

Gothenburg 2010

**A Workshop on CFD in Ship Hydrodynamics
- KCS test data -**

2010 12 10
MOERI
Suak Ho Van

Contents

Background

Resistance test

Wave & wake measurement

Surface pressure & flow (prop.)

Added resistance & seakeeping

References

- Van, S.H., Kim, W.J., Yim, G.T., Kim, D.H., and Lee, C.J., (1998b), "Experimental Investigation of the Flow Characteristics Around Practical Hull Forms," Proceedings 3rd Osaka Colloquium, Osaka, Japan
- Kim, W.J., Van, D.H. and Kim, D.H., (2001), " Measurement of flows around modern commercial ship models", Exp. in Fluids, Vol. 31.
- Hino, T., (2005 ed.), "Proceedings of CFD Workshop Tokyo 2005", NMRI report 2005
- Simonsen, C., Otzen, J., and Stern, F., (2008), "EFD and CFD for KCS heaving and pitching in regular head waves," Proc. 27th Symp. Naval ydrodynamics, Seoul, Korea.
- Ken-ichi Kume, Yoshitaka Ukon, Haruya Takeshi, (2000), "Measurements of Surface Pressure and Local Velocity Field around a KCS Model and Uncertainty Analysis", G2000 Workshop preprint.

MOERI's benchmark data

Model	Ship type	Lpp	Beam	Draft	Prop . D	CB	Speed (knots)	Fn	Year
		(meter)							
KCS	3,600 TEU Container Ship	230	32.2	10.8	7.9	0.651	24.0	0.259	1997
KVLCC	320K VLCC	320	58.0	20.8	9.86	0.810	15.5	0.141	1998
KLNG	138,000m ³ LNGC	266	42.6	11.3	8.5	0.749	19.5	0.196	2002

Modern Hull Form

- Bulbous bow
- Stern end bulb
- Rudder
- Propeller (Self-propulsion) data
- No Full Scale Ship : No shipyard

Summary of test cases : KCS

Case	Type of data	Scale	Lpp (m)	Speed (m/s)	Fn	Rn	Rudder	DoF	EFD
2.1	Wave pattern, mean velocity	31.6	7.2786	2.196	0.26	1.4×10^7	No	FX ₀	MOERI
2.2a	Res			2.196	0.26	1.4×10^7	Yes	FX ₀	MOERI
2.2b	Res, S&T			0.915- 2.379	0.1083- 0.2816	5.2×10^6 - 1.4×10^7	Yes	FR _z θ	MOERI
2.3a	Self prop(ship), Surface P. Vel.	52.667	4.3671	2.196	0.26	1.4×10^7	No (Yes)	FX ₀	NMRI (MOERI)
2.3b	Self prop, S&T (model point)			1.701	0.26	6.52×10^6	Yes	FR _z θ	FORCE
2.4	Pitch, heave Added Res.			1.701, 2.151	0.26, 0.33	6.52×10^6 8.27×10^6	Yes	FR _z θ	FORCE

Model Test Facilities

Institute	Length	Breadth	Water depth
MOERI	220	16.0	7.0
NMRI	400	18.0	8.0
FORCE	200	12.0	5.5

POSTECH(wind tunnel) : 4.3x1.8x1.5(LxWxH), Vmax=70m/s

MOERI

Fixed condition

- FX : Actually fixed
- FX_{FR} : Pre-trimmed, even-keel when running

Resistance test FR condition



Resistance test FX_{FR} condition

- To measure the resistance for fixed condition, model-ship is initially trimmed to have an even draft when model-ship is running. Two or three times of trial & error to determine the amount of initial trim based on the sinkage values measured during the Free condition test.



