Prof. Dr.-Ing. M.Schmiechen

MS 0306011630
0310091100
1107121300

1205041600
1207201300

1301051100
1305061500

To whom it may concern

Powering performance of a bulk carrier during speed trials in ballast condition at two trim settings reduced to the no wind condition

Units, constants routines

Units

second	$s := sec$	
minute	$min := 60 \cdot s$	
hour	$hr := 3600 \cdot s$	
frequency	$Hz := \frac{1}{s}$	$Rpm := \frac{1}{min}$
distance	$nm := 1852 \cdot m$	
speed	$kn := \frac{nm}{hr}$	$kn = 0.514\,\frac{m}{s}$
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	$\rho := 1.025 \cdot 10^3 \cdot kg \cdot m^{-3}$	$\rho := \frac{\rho}{kg \cdot m^{-3}}$
tidal frequency	$\omega_T := \frac{2 \cdot \pi}{12.417 \cdot hr}$	$\omega_T := \omega_T \cdot hr$

Constants related to trials

identification	$TID := \text{"ANONYMA"}$	
diameter of propeller	$D := 5.80 \cdot m$	$D := \frac{D}{m}$
date	$Date := \text{"2012-02-05"}$	
distance between trial 1 and 2, positive north	$\Delta s_{12} := 50 \cdot nm$	$\Delta s_{12} := \frac{\Delta s_{12}}{nm}$
mean daytime of trial 1	$t_{1.m} := 4.474 \cdot hr$	$t_{1.m} := \frac{t_{1.m}}{hr}$
mean daytime of trial 1	$t_{2.m} := 11.474 \cdot hr$	$t_{2.m} := \frac{t_{2.m}}{hr}$

Courses

course down-wind, 'reference' course, towards south	$\psi_{H.do} := 220 \cdot \frac{deg}{rad}$	$\psi_{H.do} = 3.840$
course up-wind	$\psi_{H.up} := 40 \cdot \frac{deg}{rad}$	$\psi_{H.up} = 0.698$
number of runs up and down wind	$n := 6$	
courses at trials	$\psi_H := \begin{bmatrix} 3.840 \\ 0.698 \\ 0.698 \\ 0.698 \\ 3.840 \\ 3.840 \end{bmatrix}$	

Tide

rotating tide speed towards north at the location, estimated	$c_T := 400 \cdot kn$	$c_T := \frac{c_T}{kn}$
day time of high tide	$t_T := 12.667 \cdot hr$	$t_T := \frac{t_T}{hr}$

Sea state

significant wave direction	$\psi_S := \psi_H$	
significant wave height	$H_S := 3 \cdot m$	$H_S := \frac{H_S}{m}$
	$i := 0 .. n - 1$	$H_{S_i} := H_S$

$$H_S = \begin{bmatrix} 3.000 \\ 3.000 \\ 3.000 \\ 3.000 \\ 3.000 \\ 3.000 \end{bmatrix}$$

Sea state: additionally assumed (!) for various studies

significant wave period $T_S := 7.3 \cdot sec$ $\qquad T_S := \frac{T_S}{sec}$

significant wave speed $V_S := \frac{g \cdot T_S}{2 \cdot \pi}$ $\qquad V_S = 11.398$

Check disributions

Values of random variables need to be tested for normal distribution before using mean values and and standard deviations

$$norm\_distr(sampl) := \left| \begin{array}{l} r \leftarrow rows(sampl) \\ c \leftarrow cols(sampl) \\ \text{for } i \in 0..r-1 \\ \quad \left| \begin{array}{l} fract \leftarrow \frac{2 \cdot (i+1)}{r+1} - 1 \\ dst \leftarrow fract \\ distr_i \leftarrow \sqrt{2} \cdot root(erf(dst) - fract, dst) \\ \text{for } j \in 0..1 \\ \quad A_{i,j} \leftarrow \left(distr_i\right)^j \end{array} \right. \\ \text{for } j \in 0..c-1 \\ \quad sampl_{sort}^{\langle j \rangle} \leftarrow sort\left(sampl^{\langle j \rangle}\right) \\ par \leftarrow geninv(A) \cdot sampl_{sort} \\ sampl_{sort.fit} \leftarrow A \cdot par \\ \text{for } j \in 0..c-1 \\ \quad par_{2,j} \leftarrow \frac{par_{1,j}}{\sqrt{r}} \\ \begin{bmatrix} distr \\ sampl_{sort} \\ sampl_{sort.fit} \\ par \end{bmatrix} \end{array} \right.$$

