Kongsberg Maritime

KONGSBERG

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OVERSENDELSE AV DATA PÅ HUGIN HYDRODYNAMISK MODELL

I dette brevet følger en beskrivelse av den hydrodynamiske modellen til HUGIN 1000. Vi håper den matematiske modellen kommer til nytte i oppgaven "AUV pipeline following and inspection".

Den matematiske modellen oversendes med følgende betingelser:
- Kongsberg Maritime refereres i rapporten
- Kongsberg Maritime får tilsendt rapporten
- Modellparametrene skal ikke oppgis i rapporten
- Modellbeskrivelsen eller simulatorer basert på denne gis ikke videre til andre i NTNU eller andre miljøer, uten etter avtale med Kongsberg Maritime. Vi er åpne for å la andre få tilgang til modellen, men vi skal først bli kontaktet og informert om bruken, før vi gir fra oss dataene. Vi ønsker ikke at modellen skal tilflyte konkurrenter til HUGIN.

Lykke til med arbeidet og ta gjerne kontakt med meg dersom det er spørsmål angående modellen.

Vennlig hilsen

(sign.)________________________________
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HUGIN 1000

1.1 Equations of motion

$$\boldsymbol{M}\dot{\boldsymbol{v}} + \boldsymbol{C}(\boldsymbol{v})\boldsymbol{v} + \boldsymbol{D}(\boldsymbol{v})\boldsymbol{v} + \boldsymbol{g}(\boldsymbol{\eta}) = \boldsymbol{\tau}$$
$$\dot{\boldsymbol{\eta}} = \boldsymbol{J}(\boldsymbol{\eta})\boldsymbol{v}$$

$$\boldsymbol{v} = \begin{bmatrix} u & v & w & p & q & r \end{bmatrix}^T$$

u, v, and w are the velocities in surge, sway, and heave. p, q, and r are the angular velocities in roll, pitch, and heave.

$$\boldsymbol{\eta} = \begin{bmatrix} x & y & z & \phi & \theta & \psi \end{bmatrix}^T$$

x, y, and z are the position in surge, sway, and heave. ϕ, θ, and ψ are the roll, pitch, and yaw angle (Euler angles).

Mass matrix

$$\boldsymbol{M} = \begin{bmatrix} m - X_{\dot{u}} & 0 & 0 & 0 & mz_G & -my_G \\ 0 & m - Y_{\dot{v}} & 0 & -mz_G & 0 & mx_G - Y_{\dot{r}} \\ 0 & 0 & m - Z_{\dot{w}} & my_G & -mx_G - Z_{\dot{q}} & 0 \\ 0 & -mz_G & my_G & I_x & 0 & 0 \\ mz_G & 0 & -mx_G - Z_{\dot{q}} & 0 & I_y - M_{\dot{q}} & 0 \\ -my_G & mx_G - Y_{\dot{r}} & 0 & 0 & 0 & I_z - N_{\dot{r}} \end{bmatrix}$$

1.1.1 Coriolis and sentripetal matrix

$$\boldsymbol{C}(v) = \begin{bmatrix} 0 & 0 & 0 & & & \\ 0 & 0 & 0 & & & \\ 0 & 0 & 0 & & & \\ -m(y_G q + z_G r) & m(y_G p + w) & m(z_G p - v) & & & \\ m(x_G q - w) & -m(z_G r + x_G p) & m(z_G q + u) & & & \\ m(x_G r + v) & m(y_G r - u) & -m(x_G p + y_G q) & & & \\ & & & m(y_G q + z_G r) & -m(x_G q - w) & -m(x_G r + v) \\ & & & -m(y_G p + w) & m(z_G r + x_G p) & -m(y_G r - u) \\ & & & -m(z_G p - v) & -m(z_G q + u) & m(x_G p + y_G q) \\ & & & 0 & I_z r & -I_y q \\ & & & -I_z r & 0 & I_x p \\ & & & I_y q & -I_x p & 0 \end{bmatrix}$$

1.1.2 Damping matrix

$$\boldsymbol{D}(\nu) = -\begin{bmatrix} X_u + X_{uu}|u| & 0 & 0 & 0 & 0 & 0 \\ 0 & Y_v & 0 & 0 & 0 & Y_r \\ 0 & 0 & Z_w & 0 & Z_q & 0 \\ 0 & 0 & 0 & K_p & 0 & 0 \\ 0 & 0 & M_w & 0 & M_q & 0 \\ 0 & N_v & 0 & 0 & 0 & N_r \end{bmatrix}$$

