On ship speed trials

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Problem
The traditional way of conducting and evaluating ship speed trials is very costly and involved and at the same time not very trustworthy. Consequently there is a need for standardisation. Japanese colleagues have taken the lead and submitted an ISO/WD 15016, now on the way from an ISO/CD to an ISO/DIS.

ISO/CD 15016
The ISO 15016 concerns the shipbuilders not only in Japan. While the colleagues in England claimed, that the procedure cannot be standardised at all, in Germany the DIN/NSMT has formed a WG Speed Trials, which has actively contributed to the formulation of the standard.

Schedule
On 1999.07.29 the secretariat of ISO/TC8/SC9 at JSMA has circulated a revised version of ISO/CD 15016 (Committee Draft) including a new example ‘for voting until 1999.10.10 concerning distribution of the draft as an ISO/DIS (Draft ISO Standard)’
ITTC SC Trials

At the 22nd ITTC the Specialist Committee on Trials and Monitoring asked the Conference to be continued, even though it will not actively contribute to work of the ISO/TC8/SC9/ WG2!

And that may be too late anyway, if the ISO schedule is being followed and not disrupted in view of serious concerns expressed by many experts.

View of present author

From the beginning of the discussion the present author has expressed the view that there is not only a need for standardisation, but at the same time a need for rationalisation based on adequate theories and methods.

Model

Based on the METEOR experience a top-down approach embedded in the theory of the rational resolution of conflicts has been suggested.

A detailed proposal for a clear-cut procedure along this line has been submitted together with two examples as contribution to the ISO/WD 15016.

Rational method

Advantages of the rational procedure are

• a minimum number of simple conventions
• and the consistent application of systems identification methods
• requiring no reference to model test results
• and any other prior information, as it should be.

References

All contributions ‘On the evaluation of ship speed trials’, including cover letters and a large number of examples, to be found under the ‘Recent papers’ on the website of the author: t-online.de/home/m.schm.

A summary paper trl_sum.htm contains hyperlinks to all the material except for the latest evaluation of the ISO example.

Further development

Of course the rational method proposed, being still in its infancy, needs the joint effort and agreement of all experts before it can be established as a reference and a standard.

The results produced so far are very promising, but those concerned are not yet concerned!
Firstly the parameters of the power supplied or delivered, more precisely of the propeller performance in the behind condition, in the full scale wake (!), and of the current velocity can be identified simultaneously by solving one set of linear equations.

The ‘local’ model

\[ P = p_0 n^3 - p_1 n^2 V \]

relating shaft power \( P \), rate of revolutions \( n \) and speed through the water \( V \),

can be visualized as a surface in a three dimensional space.

Only rate of revolutions and torque, and consequently power, are to be measured.

The speed through the water

\[ V = V_{Grd} - V_{Curr} \]

cannot be measured directly, but speed over ground. The current is unknown!

Simplest cases harmonic tidal currents or

\[ V_{Curr} = \sum v_j t_j \]

Attention! Components in ship direction!

Vectorial subtraction of velocities!

The two plus four parameters of the two models may be identified from four or better five double runs without any reference to model test results.

In the proposed method optimum estimates, are obtained for both in one step, identifying them simultaneous by solving only one system of linear equations.

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.

The traditional procedure is obscured by the iterative identification of the ‘laws’ for power and current velocity.

For the purposes of visualisation normalised quantities are being used instead of physical quantities. This has the advantage that instead of two arguments, speed and rate of revolutions, only one, the advance ratio, is necessary.

Further, systematic effects become evident.
Examples
In a great number of examples, based on actual data from industry, it has been shown that the rational 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!**

TID 21010: Current velocity

<table>
<thead>
<tr>
<th>Current velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
</tr>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

TID 21010: Power supplied

<table>
<thead>
<tr>
<th>Power ratios vs advance ratios</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.164</td>
</tr>
<tr>
<td>0.162</td>
</tr>
<tr>
<td>0.160</td>
</tr>
<tr>
<td>0.158</td>
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</tbody>
</table>

Contract conditions
Contracted power $P_{\text{contr}}$ at the speed $V_{\text{contr}}$ and at the rate of revolutions $n_{\text{contr}}$, derived from or at least confirmed by model test results.
For given power $P_{\text{contr}}$ and speed $V_{\text{contr}}$ rate of revolutions actually required is the solution of the equation

$$P_{\text{contr}} = p_0 n_{\text{req}}^3 - p_1 n_{\text{req}}^2 V_{\text{contr}}$$

Compliance
Consequently compliance with contracted conditions can be established **without the usual reference to resistance data.** Ideally the required rate of revolutions equals the contracted rate:

$$n_{\text{req}} = n_{\text{contr}}$$

Ill-defined averages
Many problems in the evaluation of trials are due to
- waiting for steady conditions,
- ignoring all interesting information,
- and using ill-defined average values.
**Time histories**
The author has fully endorsed Recommendation of the SC on Trials to the ITTC concerning the recording of ‘time histories’.
Even if runs are considered stationary sound performance and confidence analyses have to be based on quasi-instantaneous values of the data.