Fixed condition for local flow & wave measurement

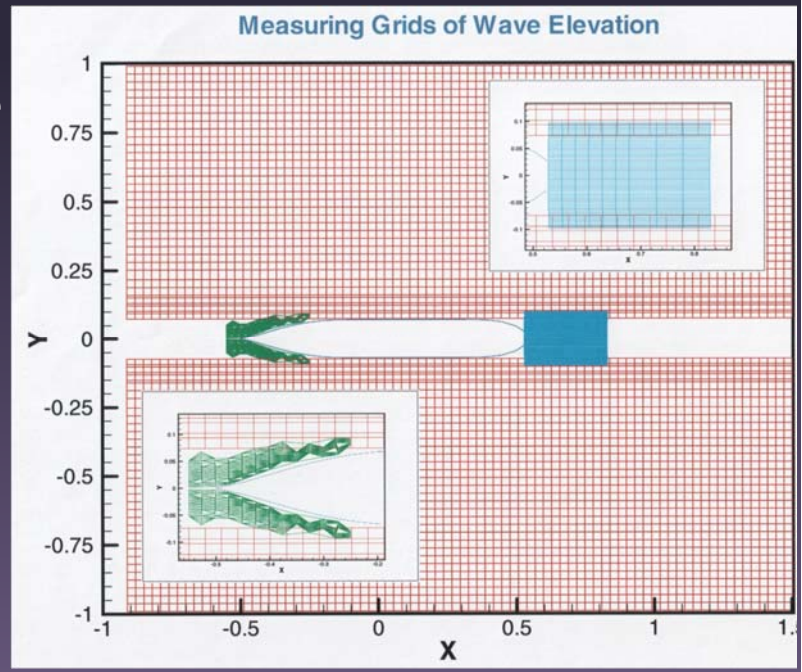
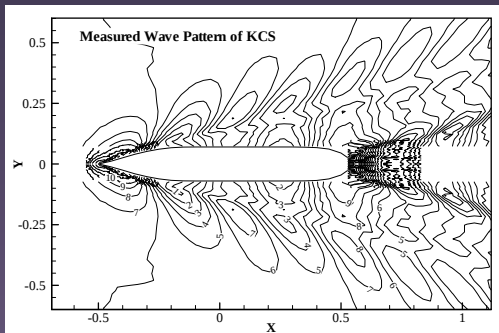
- Model-ship is firmly fixed with two posts. Wave gauge or rake of Pitot tube is attached to 3-D traverse system. Rudder is not attached.