Normalise data

$$J(D, V, N) := \frac{V}{D \cdot N}$$

$$KP(\rho, D, P, N) := \frac{P \cdot \frac{MW}{W}}{\rho \cdot D^5 \cdot N^3}$$

$$Fn(V) := \frac{V}{\sqrt{g \cdot L}}$$

$$CP(\rho, D, P, V) := \frac{P \cdot \frac{MW}{W}}{\rho \cdot D^2 \cdot V^3}$$

Sort runs

For srutiny runs have to be sorted into down-wind and up-wind runs in that order..
The criterion adopted suits the data at hand.

$$
\begin{aligned}
Sort\_runs(J_H, K_P, \psi_H) := \; & j_0 \leftarrow 0 \\
& j_1 \leftarrow 0 \\
& \text{for } i \in 0..\, last(J_H) \\
& \quad \text{if } \psi_{H_i} > \frac{\pi}{2} \\
& \quad \quad S_{j_0, 0} \leftarrow J_{H_i} \\
& \quad \quad S_{j_0, 1} \leftarrow K_{P_i} \\
& \quad \quad j_0 \leftarrow j_0 + 1 \\
& \quad \text{otherwise} \\
& \quad \quad S_{j_1, 2} \leftarrow J_{H_i} \\
& \quad \quad S_{j_1, 3} \leftarrow K_{P_i} \\
& \quad \quad j_1 \leftarrow j_1 + 1 \\
& S
\end{aligned}
$$

Supplied shaft power function

$$PS_{sup}(p, N, V) := p_0 \cdot N^3 + p_1 \cdot N^2 \cdot V$$

Current velocity function

$$VC(v, t, \omega_T, t_T) := v_0 + v_1 \cdot \sin\left[\omega_T \cdot (t - t_T)\right]$$

Required shaft power function

$$PS_{req}(q, V_H, V_{W.rel}) := q_0 \cdot V_H^3 + q_1 \cdot V_H \cdot V_{W.rel} \cdot \left| V_{W.rel} \right|$$

Directions of runs

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

Analyse power supplied
including identification of polynomial current

$$
\begin{aligned}
&\mathrm{Polyn\_current}(o,\rho,D,t,\psi_H,V_G,N_S,P_S) := \\
&\quad \text{for } i \in 0..\mathrm{last}(t) \\
&\qquad A_{sup_{i,0}} \leftarrow \left(N_{S_i}\right)^3 \\
&\qquad A_{sup_{i,1}} \leftarrow \left(N_{S_i}\right)^2 \cdot V_{G_i} \\
&\qquad A_{sup_{i,2}} \leftarrow -\left(N_{S_i}\right)^2 \cdot \mathrm{dir}\left(\psi_{H_i}\right) \\
&\qquad \text{continue if } o<1 \\
&\qquad \text{for } j \in 1..o \\
&\qquad\quad A_{sup_{i,2+j}} \leftarrow A_{sup_{i,1+j}} \cdot t_i \\
&\quad X_{sup} \leftarrow \mathrm{geninv}\left(A_{sup}\right) \cdot P_S \\
&\quad E_{sup} \leftarrow P_S - A_{sup} \cdot X_{sup} \\
&\quad \text{for } k \in 0..1 \\
&\qquad p_k \leftarrow X_{sup_k} \\
&\qquad p_{n_k} \leftarrow \frac{p_k}{\rho \cdot D^{5-k}} \cdot \frac{MW}{W} \\
&\quad \text{for } j \in 0..o \\
&\qquad v_j \leftarrow \frac{X_{sup_{2+j}}}{X_{sup_1}} \\
&\quad \text{for } i \in 0..\mathrm{last}(t) \\
&\qquad V_{C_i} \leftarrow \sum_{j=0}^{o} v_j \cdot \left(t_i\right)^j \\
&\qquad V_{H_i} \leftarrow V_{G_i} - V_{C_i} \cdot \mathrm{dir}\left(\psi_{H_i}\right) \\
&\qquad P_{S_i} \leftarrow PS_{sup}\left(p, N_{S_i}, V_{H_i}\right) \\
&\qquad J_{H_i} \leftarrow J\left(D, V_{H_i}, N_{S_i}\right) \\
&\qquad K_{P_i} \leftarrow KP\left(\rho, D, P_{S_i}, N_{S_i}\right) \\
&\quad \left[E_{sup} \;\; v \;\; V_C \;\; p \;\; V_H \;\; P_S \;\; p_n \;\; J_H \;\; K_P\right]
\end{aligned}
$$

