To whom it may concern

Sub: New ISO/CD 15016 Example
here: Re-evaluation according to the proposed rational method
Ref.: Evaluations iso_fin4 to fin7.mcd

The present re-evaluation of the new ISO/CD 15016 example includes the reduction to the no-wind and no-waves condition according to the rational method and a statistical analysis as far as the size of the sample permits. In order to obtain the maximum size of the sample and to avoid the impression that data have been excluded purposely the data of all ten runs have been included. The analysis has been carried out ten times, successively leaving out the data of one run, and additionally one time including all data.

Values computed according to the rational procedure are plotted in red, results of the reduced samples just dashed, results of the full sample denoted by boxes, final results denoted by pluses, while the values taken from ISO/CD 15016 are plotted in blue and denoted by circles and values according to the VWS method are plotted in black and denotes by crosses.

Units

<table>
<thead>
<tr>
<th>Unit</th>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>kN</td>
<td>$10^3 \cdot \text{newton}$</td>
<td>Newton</td>
</tr>
<tr>
<td>N</td>
<td></td>
<td>Newton</td>
</tr>
<tr>
<td>W</td>
<td></td>
<td>Watt</td>
</tr>
</tbody>
</table>

Test identification

<table>
<thead>
<tr>
<th>TID</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TID := &quot;23010&quot;</td>
<td>New ISO/CD 15016 example</td>
</tr>
</tbody>
</table>

Constants

| Length of ship | $L := 318 \cdot \text{m}$ |
| Diameter of propeller | $D := 9.5 \cdot \text{m}$ |

Density of sea water

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

Density of air

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

$g := 9.81$
Functions and subroutines

Normalise data

\[ J^H (V, N) := \frac{V}{D^N} \quad \text{and} \quad KP (P, N) := \frac{P}{\rho \cdot D^5 \cdot (N)^3} \]

\[ \text{Fn}(V) := \frac{V}{\sqrt{g \cdot L}} \quad \text{and} \quad \text{CP}(P, B, V) := \frac{P B}{\rho \cdot D^2 \cdot (V)^3} \]

Sort runs

\[ \text{Sort}\left( J^H, K, \psi \right) := \begin{cases} j_0 & := 0 \\ j_1 & := 0 \\ \text{for } i \in 0..\text{last}(J^H) & \begin{cases} \text{if } \psi_i > \pi & \begin{cases} S_{j_0, 0} & := J^H_i \\ S_{j_0, 1} & := K, p_i \\ j_0 & := j_0 + 1 \end{cases} \\ \text{otherwise} & \begin{cases} S_{j_1, 2} & := J^H_i \\ S_{j_1, 3} & := K, p_i \\ j_1 & := j_1 + 1 \end{cases} \end{cases} \end{cases} \]

Compute left-inverse

\[ \text{LeftInv}(A) := \begin{cases} r & := \text{rows}(A) \\ c & := \text{cols}(A) \\ s & := \text{svds}(A) \\ \text{for } i \in 0..c - 1 & \begin{cases} \text{ISV}_{i, i} & := (s_i)^{-1} \\ UV & := \text{svd}(A) \\ U & := \text{submatrix}(UV, 0, r - 1, 0, c - 1) \\ V & := \text{submatrix}(UV, r, r + c - 1, 0, c - 1) \end{cases} \\ A \text{ inv.left} & := V \cdot \text{ISV} \cdot U^T \end{cases} \]
Solve cubic equations

\[ \text{Revs}(p, V, P, N) := n_i \leftarrow \text{last}(V) \]
\[ \text{for } i \in 0..n_i \]
\[ q_0 \leftarrow P_i \]
\[ q_1 \leftarrow V_i \]
\[ n \leftarrow N_i \]
\[ N_{\text{rat}} i \leftarrow \text{root}\left(q_0 - p_0 \cdot n^3 + p_1 \cdot n^2 \cdot q_1 \cdot n\right) \]
\[ \]
\[ N_{\text{rat}} \]

