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**To whom it may concern**

# PATEs:
# Post ANONYMA trial evaluations

Still work in progress,
subject to updates
open for discussion!

## References

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# General remarks

### Rational evaluation

The rational evaluations are solely based on extremely simple propeller, current and environment conventions and on the mean data reported, though without their confidence ranges. No prior data and parameters will be used, particularly not those derived from corresponding model tests. Thus the procedure and its results are as transparent and observer independent as necessary for the rational resolution of 'conflicts' of any type!

Subsequent trustworthy predictions (!) of the powering performance at loading conditions and sea states differing from those prevailing during the trials are *not* subject of this exercise. But at the end of the Conclusions of PATE_01 serious doubts concerning any traditional convention based on prior data are being expressed and future solutions are being outlined.

### Traditional procedures

**Contrary to the rational procedure promoted and demonstrated all traditional procedures are based on prior data, and this not only for the prediction mentioned, but incorrectly already for the evaluation of the powering performance at the trials conditions.**

**But both these essential operations cannot meet the requirements of transparency and observer independence unless based on additional data observed at various conditions, permitting to identify all parameters necessary for the trustworthy prediction.**

In a way the situation is still similar to the conduct and evaluation of model tests according to Froude's procedure, where the 'essential', the frictional part cannot be modelled, but is being based on prior data.

### 'Direct power method'

The STAimo-System aggressively promoted by MARIN is based on the propulsive efficiency as input value, (to be) pulled as joker out of the sleeve and is still being based on the unsubstantiated claims, already pinpointed in the chapter on 'The Emperor's New Clothes' in my paper on 'Future Ship Powering Trials Now!' brought to the attention of colleagues worldwide in May 2013.

# Concepts and symbols

## Table of names and symbols

| Names | | Symbols | |
|---|---|---|---|
| **rational** | **traditional** | **rational** | **traditional** |
| **'Bodies'** | | | |
| Ground | | G | |
| Water | | W | water |
| Air | Wind | A | wind |
| Seaway | Waves | S | wave |
| Hull | | H | |
| Shaft | | S | |
| Propeller | | P | |
| **'Speeds'** | | | |
| Hull speed relative to ground | ship speed over ground | $V_{HG}$ | $V_G$ |
| Hull speed relative to water | ship speed in water | $V_{HW}$ | $V_H$, $V_S$ |
| Hull speed relative to air | relative wind velocity | $V_{HA} = -V_{AH}$ | $V_{Wind\ rel}$ |
| Water speed relative to ground | current velocity | $V_{WG}$ | |
| Water speed relative to hull | relative current velocity | $V_{WH}$ | |
| Air speed relative to ground | wind velocity | $V_{AG}$ | $V_{Wind}$ |
| Air speed relative to hull | | $V_{AH}$ | |
| Wave speed relative to ground | wave velocity | $V_{SG}$ | $V_{Wind}$ |
| Hull speed relative to wave | | $V_{HS}$ | |
| **Evaluations** | | | |
| rational | | rat | |
| traditional | | trad | |
| **Conditions** | | | |
| trials | | trial | |
| reference | | ref | |

## Remarks

### Speeds

The speeds relative to the hull are the longitudinal speeds, positive in the forward direction.

The notational conventions for speeds imply sign reversal with the reversal of indices, e. g.

$$V_{WH} = - V_{HW} .$$

Thus the speed of the incoming water is negative at positive forward hull speed, while traditionally the speed of wind incoming from ahead is 'counted' positive.

This inconsistency is particularly evident at the no-wind condition, precisely the 'no wind relative to the water' condition

$$V_{AW} = V_{AH} + V_{HW} = 0 ,$$

resulting correctly in the negative relative wind speed

$$V_{AH} = - V_{HW} .$$

and in the relation

$$V_{HA} = V_{HW} .$$

The reason for this confusion is to be found in the inconsistent traditional jargon. In the analysis not the air speed is being used, but the hull speed relative to the air as is the hull speed relative to the water.