Analyse power supplied
including identification of tidal current

$$
\text{Tidal\_current}(\omega_T, t_T, \rho, D, t, \psi_H, V_G, N_S, P_S) := \left|
\begin{array}{l}
\text{for } i \in 0..\,\text{last}(t) \\
\quad \left| \begin{array}{l}
A_{sup_{i,0}} \leftarrow \left(N_{S_i}\right)^3 \\
A_{sup_{i,1}} \leftarrow \left(N_{S_i}\right)^2 \cdot V_{G_i} \\
A_{sup_{i,2}} \leftarrow -\left(N_{S_i}\right)^2 \cdot \text{dir}\left(\psi_{H_i}\right) \\
A_{sup_{i,3}} \leftarrow A_{sup_{i,2}} \cdot \sin\left[\omega_T \cdot \left(t_i - t_T\right)\right]
\end{array} \right. \\
X_{sup} \leftarrow \text{geninv}\left(A_{sup}\right) \cdot P_S \\
P_{S.E.sup} \leftarrow P_S - A_{sup} \cdot X_{sup} \\
\text{for } k \in 0..\,1 \\
\quad \left| \begin{array}{l}
v_k \leftarrow \dfrac{X_{sup_{2+k}}}{X_{sup_1}} \\
p_k \leftarrow X_{sup_k} \\
p_{n_k} \leftarrow \dfrac{p_k}{\rho \cdot D^{5-k}} \cdot \dfrac{MW}{W}
\end{array} \right. \\
\text{for } i \in 0..\,\text{last}(t) \\
\quad \left| \begin{array}{l}
V_{C_i} \leftarrow VC\left(v, t_i, \omega_T, t_T\right) \\
V_{H_i} \leftarrow V_{G_i} - V_{C_i} \cdot \text{dir}\left(\psi_{H_i}\right) \\
P_{S_i} \leftarrow PS_{sup}\left(p, N_{S_i}, V_{H_i}\right) \\
J_{H_i} \leftarrow J\left(D, V_{H_i}, N_{S_i}\right) \\
K_{P_i} \leftarrow KP\left(\rho, D, P_{S_i}, N_{S_i}\right)
\end{array} \right. \\
\left[\begin{array}{ccccccccc} P_{S.E.sup} & v & V_C & p & V_H & P_S & p_n & J_H & K_P \end{array}\right]
\end{array} \right.
$$

Analyse power supplied
excluding identification of current

$$\mathrm{No_current}(\rho, D, V_H, N_S, P_S) := \left|\begin{array}{l}
\text{for } i \in 0..\,\mathrm{last}(N_S) \\
\quad \left|\begin{array}{l} A_{sup_{i,0}} \leftarrow \left(N_{S_i}\right)^3 \\ A_{sup_{i,1}} \leftarrow \left(N_{S_i}\right)^2 \cdot V_{H_i} \end{array}\right. \\
X_{sup} \leftarrow \mathrm{geninv}(A_{sup}) \cdot P_S \\
P_{S.E.sup} \leftarrow P_S - A_{sup} \cdot X_{sup} \\
\text{for } k \in 0..\,1 \\
\quad \left|\begin{array}{l} p_k \leftarrow X_{sup_k} \\ p_{n_k} \leftarrow \dfrac{p_k}{\rho \cdot D^{5-k}} \cdot \dfrac{MW}{W} \end{array}\right. \\
\text{for } i \in 0..\,\mathrm{last}(V_H) \\
\quad \left|\begin{array}{l} P_{S.sup_i} \leftarrow PS_{sup}\left(\rho, N_{S_i}, V_{H_i}\right) \\ J_{H_i} \leftarrow J\left(D, V_{H_i}, N_{S_i}\right) \\ K_{P_i} \leftarrow KP\left(\rho, D, P_{S.sup_i}, N_{S_i}\right) \end{array}\right. \\
\left[P_{S.E.sup} \;\; p \;\; P_{S.sup} \;\; p_n \;\; J_H \;\; K_P\right]
\end{array}\right.$$