Analyse power supplied

\[ \text{Supplied}(D, \rho, t, \psi_0, V_G, n, P_B) := \]
\[ \text{for } i \in 0..\text{last}(t) \]
\[ A_{\text{sup}} \leftarrow (n_i)^3 \]
\[ A_{\text{sup}} \leftarrow (n_i)^2 \cdot V_G_i \]
\[ d_{FM_i} \leftarrow \text{if}(\psi_0_i < \pi, 1, -1) \]
\[ A_{\text{sup}} \leftarrow (n_i)^2 \cdot d_{FM_i} \]
\[ A_{\text{sup}} \leftarrow A_{\text{sup}} \cdot t_i \]
\[ A_{\text{sup}} \leftarrow A_{\text{sup}} \cdot (t_i)^2 \]
\[ A_{\text{sup}} \leftarrow A_{\text{sup}} \cdot (t_i)^3 \]
\[ X_{\text{sup}} \leftarrow \text{LeftInv}\left(A_{\text{sup}}\right) \cdot P_B \]
\[ E_{\text{sup}} \leftarrow P_B - A_{\text{sup}} \cdot X_{\text{sup}} \]
\[ p_0 \leftarrow X_{\text{sup}} \]
\[ p_1 \leftarrow X_{\text{sup}} \]
\[ \text{for } j \in 0..3 \]
\[ v_j \leftarrow \frac{X_{\text{sup}}_{2+j}}{X_{\text{sup}}_1} \]
\[ \text{for } i \in 0..\text{last}(t) \]
\[ V_{F\text{.rat}} \leftarrow v_0 + v_1 \cdot t_i + v_2 \cdot (t_i)^2 + v_3 \cdot (t_i)^3 \]
\[ V_{S0\text{.rat}} \leftarrow V_G_i - V_{F\text{.rat}} \cdot d_{FM_i} \]
Schmiechen: Re-evaluation of ISO/CD 15016 Example

Analyse power required

Required \(\langle V_{S0}, P_B, Env \rangle :=\)

\[ g \leftarrow 9.81 \]

\[ V_{WindR} \leftarrow \langle Env_{0,0} \rangle_{0,0} \]

\[ \psi_{WindR} \leftarrow \langle Env_{0,0} \rangle_{0,1} \]

\[ T_{Seas} \leftarrow \langle Env_{0,1} \rangle_{0,0} \]

\[ H_{Seas} \leftarrow \langle Env_{0,1} \rangle_{0,1} \]

\[ \psi_{SeasR} \leftarrow \langle Env_{0,1} \rangle_{0,2} \]

\[ T_{Swell} \leftarrow \langle Env_{0,2} \rangle_{0,0} \]

\[ H_{Swell} \leftarrow \langle Env_{0,2} \rangle_{0,1} \]

\[ \psi_{SwellR} \leftarrow \langle Env_{0,2} \rangle_{0,2} \]

for \( i \in 0.. \text{last} \langle V_{S0} \rangle \)

\[ A_{\text{req},i,0} \leftarrow \langle V_{S0} \rangle_{1} \]

\[ A_{\text{req},i,1} \leftarrow \langle V_{S0} \rangle_{2} \]

\[ A_{\text{req},i,2} \leftarrow \langle V_{S0} \rangle_{3} \]

\[ V_{WindR.x} \leftarrow V_{WindR} \cdot \cos \left( \psi_{WindR} \right) \]

\[ A_{\text{req},i,3} \leftarrow V_{WindR.x} \cdot V_{WindR} \cdot V_{S0} \]

\[ V_{Seas.x} \leftarrow \frac{g \cdot T_{Seas}}{2 \cdot \pi} \cdot \cos \left( \psi_{SeasR} + \pi \right) \]

\[ A_{\text{req},i,4} \leftarrow (H_{Seas})^2 \cdot (V_{S0} + V_{Seas.x}) \cdot (V_{S0})^2 \]

\[ V_{Swell.x} \leftarrow \frac{g \cdot T_{Swell}}{2 \cdot \pi} \cdot \cos \left( \psi_{SwellR} + \pi \right) \]
Power supplied

