1. Hull Forms and Simulation Conditions

Hull form[1]	Test case	Approach speed U_0 (Fn)[2]	Appendages	CFD Simulation condition				EFD Data[4] (λ)[5]
				DOF[3]	U_C (kn)	$\frac{U}{U_0}$	Fn[2]	
KVLCC	1a) KVLCC1 1b) KVLCC2	15.5 kn (0.142)	- Propeller - Rudder	$FR_{z\theta}$	15.5	1.0	0.142	MOERI (58.0)
KCS	2) KCS	24.0 kn (0.260)	- Propeller - Rudder	$FR_{z\theta}$	18.6	0.775	0.202	CEHIPAR (52.667)
5415	3a) Bare hull	20.3 kn (0.280)	- Bilge keels	$FX_{\sigma\tau}$	20.3	1.0	0.280	IIHR (46.588)
	3b) Appended	30.0 kn (0.413)	- Twin propellers - Twin open-shafts with A-brackets - Twin rudders - Bilge keels	$FR_{z\theta}$	18.0 15.0	0.6 0.5	0.248 0.207	FORCE (35.480)

[1] Hull geometries, lines, appendages, propeller data, and etc. are downloadable from SIMMAN 2008 Workshop home page (www.simman2008.dk).

[2] Froude number based on L_{PP}.

[3] Degree of freedom of ship motion

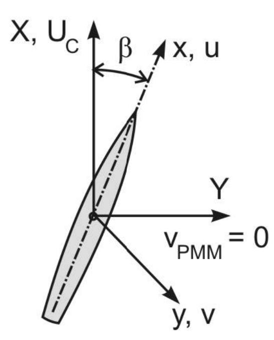
- $FR_{z\theta}$: Free to heave and pitch, roll fixed
- $FX_{\sigma\tau}$: Fixed at the dynamic sinkage and trim

[4] PMM test results to be compared with CFD simulation results

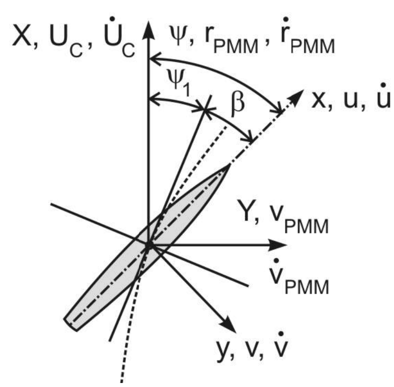
[5] Scale ratio

2. Coordinate System

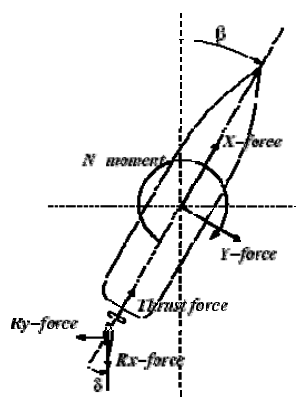
The coordinate system and sign convention is a right-handed, horizontal, body-fixed coordinate system with x positive forward of mid-ship, y positive starboard of center line and z positive down from waterline.



Static tests



Dynamic tests



Forces and moment

3. PMM Motion Parameters[1]

Prescribed motions in which the heading ψ, the surge, u, sway, v, and yaw, r, velocities and the surge $\dot{u}$, sway, $\dot{v}$, and yaw, $\dot{r}$, accelerations (in the ships local (x, y) coordinate system) are known to any given time. The motion parameters can be described by the sway amplitude, η_0, the yaw motion amplitude, ψ_0, the number of PMM rotations per minute, N, and the drift angle, β.