Analyse power required
no wave data available

$$\text{Required}\left(V_H, \psi_H, N_S, P_S, V_W, \psi_W\right) := \begin{array}{|l} \text{for } i \in 0..\text{last}\left(V_H\right) \\ \quad \begin{array}{|l} A_{req_{i,0}} \leftarrow \left(V_{H_i}\right)^3 \\ V_{W.x_i} \leftarrow -V_{W_i} \cdot \cos\left(\psi_{W_i} - \psi_{H_i}\right) \cdot \text{dir}\left(\psi_{H_i}\right) \\ A_{req_{i,1}} \leftarrow V_{W.x_i} \cdot \left|V_{W.x_i}\right| \cdot V_{H_i} \end{array} \\ X_{req} \leftarrow \text{geninv}\left(A_{req}\right) \cdot P_S \\ P_{S.req} \leftarrow A_{req} X_{req} \\ P_{S.E.req} \leftarrow P_S - P_{S.req} \\ \text{for } i \in 0..\text{last}\left(V_H\right) \\ \quad \begin{array}{|l} P_{S.req.0_i} \leftarrow A_{req_{i,0}} \cdot X_{req_0} \\ P_{S.req.1_i} \leftarrow A_{req_{i,1}} \cdot X_{req_1} \end{array} \\ q \leftarrow X_{req} \\ \left[P_{S.E.req} \;\; q \;\; P_{S.req} \;\; P_{S.req.0} \;\; P_{S.req.1}\right] \end{array}$$

Frequency of revolutions

$$\text{Identify\_freq}(p, V, P, N) := \begin{array}{|l} m_i \leftarrow \text{last}(V) \\ \text{for } i \in 0..m_i \\ \quad \begin{array}{|l} a \leftarrow P_i \\ b \leftarrow V_i \\ c \leftarrow N_i \\ N_i \leftarrow \text{root}\left(a - p_0 \cdot c^3 - p_1 \cdot c^2 \cdot b, c\right) \end{array} \\ N \end{array}$$

Analyse powers required
with hypothetical wave data

$$\text{Required\_hypo}\left(V_H, \psi_H, V_C, N_S, P_S, V_W, \psi_W, H_S\right) :=$$

$$
\begin{array}{l}
\text{for } i \in 0..\text{last}(V_H) \\
\quad A_{req_{i,0}} \leftarrow \left(V_{H_i}\right)^3 \\
\quad V_{W.x_i} \leftarrow -V_{W_i} \cdot \cos\left(\psi_{W_i} - \psi_{H_i}\right) \cdot \text{dir}\left(\psi_{H_i}\right) \\
\quad A_{req_{i,1}} \leftarrow V_{W.x_i} \cdot \left| V_{W.x_i} \right| \cdot V_{H_i} \\
\quad V_{G_i} \leftarrow V_{C_i} + V_{H_i} \\
\quad V_{S.x_i} \leftarrow -\left(V_S \cdot \text{dir}\left(\psi_{H_i}\right) - V_{G_i}\right) \\
\quad A_{req_{i,2}} \leftarrow \left(H_{S_i}\right)^2 \cdot V_{S.x_i} \cdot \left| V_{S.x_i} \right| \cdot V_{H_i} \\
X_{req} \leftarrow \text{geninv}\left(A_{req}\right) \cdot P_S \\
P_{S.req} \leftarrow A_{req} X_{req} \\
P_{S.E.req} \leftarrow P_S - P_{S.req} \\
\text{for } i \in 0..\text{last}(V_H) \\
\quad P_{S.req.0_i} \leftarrow A_{req_{i,0}} \cdot X_{req_0} \\
\quad P_{S.req.1_i} \leftarrow A_{req_{i,1}} \cdot X_{req_1} \\
\quad P_{S.req.2_i} \leftarrow A_{req_{i,2}} \cdot X_{req_2} \\
\quad P_{S.req.3_i} \leftarrow A_{req_{i,0}} \cdot X_{req_i} \\
q \leftarrow X_{req} \\
P_{S.req.part} \leftarrow \left[P_{S.req.0} \;\; P_{S.req.1} \;\; P_{S.req.2} \;\; P_{S.req.3} \right] \\
\left[P_{S.E.req} \;\; q \;\; P_{S.req} \;\; P_{S.req.part} \right]
\end{array}
$$

END
Units, constants. routines