Data reported from traditional trial measurements

<table>
<thead>
<tr>
<th>time:</th>
<th>course:</th>
<th>speed over ground:</th>
</tr>
</thead>
<tbody>
<tr>
<td>row 48</td>
<td>row 3</td>
<td>row 4</td>
</tr>
<tr>
<td>16.792</td>
<td>5.901</td>
<td>4.409</td>
</tr>
<tr>
<td>18.830</td>
<td>2.909</td>
<td>5.561</td>
</tr>
<tr>
<td>20.826</td>
<td>5.901</td>
<td>6.050</td>
</tr>
<tr>
<td>23.053</td>
<td>2.909</td>
<td>7.182</td>
</tr>
<tr>
<td>24.986</td>
<td>5.901</td>
<td>7.218</td>
</tr>
<tr>
<td>26.682</td>
<td>2.909</td>
<td>8.082</td>
</tr>
<tr>
<td>30.597</td>
<td>2.909</td>
<td>8.416</td>
</tr>
<tr>
<td>32.433</td>
<td>5.901</td>
<td>7.773</td>
</tr>
<tr>
<td>34.231</td>
<td>2.909</td>
<td>8.437</td>
</tr>
<tr>
<td>35.849</td>
<td>5.901</td>
<td>7.922</td>
</tr>
</tbody>
</table>

\[
\begin{array}{c}
A_{req,5} \leftarrow (H_{Swell})^2 \cdot (V_{S0} + V_{Swell.x}) \cdot (V_{S0})^2 \\
X_{req} \leftarrow \text{LeftInv}(A_{req}) \cdot P_B \\
E_{req} \leftarrow P_B - A_{req} \cdot X_{req} \\
P_{AWind} \leftarrow A_{req}^{<3>} \cdot X_{req} \\
P_{ASeas} \leftarrow A_{req}^{<4>} \cdot X_{req} \\
P_{ASwell} \leftarrow A_{req}^{<5>} \cdot X_{req} \\
P_{AWaves} \leftarrow P_{ASeas} + P_{ASwell} \\
\text{for } i \in 0.. \text{last}(V_{S0}) \\
P_{AAir} \leftarrow (V_{S0})^3 \cdot X_{req} \\
P_{B0} \leftarrow P_B - P_{AWaves} - P_{AWind} + P_{AAir} \\
\end{array}
\]

<table>
<thead>
<tr>
<th>t [hr]</th>
<th>ψ₀ [rad]</th>
<th>V_G [m/sec]</th>
</tr>
</thead>
<tbody>
<tr>
<td>16.792</td>
<td>5.901</td>
<td>4.409</td>
</tr>
<tr>
<td>18.830</td>
<td>2.909</td>
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<td>5.901</td>
<td>7.922</td>
</tr>
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MS 15/09/99 11:28h
Data non-dimensionalized in view of further use in some mathematical subroutines, which by definition cannot handle arguments with (different) dimensions.

\[ t := \frac{t}{\text{hr}}, \quad \psi_0 := \frac{\psi_0}{\text{rad}} \]
\[ V_G := \frac{V_G}{\text{m} \cdot \text{sec}^{-1}}, \quad n := \frac{n}{\text{Hz}}, \quad P_B := \frac{P_B}{\text{W}} \]

Normalised data

\[ J_{H_i} := JH(V_G, n) \]
\[ K_i := KP(P_B, n) \]

Check of consistency

\[ J_{H,0} := \text{Sort}(J_{H,0}, K_{P,0})^{<0>} \]
\[ K_{P,0} := \text{Sort}(J_{H,0}, K_{P,0})^{<1>} \]
\[ J_{H,1} := \text{Sort}(J_{H,1}, K_{P,0})^{<2>} \]
\[ K_{P,1} := \text{Sort}(J_{H,1}, K_{P,0})^{<3>} \]
**Input data for statistical analysis**

\[ i := 0..\text{last}(t) \]

\[ j := 0..\text{last}(t) - 1 \]

\[ K_{j,i} := \text{if}(j<i, j, j+1) \]

\[ t_{S,j,i} := t_{K,j,i} \]

\[ \psi_{0S,j,i} := \psi_{0K,j,i} \]

\[ V_{GS,j,i} := V_{GK,j,i} \]

\[ n_{S,j,i} := n_{K,j,i} \]

\[ P_{BS,j,i} := P_{BK,j,i} \]