### Powers

Further, the shaft power supplied is positive and, as matter of convenience, the shaft power required is traditionally counted positive as well, in accordance with the balance of powers

$$P_{S.sup} - P_{S.req} = 0$$

at steady conditions, 'hopefully' prevailing at traditional trials.

While the supplied power convention introduced

$$P_{S.sup} = p_0 N^3 + p_1 N^2 V_{HW}$$

is straightforward, the required power convention introduced

$$P_{S.req} = q_0 V_{HW}^2 V_{HW} + q_1 | V_{HA} | V_{HA} V_{HW}$$

in cases of constant sea state during the trials needs careful consideration.

Writing the convention in detail

$$- P_{S.req} = q_0 V_{WH}^2 V_{WH} + q_1 | V_{HA} | V_{HA} V_{WH}$$

results in the original format

$$P_{S.req} = q_0 V_{HW}^2 V_{HW} + q_1 | V_{HA} | V_{HA} V_{HW}$$

only, if not the incoming wind is considered, but the speed of the ship relative to the air, as is usually done and has been stated before.

# Conventions, i. e. axioms

**In terms of logics the conventions mentioned are axioms introduced as common reference to be agreed upon by the parties involved.** As in case of the rational theory of hull-propeller interaction the conventions are not rabbits magically pulled out of a hat, but **they are based on the simplest possible ideal models meeting the basic standards of invariance and providing a sufficiently rich structure to describe the data <u>in the usually very narrow range of data and of interest</u>.**

The aim is not to increase the complexity of the overall model, but to aggregate it so that the few remaining parameters can be identified reliably. The essential problem for theoretician and practicians alike is to understand the conventional nature of the procedure. The identification of the parameters, systems identification, is a necessary tool, but not the essential aspect.

The supplied power convention adopted

$$P_{S.sup} = p_0 N^3 + p_1 N^2 (V_{HG} - V_{WG})$$

has the 'dramatic' advantage that it permits clearly and cleanly to separate two problems, each described by a set of linear equations to be solved for the few parameters to be identified.

The first problem is to identify the parameters of the powering function and the parameters of the unknown current prevailing during the trails, often based on the convention of a simple harmonic tide superimposed on a mean current. The second problem is to identify the parameters of the environmental convention

$$P_{S.req} = q_0 V_{HW}^3 + q_1 |V_{HA}| V_{HA} V_{HW} + q_2 H_S^2 V_{HS}^2 V_{HW},$$

both operations based on the same mean data reported.

The 'local' convention for the first partial power required at the prevailing conditions (!), formerly briefly called 'required water power', implies that the propeller permanently operates at the same hull advance ratio and at the same power ratio. And this implies that the unknown propulsive efficiency is constant.

With the quadratic convention for the force of the air the 'local convention for the second partial power required at the prevailing conditions (!), formerly briefly called 'required wind power', is thus nothing else but a theorem in the context of the axiomatic system!

For lack of data the third partial power required at the prevailing conditions (!), formerly briefly called 'required wave power', with the 'observed' wave height and the 'observed' hull speed relative to the wave is usually not explicitly accounted for.

## Units

Data in SI-Units, if not explicitly stated otherwise, and non-dimensionalised in view of further use in some mathematical subroutines, which by definition cannot handle arguments of different units!

| | | |
|---|---|---|
| length | m | $nm := 1852 \cdot m$ |
| angle | rad | $deg := \frac{\pi}{180} \cdot rad$ |
| time | sec | $min := 60 \cdot sec$ |
| | | $hr := 3600 \cdot sec$ |
| frequency | $Hz := \frac{1}{sec}$ | $rpm := \frac{1}{min}$ |
| speed | $kts := \frac{nm}{hr}$ | $kts = 0.514 \frac{m}{s}$ |
| mass | kg | $t := 10000 \cdot kg$ |
| force | $N := newton$ | $kN := 10^3 \cdot N$ |
| | | $MN := 10^3 \cdot kN$ |
| power | $W := watt$ | $kW := 10^3 \cdot W$ |
| | | $MW := 10^3 \cdot kW$ |