1) PMM yaw motion
   - Heading angle $\psi = -\psi_0 \cos\left(\frac{2\pi N}{60} t\right) + \beta$
   - Yaw rate $r_{PMM} = \psi_0 \left(\frac{2\pi N}{60}\right) \sin\left(\frac{2\pi N}{60} t\right)$
   - Yaw acceleration $\dot{r}_{PMM} = \psi_0 \left(\frac{2\pi N}{60}\right)^2 \cos\left(\frac{2\pi N}{60} t\right)$

2) PMM sway motion
   - Transverse translation $\eta_{PMM} = -\eta_0 \sin\left(\frac{2\pi N}{60} t\right)$
   - Transverse velocity $v_{PMM} = -\eta_0 \left(\frac{2\pi N}{60}\right) \cos\left(\frac{2\pi N}{60} t\right)$
   - Transverse acceleration $\dot{v}_{PMM} = \eta_0 \left(\frac{2\pi N}{60}\right)^2 \sin\left(\frac{2\pi N}{60} t\right)$

3) Motions in the ship fixed coordinate system
   - Surge velocity $u = U_C \cos\psi + v_{PMM} \sin\psi$
   - Surge acceleration $\dot{u} = \dot{v}_{PMM} \sin\psi + r(v_{PMM} \cos\psi - U_C \sin\psi)$
   - Sway velocity $v = v_{PMM} \cos\psi - U \sin\psi$
   - Sway acceleration $\dot{v} = \dot{v}_{PMM} \cos\psi - r(U_C \cos\psi + v_{PMM} \sin\psi)$
   - Yaw rate $r = r_{PMM}$
   - Yaw acceleration $\dot{r} = \dot{r}_{PMM}$

4) Non-dimensional motion parameters ($U = \sqrt{u^2 + v^2}$)
   - $u' = \frac{u}{U}$
   - $\dot{u}' = \frac{\dot{u} L_{PP}}{U}$
   - $v' = \frac{v}{U}$
   - $\dot{v}' = \frac{\dot{v} L_{PP}}{U}$
   - $r' = \frac{r L_{PP}}{U}$
   - $\dot{r}' = \frac{\dot{r} L_{PP}^2}{U^2}$

[1] PMM motion equations for KSC pure yaw test are different. Please see KCS test conditions part.

4. PMM Simulation Conditions

PMM simulation summary

Test	Parameter	KVLCC	KCS	5415 (Bare)	5415 (App)
Static drift (SD)	β	12°	8°	10°	10°
Static rudder (SR)	δ	0°, 10°	0°, 10°	-	-
Pure sway (PS)	v' (β_{corr})[1)]	0.0852 (4.9°)	0.140 (8°)	0.174 (10°)	0.174 (10°)
Pure yaw (PY)	r'	0.30	0.40	0.30	0.401

[1)] Corresponding drift angle, $\beta_{corr} = \tan^{-1}(v')$

4.1 KVLCC

- Captive simulation in still water condition
- Pitch and heave free; otherwise constrained
- Speed ration U/U_0 = 1.0 with an approach speed U_0 = 15.5 kn
- model length L_{PP} = 5.52 m
- Tests performed at ship self-propulsion point
- Appendages: Propeller and rudder
- Available EFD data:
    - Static tests – Forces/Moments including rudder forces
    - Dynamic tests – Time histories of Forces/Moments including rudder forces

Test No[1)]	Test	Fn [-]	Rn (×10^6)	U_C [m/s]	n [rps]	β [deg]	δ [deg]	η_0 [m]	ψ_0 [deg]	N [rpm]	v' [-]	r' [-]
1a-1	SR	0.142	4.6	1.047	8.59	0	0	0	0	0	0	0
1a-2	SR	0.142	4.6	1.047	8.59	0	10	0	0	0	0	0
1a-3	SD	0.142	4.6	1.047	8.59	12.0	0	0	0	0	0.208	0
1a-4	PS	0.142	4.6	1.047	8.59	0	0	0.5	0	1.704	0.0852	0
1a-5	PY	0.142	4.6	1.047	8.59	0	0	1.0	13.36	2.334	0	0.30

[1)] Test numbers for KVLCC1. For KVLCC2, test numbers should be replace with 1b-1, 1b-2, 1b-3, 1b-4, and 1b-5, respectively.

