_i} \cdot \left| V_{WindR.x_i} \right| \cdot V_{S0.rat_i}$$

Additional power required due to wave resistance

Sea state observed

mean wave period (seas)
row 12

$$T_{Seas} := \begin{bmatrix} 3.90 \\ 3.90 \\ 3.90 \\ 3.90 \\ 3.90 \\ 3.90 \\ 2.80 \\ 2.80 \end{bmatrix} \cdot sec$$

significant wave height (seas)
row 13

$$H_{Seas} := \begin{bmatrix} 1.00 \\ 1.00 \\ 1.00 \\ 1.00 \\ 1.00 \\ 1.00 \\ 0.50 \\ 0.50 \end{bmatrix} \cdot m$$

incident angle of wave (seas)
row 14

$$\psi_{SeasR} := \begin{bmatrix} 2.97 \\ -0.17 \\ 2.97 \\ -0.17 \\ 2.97 \\ -0.17 \\ -0.17 \\ 2.97 \end{bmatrix}$$

$$T_{Seas} := \frac{T_{Seas}}{sec} \qquad H_{Seas} := \frac{H_{Seas}}{m} \qquad g := 9.81$$

$$V_{Seas.x_i} := \frac{g \cdot T_{Seas_i}}{2 \cdot \pi} \cdot \cos\left(\psi_{SeasR_i} + \pi\right)$$

$$A_{req_{i,4}} := \left(H_{Seas_i}\right)^2 \cdot \left(V_{S0.rat_i} + V_{Seas.x_i}\right) \cdot \left(V_{S0.rat_i}\right)^2$$

This model is the **constitutive convention of the added resistance in waves**. The format is due to the fact that an **additional** power is to be 'defined'!

Swell state observed

mean wave period (swell)
row 15

$$T_{Swell} := \begin{bmatrix} 10.59 \\ 10.59 \\ 10.59 \\ 10.59 \\ 11.32 \\ 11.32 \\ 11.32 \\ 11.32 \end{bmatrix} \cdot sec$$

significant wave height (swell)
row 16

$$H_{Swell} := \begin{bmatrix} 2.00 \\ 2.00 \\ 2.00 \\ 2.00 \\ 2.50 \\ 2.50 \\ 2.50 \\ 2.50 \end{bmatrix} \cdot m$$

incident angle of wave (swell)
row 17

$$\psi_{SwellR} := \begin{bmatrix} 0.6981 \\ -2.4435 \\ 0.6981 \\ -2.4435 \\ 0.6981 \\ -2.4435 \\ -2.4435 \\ 0.6981 \end{bmatrix}$$

$$T_{Swell} := \frac{T_{Swell}}{sec} \qquad H_{Swell} := \frac{H_{Swell}}{m}$$

$$V_{Swell.x_i} := \frac{g \cdot T_{Swell_i}}{2 \cdot \pi} \cdot \cos\left(\psi_{SwellR_i} + \pi\right)$$

$$A_{req_{i,5}} := \left(H_{Swell_i}\right)^2 \cdot \left(V_{S0.rat_i} + V_{Swell.x_i}\right) \cdot \left(V_{S0.rat_i}\right)^2$$

Least square fit

Copied from 23010_re-eval-fin4.mcd

$X_{req} := LI(A_{req}) \cdot P_B$

Residua

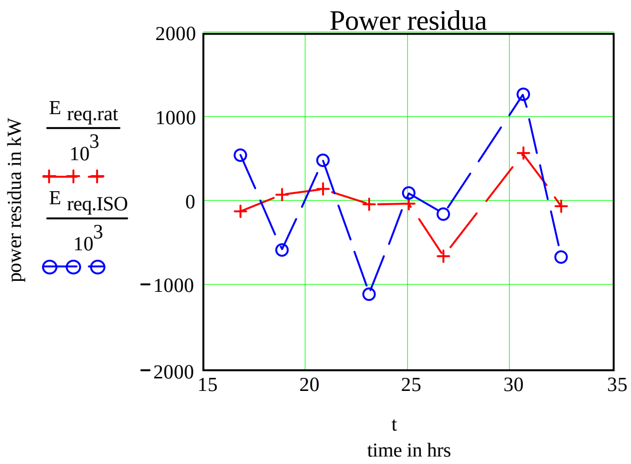
$E_{req.rat} := P_B - A_{req} \cdot X_{req}$

$$E_{req.ISO} := \begin{bmatrix} 5.614 \cdot 10^5 \\ -5.649 \cdot 10^5 \\ 5.057 \cdot 10^5 \\ -1.087 \cdot 10^6 \\ 1.147 \cdot 10^5 \\ -1.339 \cdot 10^5 \\ 1.288 \cdot 10^6 \\ -6.5 \cdot 10^5 \end{bmatrix}$$

relative residua

Quality of approximation

$\frac{|E_{req.rat}|}{|P_B|} = 2.299\,\%$ $\frac{|E_{req.ISO}|}{|P_B|} = 5.248\,\%$