## General constants

| | | | |
|---|---|---|---|
| 'field strength' | $g := 9.81 \cdot \frac{m}{s^2}$ | $g := 9.81$ | |
| density of seawater | $\rho := 1.025 \cdot 10^3 \cdot kg \cdot m^{-3}$ | $\rho := \frac{\rho}{kg \cdot m^{-3}}$ | Assumed1 |
| tidal frequency | $\omega_T := \frac{2 \cdot \pi}{12.417 \cdot hr}$ | $\omega_T := \omega_T \cdot hr$ | |

## Sample 95 % confidence radius

$$St_{95}(f) := 2 + \frac{10}{f^2}$$

95 % Student's fractiles

$$C_{95}(\Delta v, f) := \left| \begin{array}{l} s \leftarrow Stdev(\Delta v) \\ \Delta v_{95} \leftarrow \frac{St_{95}(f) \cdot s}{\sqrt{f}} \\ \Delta v_{95} \end{array} \right.$$

## Routines

### Normalise data

$$J(D,V,N) := \frac{V}{D \cdot N} \qquad KP(\rho,D,P,N) := \frac{10^6 \cdot P}{\rho \cdot D^5 \cdot N^3}$$

### Sort data in down and up-wind runs

$$\mathrm{Sort\_runs}(J_{HG}, K_P, \psi_{HG}) := \left| \begin{array}{l} j_0 \leftarrow 0 \\ j_1 \leftarrow 0 \\ \text{for } i \in 0..\mathrm{last}(\psi_{HG}) \\ \quad \left| \begin{array}{l} \text{if } \psi_{HG_i} > \frac{\pi}{2} \\ \quad \left| \begin{array}{l} S_{j_0,0} \leftarrow J_{HG_i} \\ S_{j_0,1} \leftarrow K_{P_i} \\ j_0 \leftarrow j_0 + 1 \end{array} \right. \\ \text{otherwise} \\ \quad \left| \begin{array}{l} S_{j_1,2} \leftarrow J_{HG_i} \\ S_{j_1,3} \leftarrow K_{P_i} \\ j_1 \leftarrow j_1 + 1 \end{array} \right. \end{array} \right. \\ S \end{array} \right.$$

### Tidal current convention

$$VT(v,\omega_T,\Delta t) := v_0 + v_1 \cdot \cos(\omega_T \cdot \Delta t) + v_2 \cdot \sin(\omega_T \cdot \Delta t)$$

### Directions of runs

$$\mathrm{dir}(\psi_{HG}) := \mathrm{if}\left(\psi_{HG} > \frac{\pi}{2}, 1, -1\right)$$

### Analyse power supplied

$$\mathrm{Supplied}_T(\rho, D, \Delta t, V_{HG}, \psi_{HG}, N_S, P_S) := \left| \begin{array}{l} \text{for } j \in 0..\mathrm{last}(\Delta t) \\ \quad \left| \begin{array}{l} A\_sup_{j,0} \leftarrow (N_{S_j})^3 \\ A\_sup_{j,1} \leftarrow (N_{S_j})^2 \cdot V_{HG_j} \end{array} \right. \end{array} \right.$$

$$A_{sup_{j,2}} \leftarrow -\left(N_{S_j}\right)^2 \cdot dir\left(\psi_{HG_j}\right)$$

$$A_{sup_{j,3}} \leftarrow A_{sup_{j,2}} \cdot \cos\left(\omega_T \cdot \Delta t_j\right)$$

$$A_{sup_{j,4}} \leftarrow A_{sup_{j,2}} \cdot \sin\left(\omega_T \cdot \Delta t_j\right)$$