4.2 KCS

- Captive simulation in still water condition
- Pitch and heave free; otherwise constrained
- Speed ration U/U_0 = 0.775 with an approach speed U_0 = 24.0 kn
- model length L_{PP} = 4.37 m
- Propeller self-propulsion point: refer to EFD data descriptions on SIMMAN web page
- Appendages: Propeller and rudder
- Available EFD data:
    - Static tests – Forces/Moments including rudder force/moment
    - Dynamic tests – Time histories of Forces/Moments including rudder force

Test No	Test	Fn [-]	Rn ($\times10^6$)	U_C [m/s]	n [rps]	β [deg]	δ [deg]	η_0 [m]	ψ_0 [deg]	N [rpm]	v' [-]	r' [-]
2-1	SR	0.202	4.549	1.317	10.86	0	0	0	0	0	0	0
2-2	SR	0.202	4.549	1.317	10.86	0	10	0	0	0	0	0
2-3	SD	0.202	4.549	1.317	10.86	8	0	0	0	0	0.139	0
2-4	PS	0.202	4.549	1.317	10.86	0	0	0.587	0	3.0	0.140	0
2-5	PY[1)]	0.202	4.549	1.317	10.86	0	0		22.0	3.0	0	0.40

[1)] PMM motion equations for KCS pure yaw test

- Heading angle: $\psi = -\psi_0 \cos\left(\frac{2\pi N}{60} t\right) + \beta$
- Yaw rate: $r_{PMM} = \psi_0 \left(\frac{2\pi N}{60}\right) \sin\left(\frac{2\pi N}{60} t\right)$
- Yaw acceleration: $\dot{r}_{PMM} = \psi_0 \left(\frac{2\pi N}{60}\right)^2 \cos\left(\frac{2\pi N}{60} t\right)$
- Sway velocity : $v_{PMM} = U_C \sin\psi$
- Forward velocity : $u_{PMM} = U_C \cos\psi$
- Sway motion : $\eta_{PMM} = \int_0^t v_{PMM} dt$
- Non-dimensional yaw velocity : $r' = \max(r_{PMM}) \cdot L_{PP}/U_C$

4.3 5415 Bare hull

- Captive simulation in still water condition
- Fixed at the dynamic sinkage and trim (heave/L_{PP} = 1.9209×10^{-3} & pitch = -0.136°)
- Speed ration U/U_0 = 1.0 with an approach speed U_0 = 20.3 kn
- model length L_{PP} = 3.048 m
- Appendages: Propeller and rudder
- Available EFD data:
  - Static tests – Forces/Moments
  - Dynamic tests – Time histories of Forces/Moments, PIV flow field data[1)]

Test No	Test	Fn [-]	Rn ($\times 10^6$)	U_C [m/s]	n [rps]	β [deg]	δ [deg]	η_0 [m]	ψ_0 [deg]	N [rpm]	v' [-]	r' [-]
3a-1	SD	0.280	4.4643	1.531	-	10	0	0	0	0	0.174	0
3a-2	PS	0.280	4.4643	1.531	-	0	0	0.317	0	8.0210	0.174	0
3a-3	PY	0.280	4.4643	1.531	-	0	0	0.327	10.2	8.0210	0	0.30

[1)] Available PIV data:

- Longitudinal positions (Origin at FP)
  - Pure sway test: x/L_{PP} = 0.135, 0.235, 0.735, **0.935**
  - Pure yaw test: x/L_{PP} = 0.135, **0.335**, 0.535, 0.735, **0.935**, 1.035
  - *CFD results will be compared only at 0.935 for pure sway test and at 0.335 and 0.935 for pure yaw test*

- PMM Phase angles
  - Pure sway test (deg): **0**, **45**, **90**, **135**, 180, 225, 270, 315
  - Pure yaw test (deg): **0**, 11.25, 22.5, 33.75, **45**, 56.25, 67.5, 78.75, **90**, 101.25, 112.5, 123.75, **135**, 146.25, 157.5, 168.75, 180, 191.25, 202.5, 213.75, 225, 236.25, 247.5, 258.75, 270, 281.25, 292.5, 303.75, 315, 326.25, 227.5, 348.75
  - *CFD results will be compared only at 0°, 45°, 90°, and 135°*

- Measured (Phase-averaged) flow variables
  - Velocities: $U = \bar{U}/U_C, V = \bar{V}/U_C, W = \bar{W}/U_C$
  - Reynolds stresses: $uu = \overline{uu}/U_C^2, vv = \overline{vv}/U_C^2, ww = \overline{ww}/U_C^2, uv = \overline{uv}/U_C^2,$ $uw = \overline{uw}/U_C^2, vw = \overline{vw}/U_C^2$
  - Turbulent kinetic energy: $k = \frac{1}{2}(uu + vv + ww)$
  - Axial vorticity: $\omega_x = \partial W/\partial y - \partial V/\partial z$, where y and z are non-dimensionalized with ship length, L_{PP}.