According to the comments accompanying the trial data **the swell developed as a typhoon approached. The trial was stopped** a while after 6 runs finished, i. e. after 27 h, **because the swell height became too large, but it was resumed.**

This weather condition may be the reason for the large scatter at runs 6 and 7, else the scatter being quite small.

Scatter analysis

The scatter analysis is the only way to decide on the adequacy of the models.
The sample standard deviation according to the rational method

$\mathrm{Stdev}\left(\frac{E_{req.rat}}{10^3}\right) = 338.6$ $\mathrm{Stdev}\left(\frac{E_{req.ISO}}{10^3}\right) = 773.1$

is considerably smaller than in case of the ISO results.

If the excessive values are excluded

$E_{red.rat} := E_{req.rat}$ $E_{red.rat_{6-1}} := 0$ $E_{red.rat_{7-1}} := 0$

$E_{red.ISO} := E_{req.ISO}$ $E_{red.ISO_{6-1}} := 0$ $E_{red.ISO_{7-1}} := 0$

the sample standard deviations reduce to:

$\mathrm{Stdev}\left(\frac{E_{red.rat}}{10^3}\right) = 82.4$ $\mathrm{Stdev}\left(\frac{E_{red.ISO}}{10^3}\right) = 579.5$

The **rational value,** though more than three times larger than the one obtained in the least square fit of the supplied power (24.8 kW), **is acceptable in view of the low resolution of the wave height observation. In the rational constitutive model systematic effects can no longer be observed, indicating the appropriateness of the model.**

In terms of the quality of approximation

$$\frac{\left|E_{red.rat}\right|}{\left|P_B\right|} = 0.562 \cdot \%$$

$$\frac{\left|E_{red.ISO}\right|}{\left|P_B\right|} = 4.063 \cdot \%$$

the rational method describes the data within less than 0.6% as compared to 4% of the ISO method. **The corresponding ISO values are six times larger and not acceptable due to the systematic effects in the scatter indicating that the model is not correct.**

Additional power and resistance due to wind

according to rational evaluation

$$P_{AWind.rat} := A_{req}^{\langle 3\rangle} \cdot X_{req_3}$$

according to ISO/CD evaluation

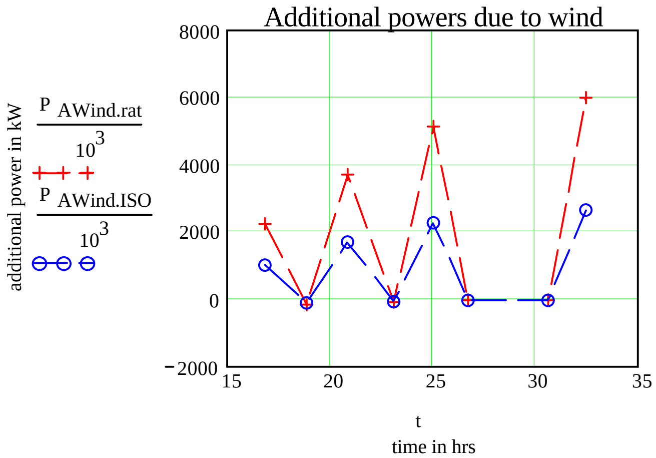
$$R_{AWind.ISO} := \begin{bmatrix} 131.5 \\ -10.9 \\ 162.3 \\ -4.5 \\ 181.2 \\ -0.3 \\ -0.1 \\ 192.7 \end{bmatrix} \cdot 10^3 \cdot N$$

$$\eta_D := 0.6$$

Propulsive efficiency, crude estimate for plausibility checks only!