$$X_{sup} \leftarrow geninv\left(A_{sup}\right) \cdot P_S$$

$$P_{S.sup} \leftarrow A_{sup} \cdot X_{sup}$$

$$\Delta P_{S.sup} \leftarrow P_S - P_{S.sup}$$

for $k \in 0..1$

$$p_k \leftarrow X_{sup_k}$$

$$p_{n_k} \leftarrow \frac{10^6 \cdot p_k}{\rho \cdot D^{(5-k)}}$$

$$p_2 \leftarrow Stdev\left(\Delta P_{S.sup}\right)$$

$$c \leftarrow svds\left(A_{sup}\right)$$

$$p_3 \leftarrow \frac{c_4}{c_0}$$

for $k \in 0..2$

$$v_k \leftarrow \frac{X_{sup_{2+k}}}{X_{sup_1}}$$

for $j \in 0..last(\Delta t)$

$$V_{WG_j} \leftarrow VT\left(v, \omega_T, \Delta t_j\right)$$

$$V_{HW_j} \leftarrow V_{HG_j} - V_{WG_j} \cdot dir\left(\psi_{HG_j}\right)$$

$$J_{HW_j} \leftarrow J\left(D, V_{HW_j}, N_{S_j}\right)$$

$$K_{P.sup_j} \leftarrow KP\left(\rho, D, P_{S.sup_j}, N_{S_j}\right)$$

$$\begin{bmatrix} \Delta P_{S.sup} & v & V_{WG} \\ V_{HW} & p & P_{S.sup} \\ J_{HW} & p_n & K_{P.sup} \end{bmatrix}$$

**Check distributions**

$$
\begin{aligned}
\text{norm\_distr}(\text{sampl}) := \;& r \leftarrow \text{rows}(\text{sampl}) \\
& c \leftarrow \text{cols}(\text{sampl}) \\
& \text{for } i \in 0..r-1 \\
& \quad \text{fract} \leftarrow \frac{2\cdot(i+1)}{r+1} - 1 \\
& \quad \text{dst} \leftarrow \text{fract} \\
& \quad \text{distr}_i \leftarrow \sqrt{2}\cdot\text{root}(\text{erf}(\text{dst}) - \text{fract}, \text{dst}) \\
& \quad \text{for } j \in 0..1 \\
& \quad\quad A_{\text{distr}_{i,j}} \leftarrow \left(\text{distr}_i\right)^j \\
& \text{for } j \in 0..c-1 \\
& \quad \text{sampl}_{\text{sort}}^{\langle j \rangle} \leftarrow \text{sort}\left(\text{sampl}^{\langle j \rangle}\right) \\
& \text{distr}_{\text{par}} \leftarrow \text{geninv}\left(A_{\text{distr}}\right)\cdot\text{sampl}_{\text{sort}} \\
& \text{sampl}_{\text{fair}} \leftarrow A_{\text{distr}}\cdot\text{distr}_{\text{par}} \\
& \text{for } j \in 0..c-1 \\
& \quad \text{distr}_{\text{par}_{2,j}} \leftarrow \frac{\text{distr}_{\text{par}_{1,j}}}{\sqrt{r}} \\
& \left[\text{distr} \;\; \text{sampl}_{\text{sort}} \;\; \text{sampl}_{\text{fair}} \;\; \text{distr}_{\text{par}}\right]
\end{aligned}
$$

**Analyse power required: wind and wave speeds correlated!**

$$\mathrm{Required}(V_{HW}, P_S, V_{HA}) := \left| \begin{array}{l} \text{for } i \in 0..\mathrm{last}(V_{HW}) \\ \quad \left| \begin{array}{l} A_{req_{i,0}} \leftarrow (V_{HW_i})^3 \\ A_{req_{i,1}} \leftarrow V_{HA_i} \cdot \left| V_{HA_i} \right| \cdot V_{HW_i} \end{array} \right. \\ X_{req} \leftarrow \mathrm{geninv}(A_{req}) \cdot P_S \\ P_{S.req} \leftarrow A_{req} X_{req} \\ \Delta P_{S.req} \leftarrow P_S - P_{S.req} \\ \text{for } k \in 0..1 \\ \quad q_k \leftarrow X_{req_k} \\ q_2 \leftarrow \mathrm{Stdev}(\Delta P_{S.req}) \\ c \leftarrow \mathrm{svds}(A_{req}) \\ q_3 \leftarrow \dfrac{c_1}{c_0} \\ \left[ \Delta P_{S.req} \;\; q \;\; P_{S.req} \;\; A_{req} \;\; X_{req} \right] \end{array} \right.$$