**Evaluation**

\[ \text{Res}_{\text{supS}_i} := \text{Supplied}\left(D, \rho , t_{S}^{<i>}, \psi_{0S}^{<i>}, V_{GS}^{<i>}, n_{S}^{<i>}, P_{BS}^{<i>}\right) \]

\[ \left[E_{\text{sup}^{<i>}} V_{F.rat}^{<i>} V_{S0.rat}^{<i>} P_{B.rat}^{<i>} J_{H.rat}^{<i>} K_{P.rat}^{<i>} P_{rat}^{<i>} \right] := \text{Res}_{\text{supS}_i} \]

\[ \text{Res}_{\text{sup}} := \text{Supplied}\left(D, \rho , t, \psi_{0}, V_{G}, n, P_{B}\right) \]

\[ \left[E_{\text{sup}} V_{F.rat} V_{S0.rat} P_{B.rat} J_{H.rat} K_{P.rat} P_{rat}\right] := \text{Res}_{\text{sup}} \]

**ISO/CD evaluation:**

current at each run:
row 52

\[
\begin{bmatrix}
0.494 \\
0.527 \\
0.525 \\
0.484 \\
0.442 \\
0.404 \\
0.324 \\
0.296 \\
0.273 \\
0.275 \\
\end{bmatrix}
\]

\[ V_{\text{F.ISO}} := \frac{m}{\text{sec}} \]

\[ V_{\text{F.ISO}} := \frac{V_{\text{F.ISO}}}{m\cdot\text{sec}^{-1}} \]
**Plots of results**

**Power residua**

According to the root mean squares of the residua no sample is to be excluded or to be preferred.

**Current velocities**

The sample without the data of the second run provides exceptional current values. Consequently this sample could be kept on the basis of the argument that the 'obvious' results are completely distorted by the data of run 2! This course of action has been followed in the evaluation of the METEOR tests in 1990. But in the present case it turned out to provide 'unlikely' results as far as this line of thought has been followed.
Schmiechen: Re-evaluation of ISO/CD 15016 Example

**Ship speed**

<table>
<thead>
<tr>
<th>Ship speed in m/s</th>
<th>time in hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td>6</td>
<td>25</td>
</tr>
<tr>
<td>8</td>
<td>30</td>
</tr>
<tr>
<td>10</td>
<td>35</td>
</tr>
<tr>
<td>12</td>
<td>40</td>
</tr>
</tbody>
</table>

**Power ratios vs advance ratio**

<table>
<thead>
<tr>
<th>Power ratios</th>
<th>Advance ratios</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.175</td>
<td>0.55</td>
</tr>
<tr>
<td>0.18</td>
<td>0.6</td>
</tr>
<tr>
<td>0.185</td>
<td>0.65</td>
</tr>
<tr>
<td>0.19</td>
<td>0.7</td>
</tr>
<tr>
<td>0.195</td>
<td>0.75</td>
</tr>
<tr>
<td>0.2</td>
<td>0.8</td>
</tr>
<tr>
<td>0.21</td>
<td>0.85</td>
</tr>
</tbody>
</table>

**Power required**

Relative wind measured

- **Relative wind velocity:**
  - **Row 7:**
    - $V_{W_{indR}} = \begin{bmatrix} 13.5 \\ 4.0 \\ 15.0 \\ 2.8 \\ 16.0 \\ 0.7 \\ 0.4 \\ 16.5 \\ 0.0 \\ 16.5 \end{bmatrix}$ m/ sec
  - **Row 8:**
    - $\Psi_{W_{indR}} = \begin{bmatrix} -0.1745 \\ 2.5307 \\ -0.1745 \\ 2.3562 \\ 0.0873 \\ 2.6180 \\ 2.3562 \\ 0.0873 \\ 2.5307 \\ -0.1745 \end{bmatrix}$ rad

- **Relative wind direction:**
  - **Row 8:**
    - $\Psi_{W_{indR}} = \begin{bmatrix} -0.1745 \\ 2.5307 \\ -0.1745 \\ 2.3562 \\ 0.0873 \\ 2.6180 \\ 2.3562 \\ 0.0873 \\ 2.5307 \\ -0.1745 \end{bmatrix}$ rad
Non-dimensional values, not normalized(!), in coherent units

\[ V_{\text{WindR}} := \frac{V_{\text{Wind}}}{\text{m}\cdot\text{sec}^{-1}} \]

\[ \psi_{\text{WindR}} := \frac{\psi_{\text{Wind}}}{\text{rad}} \]