$$R_{AWind.ISO} := \frac{R_{AWind.ISO}}{N}$$

$$P_{AWind.ISO_i} := \frac{R_{AWind.ISO_i} \cdot V_{S0.rat_i}}{\eta_D}$$



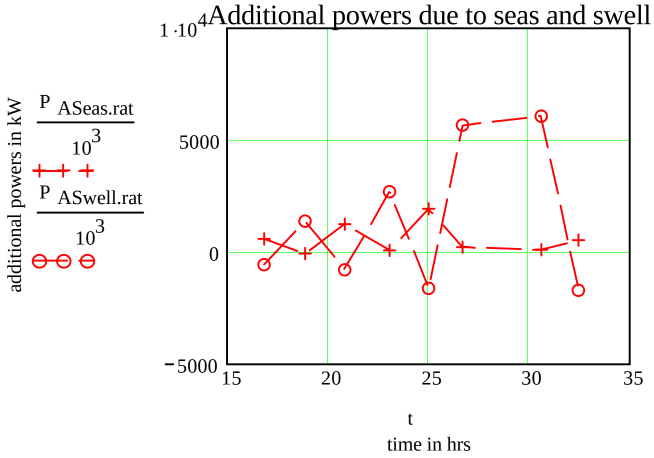
$$\frac{\left|P_{AWind.rat}\right|}{\left|P_{AWind.ISO}\right|} = 2.228$$

Additional power and resistance due to waves

according to rational evaluation

$$P_{ASeas.rat} := A_{req}^{\langle 4\rangle} \cdot X_{req_4}$$

$$P_{ASwell.rat} := A_{req}^{\langle 5 \rangle} \cdot X_{req_5}$$



$$P_{AWaves.rat} := P_{ASeas.rat} + P_{ASwell.rat}$$

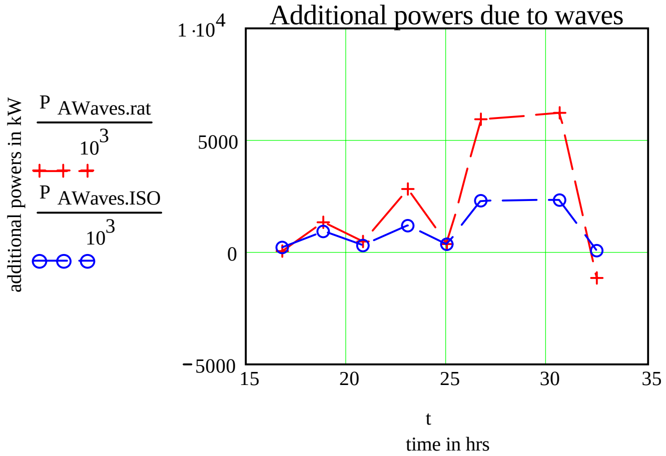
according to ISO/CD evaluation

resistance increase due to waves:
row 30

$$R_{AWaves.ISO} := \begin{bmatrix} 31.4 \\ 111.8 \\ 31.4 \\ 106.9 \\ 31.4 \\ 182.6 \\ 180.1 \\ 7.9 \end{bmatrix} \cdot 10^3 \cdot N$$

$$R_{AWaves.ISO} := \frac{R_{AWaves.ISO}}{N}$$

$$P_{AWaves.ISO_i} := \frac{R_{AWaves.ISO_i} \cdot V_{S0.rat_i}}{\eta_D}$$



$$\frac{\left| P_{AWaves.rat} \right|}{\left| P_{AWaves.ISO} \right|} = 2.501$$

Final performance data according to rational evaluation

Reduction to the no-wind and no-wave condition

$$V_{S3_i} := \left(V_{S0.rat_i} \right)^3$$

$$P_{B0.rat} := A_{req} \cdot X_{req} - P_{AWaves.rat} - P_{AWind.rat} + V_{S3} \cdot X_{req_3}$$

Rates of revolutions **Solve cubic equations**

$$\mathrm{Revs}(p, V, P, N) := \left| \begin{array}{l} n_i \leftarrow \mathrm{last}(V) \\ \text{for } i \in 0..n_i \\ \quad \left| \begin{array}{l} q_0 \leftarrow P_i \\ q_1 \leftarrow V_i \\ n \leftarrow N_i \\ N_{rat_i} \leftarrow \mathrm{root}\left(q_0 - p_0 \cdot n^3 + p_1 \cdot n^2 \cdot q_1, n\right) \end{array} \right. \\ N_{rat} \end{array} \right.$$

$$n_{0.rat} := \mathrm{Revs}\left(p_{rat}, V_{S0.rat}, P_{B0.rat}, n\right)$$

Final performance data according to rational evaluation

frequency of revolution: ship speed: brake power:

$$n_{0.rat} = \begin{bmatrix} 0.645 \\ 0.6901 \\ 0.8205 \\ 0.8753 \\ 0.9514 \\ 0.9575 \\ 0.9809 \\ 1.0308 \end{bmatrix} \qquad V_{S0.rat} = \begin{bmatrix} 4.779 \\ 5.188 \\ 6.376 \\ 6.878 \\ 7.577 \\ 7.633 \\ 7.848 \\ 8.307 \end{bmatrix} \qquad \frac{P_{B0.rat}}{10^3} = \begin{bmatrix} 3769 \\ 4598 \\ 7656 \\ 9266 \\ 11855 \\ 12080 \\ 12974 \\ 15027 \end{bmatrix}$$

Final performance data according to ISO evaluation

frequency of revolution: row 61 (5) ship speed: row 65 brake power: row 63

$$n_{0.ISO} := \begin{bmatrix} 0.7317 \\ 0.7300 \\ 0.9267 \\ 0.9267 \\ 1.0467 \\ 1.0467 \\ 1.0933 \\ 1.0950 \end{bmatrix} \cdot \mathrm{Hz} \qquad V_{S0.ISO} := \begin{bmatrix} 5.230 \\ 5.238 \\ 6.852 \\ 6.861 \\ 7.932 \\ 7.946 \\ 8.315 \\ 8.327 \end{bmatrix} \cdot \frac{m}{sec} \qquad P_{B0.ISO} := \begin{bmatrix} 5331 \\ 5293 \\ 10839 \\ 10838 \\ 15582 \\ 15578 \\ 17945 \\ 17696 \end{bmatrix} \cdot \mathrm{kW}$$

Non-dimensional values, not normalized(!), in coherent units

$$n_{0.ISO} := \frac{n_{0.ISO}}{\mathrm{Hz}} \qquad V_{S0.ISO} := \frac{V_{S0.ISO}}{m \cdot sec^{-1}} \qquad P_{B0.ISO} := \frac{P_{B0.ISO}}{W}$$

Final performance data according to VWS evaluation

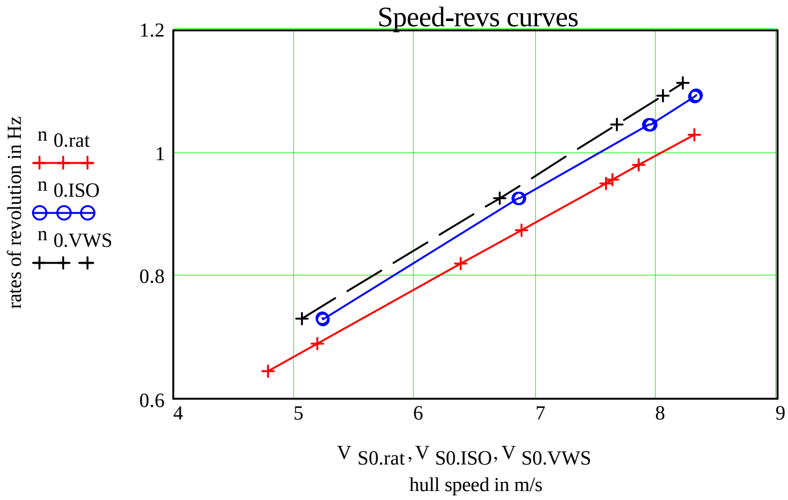
$n_{0.VWS} := \mathrm{READPRN}(\text{"NNico.prn"})$ already non-dimensional in coherent units

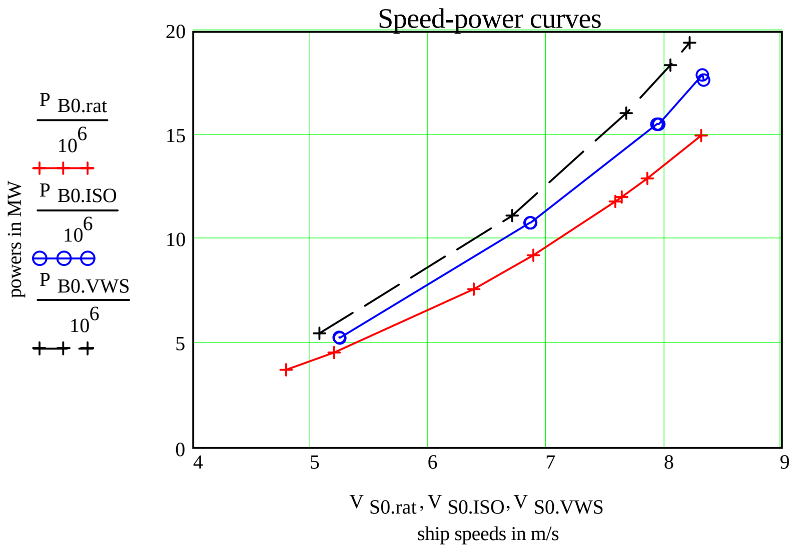
$V_{S0.VWS} := \mathrm{READPRN}(\text{"VNico.prn"})$