**Quasi-steady testing**
In the METEOR and CORSAIR trials quasi-steady test manoeuvres have been shown to be much superior to steady testing, the former 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.

**Further evaluation**
Usually a speed power relation at a given weather condition is being contracted. If one wants to do that, one opens a Pandora’s box of problems. The assumptions underlying the traditional procedure are simply too shaky. The only way to escape is to try and adhere to the principles stated. And this is possible!

**Changes in power**
More direct is the approach via changes of power due to changes of loading and weather conditions. Traditionally the relevant parameters are taken to be known apriori from former tests etc. Rational is the identification of the parameters of simple models of the power required from the trials data as well.

**Power required**
Simple models for powers required due to water resistance

\[ P_{\text{Water}} = a_1 V + a_2 V^2 + a_3 V^3 \]

and due to wind resistance

\[ P_{\text{Wind}} = b | V_{\text{Wind, rel}} | V_{\text{Wind, rel}} V. \]

Similarly the added power due to waves can be accounted for.

**Identification**
All the parameters may be identified simultaneously from a second set of linear equations based on the same trials data. Again the problem arising is ill-conditioned. The power required at the no wind condition is simply

\[ P_{\text{Air}} = b V^3. \]
Generalisation

The simple example may be generalized provided the data are sufficient for the identification of the parameters of the changes of power due to changes of loading and weather conditions. This has been done successfully in case of the new example provided with the ISO/CD 15016.

Agreements / Discrepancies

There are encouraging agreements and disturbing discrepancies to be noticed between the results of the re-evaluation and of the underlying ISO example. The final results according to the proposed ISO method show a ‘behaviour’, to be attributed to inconsistencies of the ISO method, so that nobody can seriously consider it as acceptable.

Quasisteady testing

Sufficient data for the identification of the parameters can be obtained if trials are not limited to a few steady double runs.

In the present technique conditions at ‘steady’ states are observed and averages are provided, which are ill-defined to say the least.
Detailed analysis
In the METEOR project it has been shown that a complete analysis of the powering performance can be based on data from quasi-steady tests. And in the CORSAIR project it has been shown that even the inertia of the ship and the resistance in shallow water can be identified.

Performance parameters, behind

\[
\begin{align*}
KT &= KT0 + KTH JH \\
KQ &= KQ0 + KQH JH \\
JH_{\text{min}} &\quad JH_{\text{max}} \\
JH &= 0.4 \quad 0.5 \\
KX_0 &\quad KX_H \\
KT &= 0.0186 \quad 0.2854 \\
KQ &= 0.0128 \quad 0.0278
\end{align*}
\]

Rate of revolutions
Oscillations and auto covariance

\[
\begin{align*}
\Delta N \quad [1/s] \\
C_{NN} \quad [1/s^2] \\
\tau \quad [s]
\end{align*}
\]

Velocity over ground
Oscillations and covariance with revs

\[
\begin{align*}
\Delta V \quad [m/s] \\
C_{VN} \quad [m/s^2] \\
\tau \quad [s]
\end{align*}
\]

Thrust
Oscillations and covariance with revs

\[
\begin{align*}
\Delta T \quad [kN] \\
C_{TN} \quad [kN/s] \\
\tau \quad [s]
\end{align*}
\]
**Momentum balance**

Momentum balance
\[ M \Delta A + R(V) + S(V,N) = T(V,N) + F \]

Mean values
\[ M A_m + R_m + t_m T_m = T_m \]

Oscillations
\[ M \Delta A + R(V) \Delta V + t_m \Delta T = \Delta T \]

Linearized equation
\[ (M \omega + R_o) V_t = (1 - t_m) T_t - T_m \]

**Thrust deduction axiom**

according to Schmiechen

\[ T + F = R + S = T + F \]
\[ R = F'_{T=0} \]
\[ S = t' T \]
\[ t = t_H J_H \]
\[ t_H = t g \alpha \]

**Complex force diagram**

In case of constant thrust deduction fraction

\[ M i \omega V \]
\[ R_o V_t \]
\[ (1 - t) T_t \]

**Data identified**

- \( N_m = 10.84 \) Hz
- \( V_m = 5.878 \) m/s
- \( A_m = -0.001 \) m/s²
- \( T_m = 73.70 \) kN
- \( M = 158.9 \) t
- \( R_v = 39.54 \) kN s/m
- \( t_m = 0.020 \) 1
- \( R_m = 72.47 \) kN

**Resistance**

Normalised as function of Froude number

\[ R / (\rho D^2 v^2) \]

**Conclusions**

It has been shown that a rational evaluation of ship speed trials without reference to model data is possible. If necessary the conventions (axioms) and procedures proposed can be improved according to the principles stated.

There is no way and no need to go back to the traditional conventions and procedures.