Sea state observed

<table>
<thead>
<tr>
<th>mean wave period (seas)</th>
<th>significant wave height (seas)</th>
<th>incident angle of wave (seas)</th>
</tr>
</thead>
<tbody>
<tr>
<td>row 12</td>
<td>row 13</td>
<td>row 14</td>
</tr>
</tbody>
</table>

\[
\begin{align*}
T_{\text{Seas}} & := T_{\text{Seas}} & H_{\text{Seas}} & := H_{\text{Seas}} & \psi_{\text{SeasR}} & := \\
3.90 & 3.90 & 3.90 & 3.90 & 3.90 & 3.90 & \text{sec} \\
1.00 & 1.00 & 1.00 & 1.00 & 1.00 & 1.00 & \text{m} \\
-0.17 & 2.97 & -0.17 & 2.97 & -0.17 & 2.97 & \text{rad} \\
\end{align*}
\]

Swell state observed

<table>
<thead>
<tr>
<th>mean wave period (swell)</th>
<th>significant wave height (swell)</th>
<th>incident angle of wave (swell)</th>
</tr>
</thead>
<tbody>
<tr>
<td>row 15</td>
<td>row 16</td>
<td>row 17</td>
</tr>
</tbody>
</table>

\[
\begin{align*}
T_{\text{Swell}} & := T_{\text{Swell}} & H_{\text{Swell}} & := H_{\text{Swell}} & \psi_{\text{SwellR}} & := \\
10.59 & 10.59 & 10.59 & 10.59 & 11.32 & 11.32 & \text{sec} \\
2.00 & 2.00 & 2.00 & 2.00 & 2.50 & 2.50 & \text{m} \\
-2.4435 & 0.6981 & -2.4435 & 0.6981 & -2.4435 & 0.6981 & \text{rad} \\
\end{align*}
\]

\[
\begin{align*}
T_{\text{Swell}} & := T_{\text{Swell}} & H_{\text{Swell}} & := H_{\text{Swell}} \\
10.59 & 10.59 & 10.59 & 10.59 & 11.32 & 11.32 & \text{sec} \\
2.00 & 2.00 & 2.00 & 2.00 & 2.50 & 2.50 & \text{m} \\
-2.4435 & 0.6981 & -2.4435 & 0.6981 & -2.4435 & 0.6981 & \text{rad} \\
\end{align*}
\]
Input data for statistical analysis

\[
\begin{align*}
V_{\text{WindRS}}_{j,i} &:= V_{\text{WindRK}}_{j,i} \quad \psi_{\text{WindRS}}_{j,i} := \psi_{\text{WindRK}}_{j,i} \\
W_{\text{Wind}} &:= \begin{bmatrix} V_{\text{WindR}} \quad \psi_{\text{WindR}} \end{bmatrix} \\
T_{\text{SeasS}}_{j,i} &:= T_{\text{SeasK}}_{j,i} \quad H_{\text{SeasS}}_{j,i} := H_{\text{SeasK}}_{j,i} \quad \psi_{\text{SeasRS}}_{j,i} := \psi_{\text{SeasRK}}_{j,i} \\
S_{\text{Seas}} &:= \begin{bmatrix} T_{\text{Seas}} \quad H_{\text{Seas}} \quad \psi_{\text{SeasR}} \end{bmatrix} \\
T_{\text{SwellS}}_{j,i} &:= T_{\text{SwellK}}_{j,i} \quad H_{\text{SwellS}}_{j,i} := H_{\text{SwellK}}_{j,i} \quad \psi_{\text{SwellRS}}_{j,i} := \psi_{\text{SwellRK}}_{j,i} \\
S_{\text{Swell}} &:= \begin{bmatrix} T_{\text{Swell}} \quad H_{\text{Swell}} \quad \psi_{\text{SwellR}} \end{bmatrix} \\
E_{\text{Env}} &:= \begin{bmatrix} W_{\text{EnvS}} \quad W_{\text{EnvS}} \quad W_{\text{SwellS}} \end{bmatrix}
\end{align*}
\]