$ii := 0 .. \mathrm{last}(n_{0.VWS})$

$P_{B0.VWS} := \mathrm{READPRN}(\text{"PBNico.prn"})$

$$n_{0.VWS} = \begin{bmatrix} 0.731 \\ 0.927 \\ 1.047 \\ 1.094 \\ 1.115 \end{bmatrix} \qquad V_{S0.VWS} = \begin{bmatrix} 5.063 \\ 6.701 \\ 7.67 \\ 8.047 \\ 8.211 \end{bmatrix} \qquad P_{B0.VWS} = \begin{bmatrix} 5.52\cdot 10^6 \\ 1.119\cdot 10^7 \\ 1.612\cdot 10^7 \\ 1.843\cdot 10^7 \\ 1.95\cdot 10^7 \end{bmatrix}$$





Normalized values

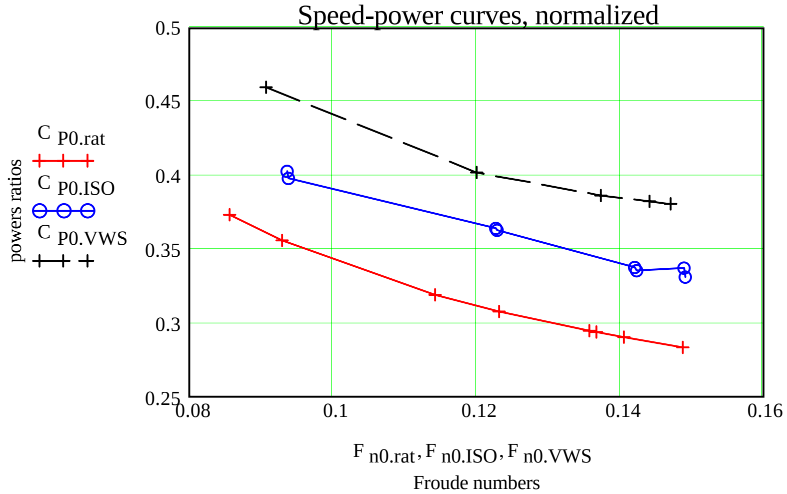
Froude numbers, power numbers

$$F_n(V) := \frac{V}{\sqrt{g\cdot L}} \qquad C_P(P_B, V) := \frac{P_B}{\rho\cdot D^2\cdot (V)^3}$$

$F_{n0.rat_i} := F_n\left(V_{S0.rat_i}\right)$ $\quad C_{P0.rat_i} := C_P\left(P_{B0.rat_i}, V_{S0.rat_i}\right)$

$F_{n0.ISO_i} := F_n\left(V_{S0.ISO_i}\right)$ $\quad C_{P0.ISO_i} := C_P\left(P_{B0.ISO_i}, V_{S0.ISO_i}\right)$

$F_{n0.VWS_{ii}} := F_n\left(V_{S0.VWS_{ii}}\right)$ $\quad C_{P0.VWS_{ii}} := C_P\left(P_{B0.VWS_{ii}}, V_{S0.VWS_{ii}}\right)$