No rudder

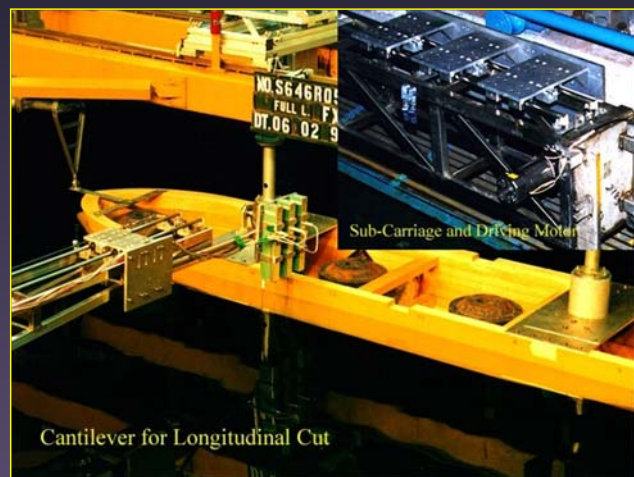
Wave pattern measurement

- Hull surface
- Bow & stern wave
- Longitudinal cut
3x13runs



Wave pattern measurement

- Servo-needle type wave gauge x 3



Stern wave measurement

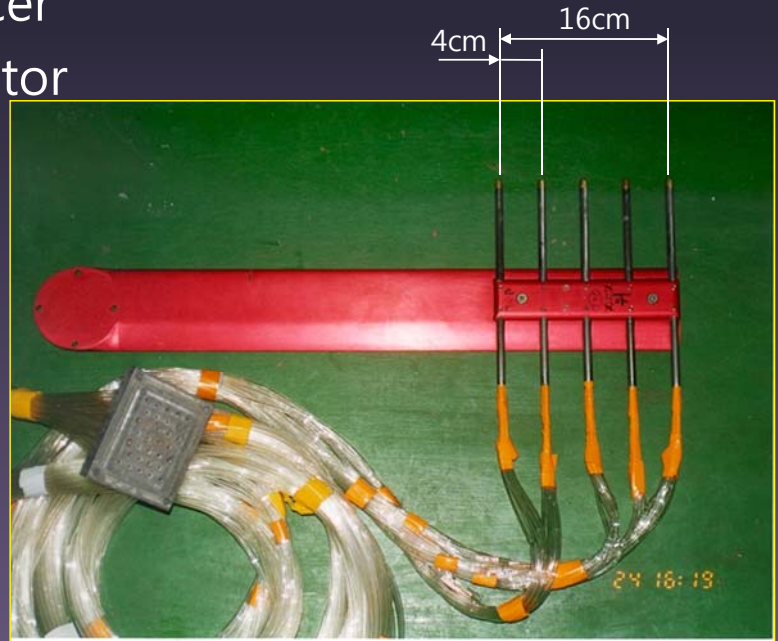


Longitudinal cut



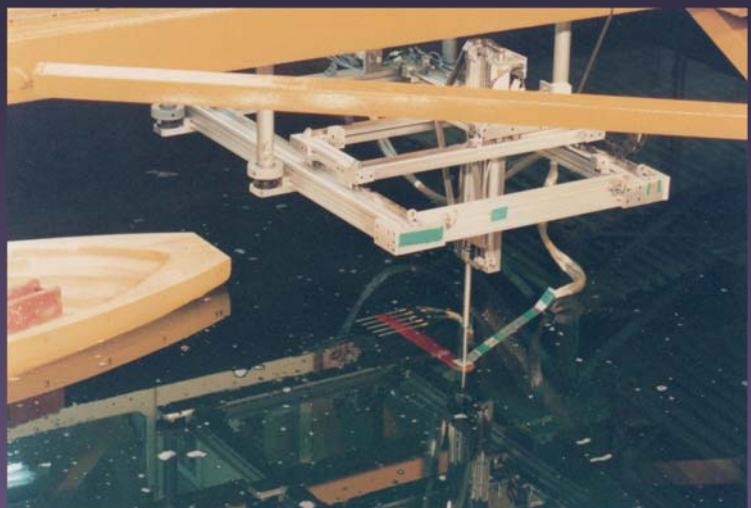
Wake measurement