Evaluation

\[
\text{Res}_{\text{reqS}}_{i} := \text{Required} \left( V_{\text{S0.ratS}}^{<i>}, P_{\text{BS}}^{<i>}, E_{\text{reqS}} \right)
\]
\[
\begin{bmatrix} E_{\text{reqS}}^{<i>} \quad P_{\text{AWind.ratS}}^{<i>} \quad P_{\text{AWaves.ratS}}^{<i>} \quad P_{\text{B.ratS}}^{<i>} \end{bmatrix} := \text{Res}_{\text{reqS}}_{i}
\]

\[
\text{Res}_{\text{req}} := \text{Required} \left( V_{\text{S0.rat}}, P_{\text{B}}, E_{\text{req}} \right)
\]
\[
\begin{bmatrix} E_{\text{req}} \quad P_{\text{AWind.rat}} \quad P_{\text{AWaves.rat}} \quad P_{\text{B.rat}} \end{bmatrix} := \text{Res}_{\text{req}}
\]

Plots of results

Power residua

\[
e_{\text{reqS}} := \frac{E_{\text{reqS}}^{<i>}}{10^{6}}
\]

\[
\begin{array}{c|c|c|c|c|c|c}
\text{t S:i} & 0 & 5 & 10 & 15 & 20 & 25 \\
\hline
\text{time of run} & 1.838 & 2.79 & 3.05 & 2.45 & 2.904 & 3.049 \\
\hline
\text{power residual in kW} & 2.728 & 2.53 & 2.895 & 3.094 & 2.895 & 3.094 \\
\hline
\end{array}
\]
According to the root mean squares of the residua no sample is to be excluded or to be preferred.

**Additional power and resistance due to wind according to ISO/CD evaluation**

\[ \eta_D := 0.6 \quad \text{Propulsive efficiency, crude estimate for plausibility checks only!} \]

\[
R_{\text{Awind.ISO}} := \frac{R_{\text{Awind.ISO}}}{N}
\]

\[
P_{\text{Awind.ISO}_i} := \frac{R_{\text{Awind.ISO}_i} \cdot V_{S0.rat_i}}{\eta_D}
\]

<table>
<thead>
<tr>
<th>t_s, t</th>
<th>P_{\text{Awind.ratS}}</th>
<th>P_{\text{Awind.rat}}</th>
<th>P_{\text{Awind.ISO}}</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>~5</td>
<td>~5</td>
<td>~5</td>
</tr>
<tr>
<td>20</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>25</td>
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</tr>
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</tr>
<tr>
<td>40</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
</tbody>
</table>

**Additional powers due to wind**

resistance increase due to wind row 29:

\[
\begin{bmatrix}
131.5 \\
-10.9 \\
162.3 \\
-4.5 \\
181.2 \\
-0.3 \\
-0.1 \\
192.7 \\
0 \\
196.5
\end{bmatrix} \cdot 10^3 \cdot \text{N}
\]

\[
\frac{P_{\text{Awind.rat}}}{P_{\text{Awind.ISO}}} = 3.382
\]

<table>
<thead>
<tr>
<th>t_s, t</th>
<th>P_{\text{Awind.ratS}}</th>
<th>P_{\text{Awind.rat}}</th>
<th>P_{\text{Awind.ISO}}</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>~5</td>
<td>~5</td>
<td>~5</td>
</tr>
<tr>
<td>20</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>25</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>30</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>35</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>40</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
</tbody>
</table>

**Additional power and resistance due to waves according to ISO/CD evaluation**

resistance increase due to waves row 30:

\[
R_{\text{Awaves.ISO}} := \frac{R_{\text{Awaves.ISO}}}{N}
\]

\[
P_{\text{Awaves.ISO}_i} := \frac{R_{\text{Awaves.ISO}_i} \cdot V_{S0.rat_i}}{\eta_D}
\]

<table>
<thead>
<tr>
<th>t_s, t</th>
<th>P_{\text{Awaves.ratS}}</th>
<th>P_{\text{Awaves.rat}}</th>
<th>P_{\text{Awaves.ISO}}</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>~5</td>
<td>~5</td>
<td>~5</td>
</tr>
<tr>
<td>20</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>25</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>30</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>35</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>40</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
</tbody>
</table>

\[
\begin{bmatrix}
31.4 \\
111.8 \\
31.4 \\
106.9 \\
31.4 \\
182.6 \\
180.1 \\
7.9 \\
264.7 \\
7.9
\end{bmatrix} \cdot 10^3 \cdot \text{N}
\]

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Checking results

The following steps are necessary in view of the very large residua in the power required. These are due to the extremely low resolution in the observation of the wave data. And this is the first time that values are being disregarded in the evaluation!