4.4 5415 Appended

- Captive simulation in still water condition
- Pitch and heave free; otherwise constrained
- Speed ration U/U_0 = 0.6 and 0.5 with an approach speed U_0 = 30.0 kn
- model length L_{PP} = 4.0023 m
- Propeller self-propulsion point set in model scale
- Appendages:
  - Twin open-shaft arrangements with A-bracket supports
  - Twin balanced spade rudders and bilge keels
  - Four-bladed right- and left-handed inward rotating twin propellers
- Available EFD data:
  - Static tests – Forces/Moments (Rudder force not measured)
  - Dynamic tests – Time histories of Forces/Moments (Rudder force not measured)

Test No	Test	Fn [-]	Rn ($\times 10^6$)	U_C [m/s]	n [rps]	β [deg]	δ [deg]	η_0 [m]	ψ_0 [deg]	N [rpm]	v' [-]	r' [-]
3b-1	SD	0.248	5.19	1.554	10.53	10	0	0	0	0	0.174	0
3b-2	PS	0.248	5.19	1.554	10.53	0	0	0.654	0	4.0	0.174	0
3b-3	PY	0.207	4.34	1.299	9.99	0	0	0.240	8.8	8.0	0	0.410

5. Data reduction equations

All forces are defined in a coordinate system following the ship, meaning that *X*-components act in the longitudinal direction of the ship and *Y*-components perpendicular to this direction. The yaw moment is taken with respect to the mid-ship position at $L_{PP}/2$.

5.1 Static tests

All forces and moments should be non-dimensionalized by the following data reduction equations

$$X' = \frac{F_x}{0.5\rho U_C^2 A_0}, \qquad Y' = \frac{F_y}{0.5\rho U_C^2 A_0}, \qquad N' = \frac{M_z}{0.5\rho U_C^2 A_0 L_{PP}}$$

$$T' = \frac{T}{0.5\rho U_C^2 A_0}, \qquad R_x' = \frac{R_x}{0.5\rho U_C^2 A_0}, \qquad R_y' = \frac{R_y}{0.5\rho U_C^2 A_0}$$

where ρ is the water density. F_x, F_y and M_z are the total *X*- and *Y*-forces and the yaw moment, respectively, T is the propeller thrust force, and R_x and R_y are the rudder x- and y-force, respectively . U_C is the model towing speed. A_0 is the lateral underwater area defined as $A_0 = L_{PP} \cdot T_m$. L_{PP} and T_m are the length between perpendiculars and the mean draft, respectively. L_{PP} is also used as the characteristic arm for yaw moment.

5.2 Dynamic tests

All hydrodynamic forces and moments should be non-dimensionalized by the following data reduction equations

$$X' = \frac{F_{x\,Hydro}}{0.5\rho U^2 A_0} = \frac{F_x + m(\dot{u} - rv - x_G r^2)}{0.5\rho U^2 T_m L_{PP}}$$

$$Y' = \frac{F_{y\,Hydro}}{0.5\rho U^2 A_0} = \frac{F_y + m(\dot{v} + ru + x_G \dot{r})}{0.5\rho U^2 T_m L_{PP}}$$

$$N' = \frac{M_{z\,Hydro}}{0.5\rho U^2 A_0 L_{PP}} = \frac{M_z + I_z \dot{r} + m \cdot x_G(\dot{v} + ru)}{0.5\rho U^2 T_m L_{PP}^2}$$

where ρ is the water density, m is ship mass, and x_G is the longitudinal center of gravity (COG). F_x, F_y and M_z are the total *X*- and *Y*-forces and the yaw moment, respectively. $U = \sqrt{u^2 + v^2}$ is the ship speed which varies in the dynamic test. A_0 is the lateral underwater area defined as $A_0 = L_{PP} \cdot T_m$. L_{PP} and T_m are the length between perpendiculars and the mean draft, respectively. L_{PP} is also used as the characteristic arm for yaw moment. Note that the transverse COG is assumed to be zero, $y_G = 0$.