- Five 5-hole Pitot tubes
- Pressure transducer
- Carrier demodulator

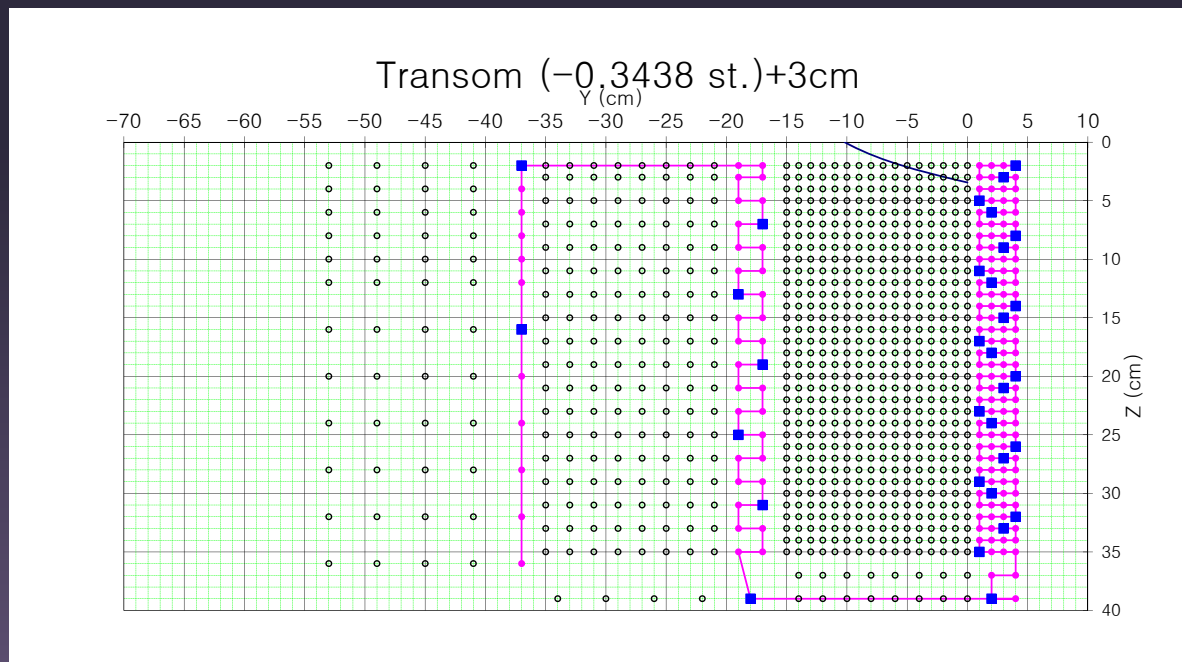


Wake measurement

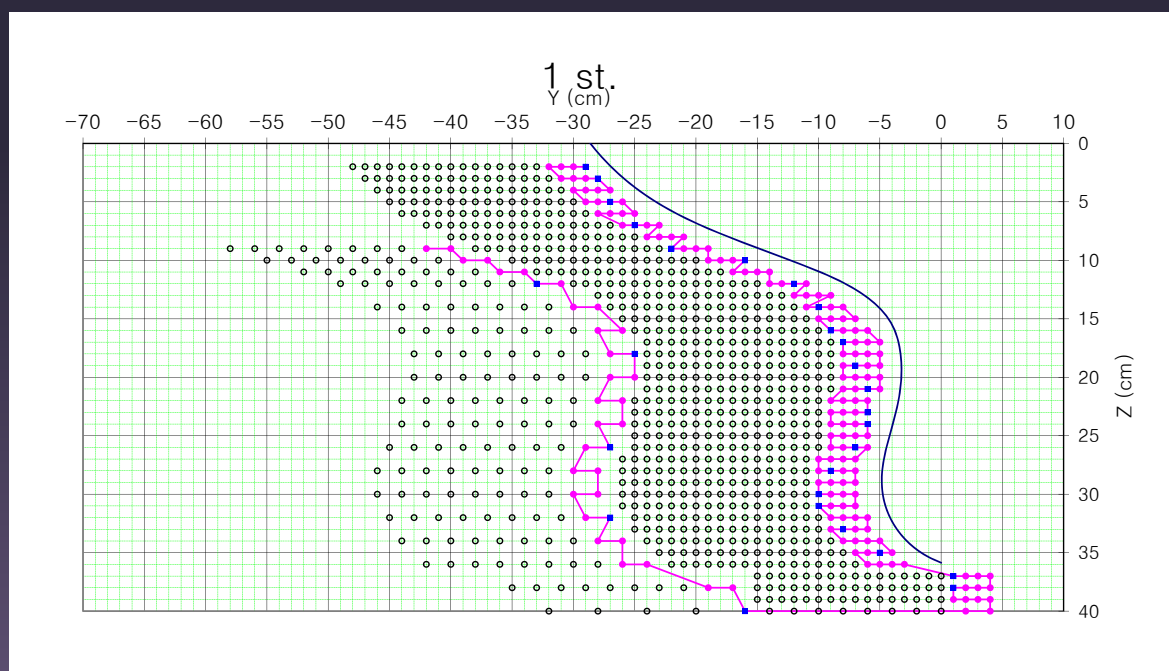
- 5~6 stations, including propeller plane
- 1cm for inner , 2cm outer region
- 3-D traverse+Pitot tube rake



Traverse path (KVLCC)



Traverse path (KVLCC)



Uncertainty analysis (KLNG, 2002)