**Fairing**

\[ i := 0 \ldots \text{last}(t) - 3 \quad j := 0 \ldots 3 \quad \text{cubic 'spline'}! \]

\[ A_{i,j} := \begin{pmatrix} V_{S0.rat} \end{pmatrix}^{i,j} \]

\[ B_i := P_{B.rat}^{i} \]

\[ X := \text{LeftInv}(A) \cdot B \]

Actually only runs 8 and 9 needed to be disregarded!

**Extrapolating**

\[ i := 0 \ldots \text{last}(t) \]

\[ A_{i,j} := \begin{pmatrix} V_{S0.rat} \end{pmatrix}^{i,j} \]

\[ P_{B0.rat} := A \cdot X \]
**Interpolating**

\[ \text{k} := 0.74 \]
\[ V_{S0,\text{int}}^k := 4.8 + 0.05 \cdot \text{k} \]
\[ A_{k,j} := \left(V_{S0,\text{int}}\right)_j^k \]
\[ P_{B0,\text{int}} := A \cdot X \]
\[ n_{\text{int}} := 1 \]  \text{initial values} 

**Final performance**

**Final performance data according to rational evaluation**

\[ n_{\text{0, rat}}^{<i>} := \text{Revs} \left( p_{\text{rat}}^{<i>}, V_{S0,\text{rat}}^{<i>}, P_{B,\text{rat}}^{<i>}, n \right) \]

\[ n_{\text{0, rat}} := \text{Revs} \left( p_{\text{rat}}, V_{S0,\text{rat}}, P_{B0,\text{rat}}, n \right) \]

\[ n_{\text{0, int}} := \text{Revs} \left( p_{\text{rat}}, V_{S0,\text{int}}, P_{B0,\text{int}}, n_{\text{int}} \right) \]  \text{all non-dimensional values in coherent units} 

<table>
<thead>
<tr>
<th>frequency of revolution:</th>
<th>ship speed:</th>
<th>brake power:</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.656</td>
<td>4.869</td>
<td>3.952</td>
</tr>
<tr>
<td>0.729</td>
<td>5.263</td>
<td>5.464</td>
</tr>
<tr>
<td>0.861</td>
<td>6.320</td>
<td>8.960</td>
</tr>
<tr>
<td>0.919</td>
<td>6.845</td>
<td>10.848</td>
</tr>
<tr>
<td>1.017</td>
<td>7.652</td>
<td>14.654</td>
</tr>
<tr>
<td>1.005</td>
<td>7.566</td>
<td>14.171</td>
</tr>
<tr>
<td>1.047</td>
<td>7.875</td>
<td>15.996</td>
</tr>
<tr>
<td>1.089</td>
<td>8.174</td>
<td>18.044</td>
</tr>
<tr>
<td>1.110</td>
<td>8.313</td>
<td>19.109</td>
</tr>
<tr>
<td>1.017</td>
<td>7.654</td>
<td>14.661</td>
</tr>
</tbody>
</table>
**Final performance data** according to ISO evaluation

<table>
<thead>
<tr>
<th>frequency of revolution:</th>
<th>ship speed:</th>
<th>brake power:</th>
</tr>
</thead>
<tbody>
<tr>
<td>row 61 (5)</td>
<td>row 65</td>
<td>row 63</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(n_{0.ISO}) :=</td>
<td>(V_{S0.ISO}) :=</td>
<td>(P_{B0.ISO}) :=</td>
</tr>
<tr>
<td>(0.7317) Hz</td>
<td>(5.230) m/sec</td>
<td>(5331) kW</td>
</tr>
<tr>
<td>(0.7300) Hz</td>
<td>(5.238) m/sec</td>
<td>(5293) kW</td>
</tr>
<tr>
<td>(0.9267) Hz</td>
<td>(6.852) m/sec</td>
<td>(10839) kW</td>
</tr>
<tr>
<td>(0.9267) Hz</td>
<td>(6.861) m/sec</td>
<td>(10838) kW</td>
</tr>
<tr>
<td>(1.0467) Hz</td>
<td>(7.932) m/sec</td>
<td>(15582) kW</td>
</tr>
<tr>
<td>(1.0467) Hz</td>
<td>(7.946) m/sec</td>
<td>(15578) kW</td>
</tr>
<tr>
<td>(1.0933) Hz</td>
<td>(8.315) m/sec</td>
<td>(17945) kW</td>
</tr>
<tr>
<td>(1.0950) Hz</td>
<td>(8.327) m/sec</td>
<td>(17696) kW</td>
</tr>
<tr>
<td>(1.1167) Hz</td>
<td>(8.501) m/sec</td>
<td>(18606) kW</td>
</tr>
<tr>
<td>(1.1133) Hz</td>
<td>(8.480) m/sec</td>
<td>(19022) kW</td>
</tr>
</tbody>
</table>