6. CFD simulation result submission

6.1 General

- Simulation results should be submitted in model scale values.
- SI units should used for all dimensional variables.
- All data file should be submitted in plain text (ASCII) format except for flow field data.
- Flow field data should be submitted in figures conforming instructions 6.4-(2). Please put a label of your affiliation and code name in each of your figure at upper right corner.

6.2 File name convention

All data file names should be : ***Organization_CodeName_ShipName_TestNo_Result*.dat (or *.zip*)**

where,

- *Organization*: Institute name affiliated (ex: IIHR, MOERI, CEHIPAR, etc.)
- *CodeName*: CFD code name (ex: CFDSHIPIOWA, FLUENT, etc.)
- *ShipName*: Simulated ship name (ex: KVLCC, KCS, 5415)
- *TestNo*: Test number simulated (ex: 1b-1, 2-4, 3a-3, etc.)
- *Result*:
  - 'FM' for force/moment data
  - 'FF-n.nnn' for flow field data
    - n.nnn: x/L_{PP} such as 0.335 or 0.935.

Examples:

MOERI_WAVIS_KVLCC_1b-3_FM.dat	Force/moment data of static drift simulation for KVLCC2 model using WAVIS code by MOERI
IIHR_CFDSHIP-IOWA_5415_3a-3_FF-0.935.zip	Flow field data of pure yaw simulation at x/L_{PP} = 0.935 for 5415 bare hull model using CFDHIP-IOWA code by IIHR

6.3 Static tests

Data should be written as following format:

Affiliation and code name	(ex: IIHR, CFDSHIP-IOWA)
Ship name and Test number	(ex: 5415, 3a-3)

Xp =	*value*	Yp =	*value*	Np =	*value*
Usn of Xp =	*value*	Usn of Yp =	*value*	Usn of Np =	*value*
Uv of Xp =	*value*	Uv of Yp =	*value*	Uv of Np =	*value*
E of Xp =	*value*	E of Yp =	*value*	E of Np =	*value*

Rxp =	*value*	Ryp =	*value*
Usn of Rxp =	*value*	Usn of Ryp =	*value*
Uv of Rxp =	*value*	Uv of Ryp =	*value*
E of Rxp =	*value*	E of Ryp =	*value*

where,

Xp = X' Yp = Y' Np = N'

Rxp = R'_x Ryp = R'_y

Usn, Uv, E : Uncertainty analysis results. Refer to following references.

- QM Section 4.9-04-01-01, "Uncertainty Assessment in CFD Methodology"
- QM Section 4.9-04-01-02, "Guidelines for RANS Codes"

Unavailable and/or non-applicable variables should be replaced with “xxx”

Ex: Tp = xxx

Example data file, “IIHR_CFDSHIP-IOWA_5415_3a-1_FM.dat”

```
IIHR, CFDSHIP-IOWA
5415, 3a-1)

Xp =          -0.0188        Yp =          0.0608        Np =          0.0284
Usn of Xp =   xxx            Usn of Yp =   xxx           Usn of Np =   xxx
Uv of Xp =    xxx            Uv of Yp =    xxx           Uv of Np =    xxx
E of Xp = xxx           E of Yp = xxx           E of Np = xxx

Tp =          xxx            Rxp =         xxx           Ryp =         xxx
Usn of Tp =   xxx            Usn of Rxp =  xxx           Usn of Ryp =  xxx
Uv of Tp =    xxx            Uv of Rxp =   xxx           Uv of Ryp =   xxx
E of Tp = xxx           E of Rxp =       xxx          E of Ryp =        xxx
```

6.4 Dynamic tests

(1) Force/Moment data

Time series data for one complete PMM cycle should be submitted. Data should be written as following format:

Line 1: Affiliation and code name (ex: IIHR, CFDSHIP-IOWA)
Line 2: Ship name and Test number (ex: 5415, 3a-3)
Line 3: List of variables
Line 4 - : see following table