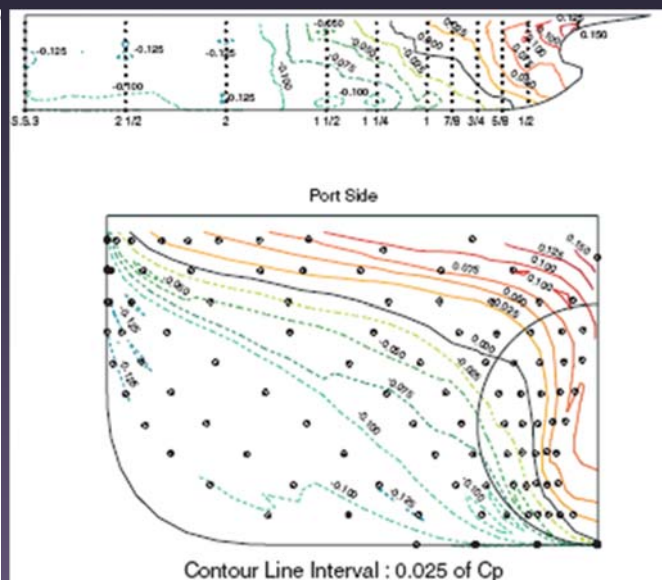
Measurement quantity	Bias error	Precision error	Uncertainty
C_{TM}	1.19%	0.43%	1.47%
T	0.93%	1.72%	3.57%
w_M	1.16%	—	1.16%
η_R	1.57%	0.50%	1.86%
Wave elevation along the hull surface	0.50 mm	—	0.50 mm
Longitudinal cut	0.30 mm	0.05 mm	0.70 mm
Transverse cut	0.30 mm	0.16 mm	0.44 mm
Velocity components			
Outside B.L.	0.25%	0.30%	0.84%
Inside B.L.	2.00%	3.00%	6.32%
Strong velocity defect region (bare hull)	3.00%	5.00%	10.44%
Behind propeller	1.00%	7.00%	14.04%