**Analyse power required: sea state provisionally accounted for**

$$\text{Required}_S\left(V_{HW}, P_S, V_{HA}, H_S, V_{HS}\right) := \left|\begin{array}{l} \text{for } i \in 0..\text{last}\left(V_{HW}\right) \\ \quad \left|\begin{array}{l} A_{req_{i,0}} \leftarrow \left(V_{HW_i}\right)^3 \\ A_{req_{i,1}} \leftarrow V_{HA_i} \cdot \left|V_{HA_i}\right| \cdot V_{HW_i} \\ A_{req_{i,2}} \leftarrow \left(H_{S_i} \cdot V_{HS_i}\right)^2 \cdot V_{HW_i} \end{array}\right. \\ X_{req} \leftarrow \text{geninv}\left(A_{req}\right) \cdot P_S \\ P_{S.req} \leftarrow A_{req} X_{req} \\ \Delta P_{S.req} \leftarrow P_S - P_{S.req} \\ \text{for } k \in 0..2 \\ \quad q_k \leftarrow X_{req_k} \\ q_3 \leftarrow \text{Stdev}\left(\Delta P_{S.req}\right) \\ c \leftarrow \text{svds}\left(A_{req}\right) \\ q_4 \leftarrow \dfrac{c_1}{c_0} \\ \left[\Delta P_{S.req} \;\; q \;\; P_{S.req} \;\; A_{req} \;\; X_{req}\right] \end{array}\right.$$

**Analyse power required: wind and wave speeds correlated!**
**'in ideal' ill-conditioned (!) case,** parameter of first partial power
introduced as identified for sister ship

$$
\text{Required}_R\left(V_{HW}, P_S, V_{HA}, X_{req.0}\right) :=
\begin{array}{|l}
\text{for } i \in 0..\text{last}\left(V_{HW}\right) \\
\quad \begin{array}{|l} A_{req_{i,0}} \leftarrow \left(V_{HW_i}\right)^3 \\ A_{req_{i,1}} \leftarrow V_{HA_i} \cdot \left|V_{HA_i}\right| \cdot V_{HW_i} \end{array} \\
X_{req_0} \leftarrow X_{req.0} \\
P_{S.req.1} \leftarrow X_{req_0} \cdot A_{req}^{\langle 0 \rangle} \\
X_{req_1} \leftarrow \dfrac{A_{req}^{\langle 1 \rangle} \cdot \left(P_S - P_{S.req.1}\right)}{A_{req}^{\langle 1 \rangle} \cdot A_{req}^{\langle 1 \rangle}} \\
P_{S.req.2} \leftarrow A_{req}^{\langle 1 \rangle} \cdot X_{req_1} \\
P_{S.req} \leftarrow P_{S.req.1} + P_{S.req.2} \\
\Delta P_{S.req} \leftarrow P_S - P_{S.req} \\
\text{for } k \in 0..1 \\
\quad q_k \leftarrow X_{req_k} \\
q_2 \leftarrow \text{Stdev}\left(\Delta P_{S.req}\right) \\
c \leftarrow \text{svds}\left(A_{req}\right) \\
q_3 \leftarrow \dfrac{c_1}{c_0} \\
\left[\Delta P_{S.req} \;\; q \;\; P_{S.req} \;\; A_{req} \;\; X_{req}\right]
\end{array}
$$

# END of PATEs:
# Post ANONYMA trial evaluations
# Preliminaries