Colum	Variable	Unit	Meaning
1	t	-	Non-dimensional time, physical time over PMM motion period, t/P
2	eta	m	Transverse position of the ship, η
3	psi	rad	Heading of the ship, ψ
4	u	m/s	Surge velocity, u
5	v	m/s	Sway velocity, v
6	r	rad/s	Yaw rate, r
7	udot	m/s^2	Surge acceleration, $\dot{u}$
8	vdot	m/s^2	Sway acceleration, $\dot{v}$
9	rdot	rad/s^2	Yaw acceleration, $\dot{r}$
10	Xp	-	Non-dimensional longitudinal force, X'
11	Yp	-	Non-dimensional transverse force, Y'
12	Np	-	Non-dimensional yaw moment, N'
13	Rxp	-	Non-dimensional rudder force, R'_x (Not applicable for 5415)
14	Ryp	-	Non-dimensional rudder force, R'_y (Not applicable for 5415)

Example data file, "IIHR_CFDSHIP-IOWA_5415_3a-3_FM.dat"

```
IIHR, CFDSHIP-IOWA
5415, 3a-3
t, eta, psi, u, v, r, udot, vdot, rdot, Xp, Yp, Np
   0.00000   -1.59260  -0.18008  1.55214  0.00069  0.00005  0.00085  -0.00474  0.12547  -0.01711  -0.00102  -0.00329
   0.00134   -4.36613  -0.18008  1.55214  0.00064  0.00130  0.00048  -0.00464  0.12552  -0.01710  -0.00112  -0.00340
   0.00268   -7.13992  -0.18006  1.55215  0.00060  0.00256  0.00010  -0.00453  0.12557  -0.01710  -0.00121  -0.00351
   0.00402   -9.91377  -0.18003  1.55215  0.00055  0.00382  -0.00027  -0.00441  0.12561  -0.01710  -0.00130  -0.00362
   0.00536  -12.68747  -0.17998  1.55214  0.00051  0.00507  -0.00065  -0.00428  0.12564  -0.01710  -0.00140  -0.00373
   0.00670  -15.46080  -0.17993  1.55213  0.00047  0.00633  -0.00103  -0.00414  0.12567  -0.01710  -0.00149  -0.00383
   0.00804  -18.23355  -0.17986  1.55212  0.00043  0.00759  -0.00141  -0.00399  0.12569  -0.01710  -0.00158  -0.00394
   0.00938  -21.00551  -0.17978  1.55210  0.00039  0.00884  -0.00179  -0.00383  0.12571  -0.01710  -0.00167  -0.00405
   0.01072  -23.77647  -0.17968  1.55208  0.00035  0.01010  -0.00218  -0.00366  0.12572  -0.01710  -0.00176  -0.00415
   0.01206  -26.54620  -0.17957  1.55206  0.00032  0.01135  -0.00256  -0.00349  0.12572  -0.01710  -0.00185  -0.00426
   0.01340  -29.31450  -0.17945  1.55203  0.00028  0.01261  -0.00295  -0.00330  0.12571  -0.01711  -0.00194  -0.00437
   0.01474  -32.08115  -0.17932  1.55200  0.00025  0.01387  -0.00333  -0.00311  0.12570  -0.01710  -0.00203  -0.00448
   0.01608  -34.84592  -0.17917  1.55197  0.00022  0.01513  -0.00372  -0.00291  0.12568  -0.01711  -0.00212  -0.00458
   0.01742  -37.60860  -0.17902  1.55193  0.00019  0.01638  -0.00411  -0.00271  0.12566  -0.01711  -0.00221  -0.00469
```

(2) Flow field data (only for 5415 bare hull case)

File name convention:

Organization_CodeName_5415_Test_FigName_LongiPos_Phase.tif

where,

- *Organization*: Institute name affiliated (ex: IIHR, MOERI, CEHIPAR, etc.)
- *CodeName*: CFD code name (ex: CFDSHIPIOWA, FLUENT, etc.)
- *Test*: Test number simulated
  - 'PS' : Pure sway test
  - 'PY' : Pure yaw test
- *FigName*: Figure name
  - 'U': Axial velocity contours and cross flow vectors
  - 'V': Transverse velocity contours
  - 'W': Vertical velocity contours
  - 'k' : Turbulent kinetic energy contours
  - 'wx': Axial vorticity contours
- *LongiPos*: Longitudinal location
  - '0335' : x/L_{PP} = 0.335 (Pure yaw test only)
  - '0935' : x/L_{PP} = 0.935 (Pure sway and pure yaw tests)
- *Phase*: PMM motion phase, γ, in degree
  - '000' : γ = 0°
  - '045' : γ = 45°
  - '090' : γ = 90°
  - '135' : γ = 135°

Examples:

MOERI_WAVIS_5415_PS_U_0935_000.tif	Axial velocity contour and transverse velocity vectors of pure sway simulation at x/L_{PP} = 0.935 and PMM phase 0° using WAVIS code by MOERI
IIHR_CFDSHIP-IOWA_5415_PY_k_0335_045.tif	Turbulent kinetic energy contours of pure yaw simulation at x/L_{PP} = 0.335 and PMM phase 45° using CFDHIP-IOWA code by IIHR

Fig. 1 Axial velocity contours and cross flow vectors	
Horizontal-axis variable and range	$-0.1 \leq y/L_{PP} \leq 0.1$
Vertical-axis variable and range	$-0.08 \leq z/L_{PP} \leq 0.053$
Contour levels	$0.5 \leq U \leq 1.0$, $\Delta U = 0.05$
Tecplot setups	Frame size = 9 × 6 [paper ruler units] Axis area/viewport position(%): Left 10, Right 95, Top 95, Bottom 10 Export image: Tiff format, width = 800
Style (Tecplot)	Contour with Flood & Line option Contour line color and size: black, 0.1% Vectors size = 0.025 relative (Grid units/ Magnitude) Vector line color and size : black, 0.1%

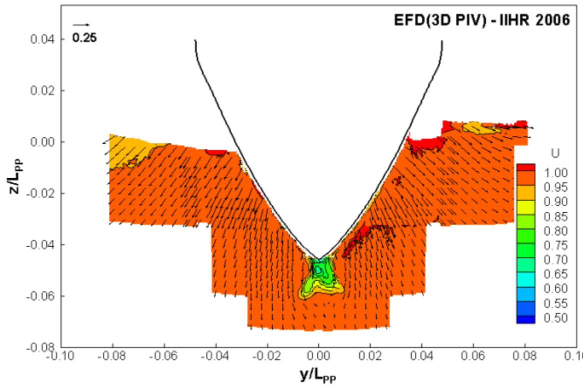
Fig. 2 Transverse velocity contours	
Horizontal-axis variable and range	$-0.1 \leq y/L_{PP} \leq 0.1$
Vertical-axis variable and range	$-0.08 \leq z/L_{PP} \leq 0.053$
Contour levels	$-0.2 \leq V \leq 0.2$, $\Delta V = 0.05$
Tecplot setups	Frame size = 9 × 6 [paper ruler units] Axis area/viewport position(%): Left 10, Right 95, Top 95, Bottom 10 Export image: Tiff format, width = 800
Style (Tecplot)	Contour with Flood & Line option Contour line color and size: black, 0.1%

Fig.3 Vertical velocity contours	
Horizontal-axis variable and range	$-0.1 \leq y/L_{PP} \leq 0.1$
Vertical-axis variable and range	$-0.08 \leq z/L_{PP} \leq 0.053$
Contour levels	$-0.2 \leq W \leq 0.2$, $\Delta W = 0.05$
Tecplot setups	Frame size = 9 × 6 [paper ruler units] Axis area/viewport position(%): Left 10, Right 95, Top 95, Bottom 10 Export image: Tiff format, width = 800
Style (Tecplot)	Contour with Flood & Line option Contour line color and size: black, 0.1%