NMRI

MEASURING SYSTEM

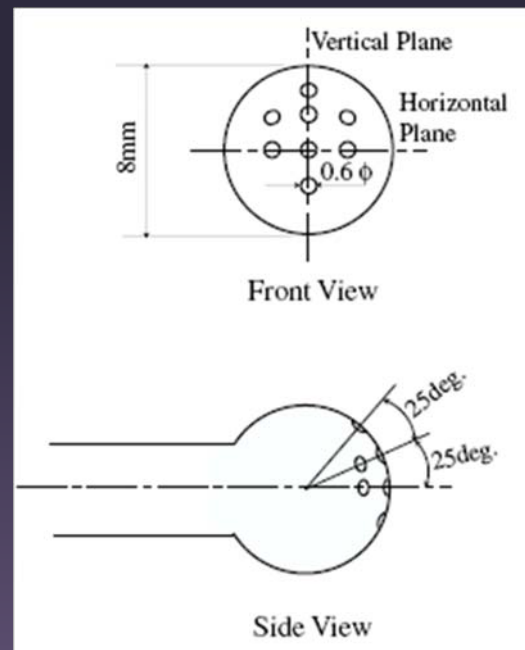


- 148 pressure tabs

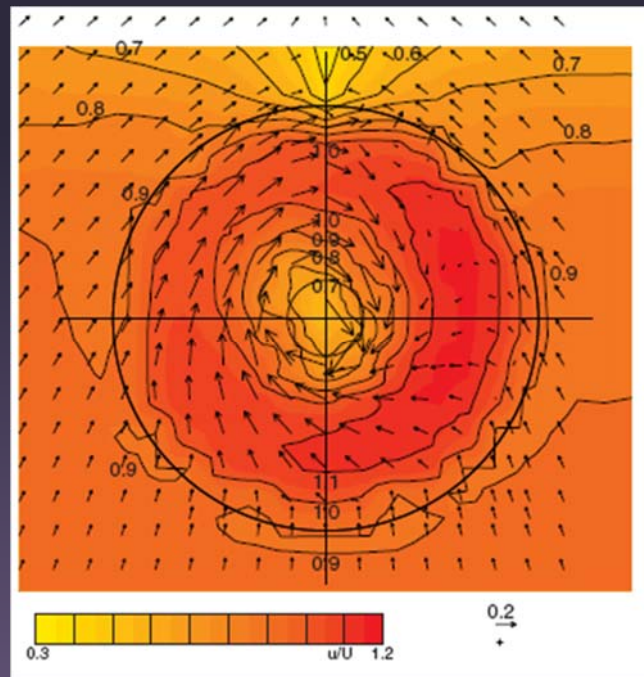
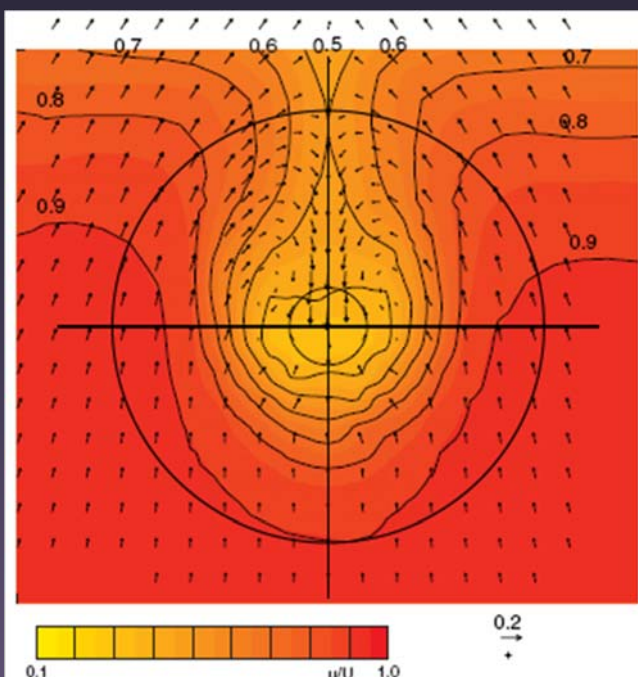


Velocity measurement

- Eighthole Pitot tube

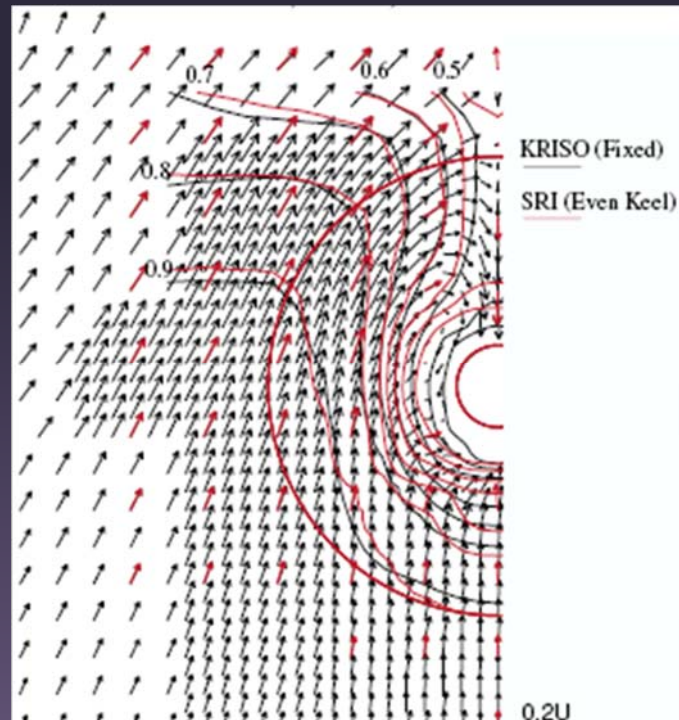


Wake w/ & w/o propeller



Comparison between KRISO & SRI

- Propeller plane
 - Black : KRISO (MOERI)
 - Red : SRI (NMRI)



Uncertainty analysis (w/o Prop.)