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

\[
n_{0.ISO} := \frac{n_{0.ISO}}{Hz} \quad V_{S0.ISO} := \frac{V_{S0.ISO}}{m\cdot sec^{-1}} \quad P_{B0.ISO} := \frac{P_{B0.ISO}}{W}
\]

**Final performance data** according to VWS evaluation

already non-dimensional values in coherent units

\[
n_{0.VWS} := \text{READPRN}("NNico.prn") \quad V_{S0.VWS} := \text{READPRN}("VNico.prn") \quad P_{B0.VWS} := \text{READPRN}("PBNico.prn")
\]

<table>
<thead>
<tr>
<th>frequency of revolution:</th>
<th>ship speed:</th>
<th>brake power:</th>
</tr>
</thead>
<tbody>
<tr>
<td>(n_{0.VWS})</td>
<td>(V_{S0.VWS})</td>
<td>(P_{B0.VWS})</td>
</tr>
<tr>
<td>(0.731)</td>
<td>(5.063)</td>
<td>(5.520)</td>
</tr>
<tr>
<td>(0.927)</td>
<td>(6.701)</td>
<td>(11.190)</td>
</tr>
<tr>
<td>(1.047)</td>
<td>(7.670)</td>
<td>(16.120)</td>
</tr>
<tr>
<td>(1.094)</td>
<td>(8.047)</td>
<td>(18.430)</td>
</tr>
<tr>
<td>(1.115)</td>
<td>(8.211)</td>
<td>(19.500)</td>
</tr>
</tbody>
</table>

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Plots of final results

**Speed-revs curves**

- Hull speed in m/s
- Rates of revolution in Hz

**Speed-power curves**

- Ship speeds in m/s
- Brake powers in MW

Normalized values

**Advance ratios, power ratios**

<table>
<thead>
<tr>
<th>Advance Ratios</th>
<th>Power Ratios</th>
</tr>
</thead>
<tbody>
<tr>
<td>J₁₀,rat := J₁₀(V₁₀,rat, n₁₀,rat)</td>
<td>K₀,rat := K₀(P₀, rat, n₀, rat)</td>
</tr>
<tr>
<td>J₁₀,VWS := J₁₀(V₁₀,VWS, n₁₀,VWS)</td>
<td>K₀,VWS := K₀(P₀,VWS, n₀,VWS)</td>
</tr>
</tbody>
</table>

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Normalized values

Froude numbers, power numbers

\[ F_{n0.rat_i} := F_n \left( V_{S0.rat_i} \right) \]
\[ F_{n0.int_k} := F_n \left( V_{S0.int_k} \right) \]
\[ F_{n0.ISO_i} := F_n \left( V_{S0.ISO_i} \right) \]
\[ F_{n0.VWS_{ii}} := F_n \left( V_{S0.VWS_{ii}} \right) \]

\[ C_{P0.rat_i} := C_P \left( B_{0.rat_i} , V_{S0.rat_i} \right) \]
\[ C_{P0.int_k} := C_P \left( B_{0.int_k} , V_{S0.int_k} \right) \]
\[ C_{P0.ISO_i} := C_P \left( B_{0.ISO_i} , V_{S0.ISO_i} \right) \]
\[ C_{P0.VWS_{ii}} := C_P \left( B_{0.VWS_{ii}} , V_{S0.VWS_{ii}} \right) \]
Conclusions

The new ISO/CD 15016 example provides another test case for the rational evaluation of trials proposed. **There remain differences in the evaluations** further 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 requiring no reference to model test results and other prior data, as it should be.**

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 **systematic errors in the observations are to a great extent automatically accounted for.** 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 the necessary references for the suppression of the omnipresent noise, even at service conditions in heavy weather.**