Normalized values

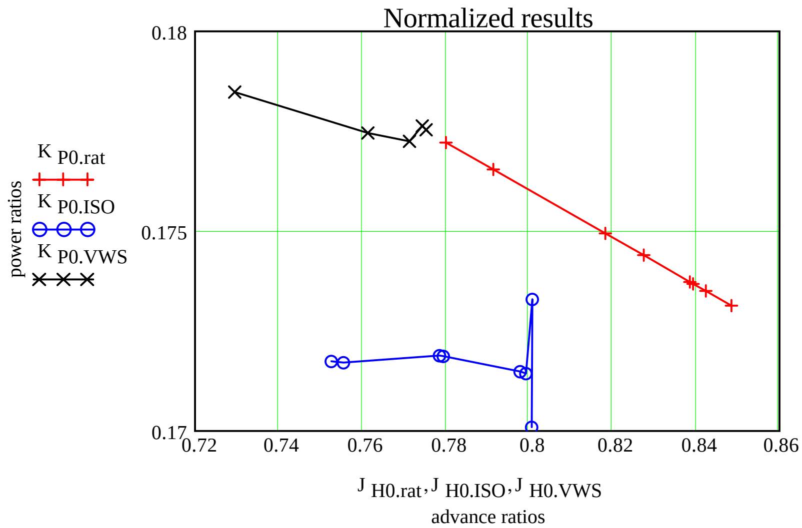
Advance ratios, power ratios

$$J_H(V, N) := \frac{V}{D \cdot N} \qquad K_P(P, N) := \frac{P}{\rho \cdot D^5 \cdot (N)^3}$$

$J_{H0.rat_i} := J_H\left(V_{S0.rat_i}, n_{0.rat_i}\right)$ $\quad K_{P0.rat_i} := K_P\left(P_{B0.rat_i}, n_{0.rat_i}\right)$

$J_{H0.ISO_i} := J_H\left(V_{S0.ISO_i}, n_{0.ISO_i}\right)$ $\quad K_{P0.ISO_i} := K_P\left(P_{B0.ISO_i}, n_{0.ISO_i}\right)$

$J_{H0.VWS_{ii}} := J_H\left(V_{S0.VWS_{ii}}, n_{0.VWS_{ii}}\right)$ $\quad K_{P0.VWS_{ii}} := K_P\left(P_{B0.VWS_{ii}}, n_{0.VWS_{ii}}\right)$



Conclusions

The new ISO/CD 15016 example provides another test case for the rational evaluation of trials proposed. **There remain differences in the evaluations** still to be analysed. Independent of this analysis **the differences** in magnitude and, particularly, in trend of the normalized results between the proposed rational and the proposed ISO evaluations **can be ascribed to inconsistencies in the ISO procedure.**

Of course the rational method proposed does not yet cope with all the problems and details being still in its infancy and needing the joint effort and agreement of all experts before it can be established as a standard. **The advantages of the rational procedure are a minimum number of conventions and the consistent application of systems identification methods <u>requiring no reference to model test results and other prior data, as it should be.</u>**

The propeller performance in the behind condition, i.e. in the full scale wake (!), and the current velocity can be identified simultaneously by solving one set of linear equations. After the 'calibration' the propeller power characteristic in the behind condition can be used for monitoring purposes, e.g. to determine the value of current velocity from measured values of the rate of revolution and the torque, or to determine the value of resistance after additional calibrations or even crude assumptions.

Further the power required due to the resistance in water, in wind and in waves can be identified simultaneously by solving another set of linear equations. Identifying parameters of models from observed data, even visually observed wave data, has the advantage that **<u>systematic errors in the observations are to a great extent automatically accounted for.</u> In case of the proposed, very involved ISO method this does not apply, although it is based on the same crude wave data. This fact is one major reason for the concerns about the method expressed nearly unisono by experts in shipyards and institutions.**

From the data at hand the values of the added power due to waves being identified according to the rational method are more than twice as large as the 'nominal' values computed according to the proposed ISO method. And the latter was particularly designed to deal with this problem, just with reference to the very crude data of wave observation, but without any reference to the observed data of brake power!

In view of the ill-conditioned problems arising there is no chance to solve the equations with do-it-yourself algorithms, **singular value decomposition is an absolute requirement**. In a great number of examples, based on actual data from industry, it has been shown that this procedure is superior to the traditional procedures of solving eight or ten simultaneous equations iteratively. The author has no idea how this can be done reliably!

In his contribution to the discussion of the Report of the Specialist Committee on Trials and Monitoring to the 22nd ITTC in Seoul and Shanghai September 05/11, 1999 **the author fully endorses Recommendation 5 to the Conference concerning the recording of 'time histories'. Even if runs are considered stationary sound performance and confidence analyses have to be based on 'instantaneous' values of the data. The present samples of at best eight 'doubtful' averages are just too small in size for serious applications of statistical methods.**

Many problems in the evaluation of trials are due to waiting for steady conditions and using ill-defined average values. In the METEOR and CORSAIR trials **quasisteady test manoeuvres have been shown to be much superior to steady testing, providing not only much more information, but at the same time <u>the necessary references for the suppression of the omnipresent noise</u>, even at service conditions in heavy weather.**

END Rational re-evaluation of new ISO/CD 15016 example