1.1.3 Restoring forces

$$\boldsymbol{g}(\boldsymbol{\eta}) = \begin{bmatrix} 0 \\ 0 \\ 0 \\ -y_G W c_\theta c_\phi + z_G W c_\theta s_\phi \\ z_G W s_\theta + x_G W c_\theta c_\phi \\ -x_G W c_\theta s_\phi - y_G W s_\theta \end{bmatrix}$$

1.1.4 Transformation matrix

$$\boldsymbol{J} = \begin{bmatrix} \boldsymbol{J}_1 & \boldsymbol{0}_{3\times3} \\ \boldsymbol{0}_{3\times3} & \boldsymbol{J}_2 \end{bmatrix}$$

where

$$\boldsymbol{J}_1(\boldsymbol{\eta}_2) = \begin{bmatrix} c_\psi c_\theta & -s_\psi c_\phi + c_\psi s_\theta s_\phi & s_\psi s_\phi + c_\psi c_\phi s_\theta \\ s_\psi c_\theta & c_\psi c_\phi + s_\phi s_\theta s_\psi & -c_\psi s_\phi + s_\theta s_\psi c_\phi \\ -s_\theta & c_\theta s_\phi & c_\theta c_\phi \end{bmatrix}$$

$$\boldsymbol{J}_2(\boldsymbol{\eta_2}) = \begin{bmatrix} 1 & s_\phi t_\theta & c_\phi t_\theta \\ 0 & c_\phi & -s_\phi \\ 0 & s_\phi / c_\theta & c_\phi / c_\theta \end{bmatrix}$$

and

$$s_\phi = \sin\phi, s_\theta = \sin\theta, s_\psi = \sin\psi, t_\theta = \tan\theta$$
$$c_\phi = \cos\phi, c_\theta = \cos\theta, c_\psi = \cos\psi$$

1.1.5 Propeller and rudder

$$\boldsymbol{\tau} = \boldsymbol{\tau}_{\text{Propeller}} + \boldsymbol{\tau}_{\text{Rudder}}$$

$$\boldsymbol{\tau}_{\text{Propeller}} = \begin{bmatrix} T & 0 & 0 & Q & 0 & 0 \end{bmatrix}^T$$
$$T = T_{nn} n^2 + T_{un} u n$$
$$Q = Q_{nn} n^2 + Q_{un} u n$$

where u is the vessel speed and n is the angular velocity of the propeller (revolutions per second)

$$\boldsymbol{\tau}_{\text{Rudder}} = \boldsymbol{B}\delta u^2$$

$$\boldsymbol{B} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ Y_{\delta u^2} & Y_{\delta u^2} & 0 & 0 \\ 0 & 0 & Z_{\delta u^2} & Z_{\delta u^2} \\ Y_{\delta u^2} l_z & -Y_{\delta u^2} l_z & -Z_{\delta u^2} l_y & Z_{\delta u^2} l_y \\ 0 & 0 & Z_{\delta u^2} l_x & Z_{\delta u^2} l_x \\ -Y_{\delta u^2} l_x & -Y_{\delta u^2} l_x & 0 & 0 \end{bmatrix}$$

$$\delta = \begin{bmatrix} \delta_{\text{top}} \\ \delta_{\text{bottom}} \\ \delta_{\text{port}} \\ \delta_{\text{starboard}} \end{bmatrix}$$

δ_{top} is the angle of the top rudder, δ_{bottom} is the angle of the bottom rudder.
δ_{port} is the angle of the port sternplane, $\delta_{\text{starboard}}$ is the angle of the starboard sternplane.

1.2 Parameters

1.2.1 Center of gravity

Symbol	Value
x_G	0
y_G	0
z_G	0.0328

1.2.2 Mass and moment of inertia

Symbol	Value
m	1380
I_x	86.53
I_y	1247
I_z	1247

1.2.3 Added mass

Symbol	Value
$X_{\dot{u}}$	-85.57
$Y_{\dot{v}}$	-1092.9
$Y_{\dot{r}}$	-84.1448
$Z_{\dot{w}}$	-1092.9
$Z_{\dot{q}}$	84.1448
$M_{\dot{q}}$	-795.1686
$N_{\dot{r}}$	-795.1686

1.2.4 Damping

Name	Value
X_u	-19.1881
X_{uu}	-3.8938
Y_v	-931.9715
Y_r	1915.8
Z_w	-931.9715
Z_q	-1915.8
K_p	-1000
M_w	1760.7
M_q	-8386.3
N_v	-1760.7
N_r	-8386.3

1.2.5 Propeller and rudder

Name	Value
T_{nn}	53.85
T_{un}	-59.45
Q_{nn}	5.47
Q_{un}	-5.65
$Y_{\delta u^2}$	118.0105
$Z_{\delta u^2}$	-118.0105
l_x	2.0470
l_y	0.2125
l_z	0.2125