Fig.4 Turbulent kinetic energy contours	
Horizontal-axis variable and range	$-0.1 \leq y/L_{PP} \leq 0.1$
Vertical-axis variable and range	$-0.08 \leq z/L_{PP} \leq 0.053$
Contour levels	k = 0.001, 0.002, 0.003, 0.004, 0.005, 0.006, 0.008, 0.01, 0.02
Tecplot setups	Frame size = 9 $\times$ 6 [paper ruler units] Axis area/viewport position(%): Left 10, Right 95, Top 95, Bottom 10 Export image: Tiff format, width = 800
Style (Tecplot)	Contour with Flood & Line option Contour line color and size: black, 0.1%

Fig.5 Axial vorticity contours	
Horizontal-axis variable and range	$-0.1 \leq y/L_{PP} \leq 0.1$
Vertical-axis variable and range	$-0.08 \leq z/L_{PP} \leq 0.053$
Contour levels	ω_x = -120, -50, -20, -15, -10, -5, 5, 10, 15, 20, 50, 120
Tecplot setups	Frame size = 9 $\times$ 6 [paper ruler units] Axis area/viewport position(%): Left 10, Right 95, Top 95, Bottom 10 Export image: Tiff format, width = 800
Style (Tecplot)	Large Rainbow color map Contour with Flood & Line option Contour line color and size: black, 0.1%

EXAMPLES



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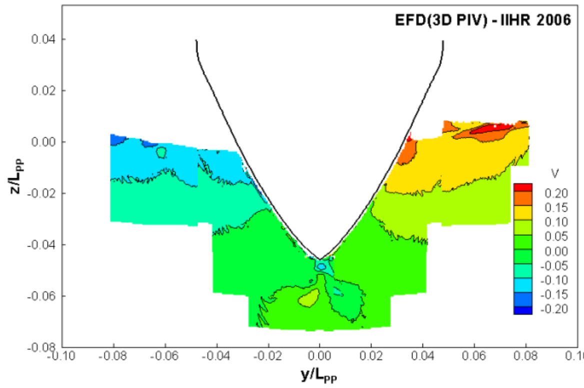

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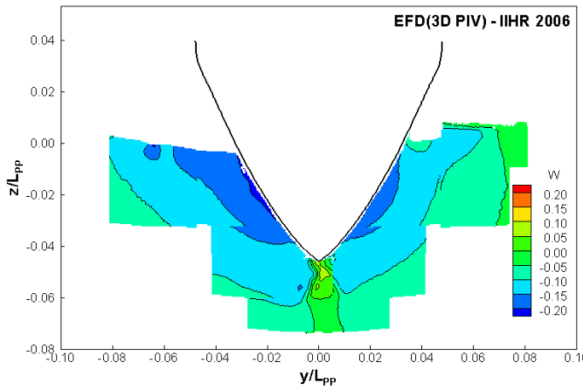

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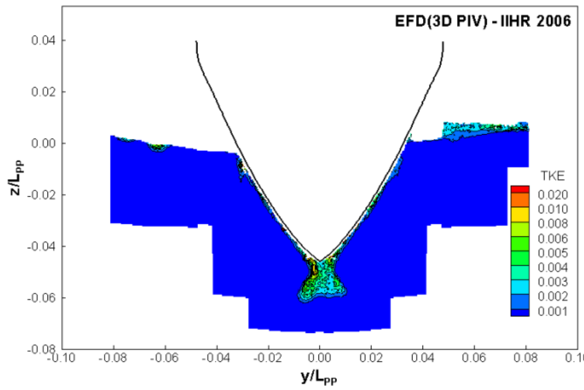

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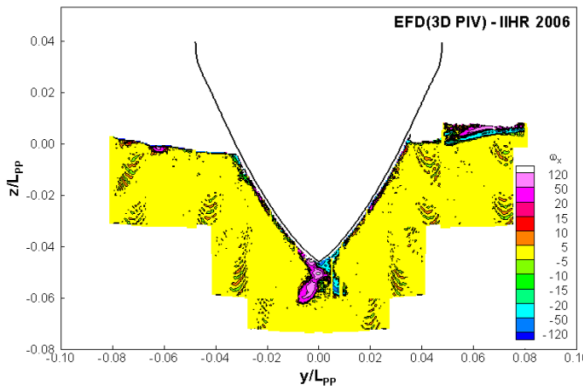

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