Position No.	1	2	3
x (mm)	3574.5	3574.5	3574.5
y (mm)	-80.0	-60.0	-40.0
z (mm)	-160.0	-160.0	-160.0
u	0.8564	0.7357	0.5455
v	-0.0695	-0.0959	-0.0635
w	-0.1644	-0.1293	-0.0400
Uu+	0.0152	0.0129	0.0187
Uu-	0.0482	0.0476	0.0495

Uncertainty analysis (w/ Prop.)

Position No.	1	2	3
x (mm)	3574.5	3574.5	3574.5
y (mm)	-80.0	-60.0	-40.0
z (mm)	-160.0	-160.0	-160.0
u	1.0266	1.0187	0.9648
v	-0.1734	-0.2088	-0.2528
w	-0.2300	-0.2457	-0.2208
Uu+	0.0112	0.0114	0.0118
Uu-	0.0471	0.0472	0.0473

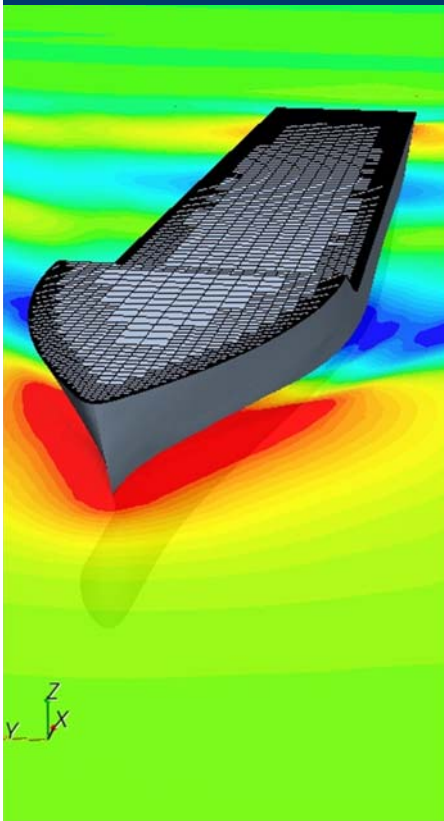
Uncertainty analysis

Items	P.T.No.1	P.T.No.2	P.T.No.3	P.T.No.4	P.T.No.5	P.T.No.6
$B_{C_p}^{SEE}$	0.0019	0.0012	0.0027	0.0014	0.0036	0.0004
$B_{C_p}^{V_e+}$	0.0003	0.0002	0.0003	0.0002	0.0001	0.0000
$B_{C_p}^{V_e-}$	0.0016	0.0008	0.0014	0.0009	0.0005	0.0002
$S_{C_p}^{V_e}$	0.0004	0.0002	0.0004	0.0002	0.0001	0.0001
$S_{C_p}^{dispersion}$	0.0038	0.0034	0.0036	0.0020	0.0016	0.0019
$B_{C_p}^+$	0.0019	0.0012	0.0027	0.0014	0.0036	0.0004
$B_{C_p}^-$	0.0025	0.0014	0.0030	0.0017	0.0036	0.0004
S_{C_p}	0.0038	0.0034	0.0036	0.0020	0.0016	0.0019
$U_{C_p}^+$	0.0079	0.0070	0.0077	0.0043	0.0049	0.0038
$U_{C_p}^-$	0.0081	0.0070	0.0078	0.0044	0.0049	0.0038
C_p	-0.1227	-0.0642	-0.1107	-0.0690	-0.0409	0.0127

Uncertainty analysis

Items	P.T.No.1	P.T.No.2	P.T.No.3	P.T.No.4	P.T.No.5	P.T.No.6
$B_{C_p}^{SEE}$	0.0011	0.0010	0.0013	0.0008	0.0027	0.0004
$B_{C_p}^{V_e+}$	0.0003	0.0002	0.0003	0.0002	0.0001	0.0000
$B_{C_p}^{V_e-}$	0.0015	0.0009	0.0015	0.0009	0.0006	0.0000
$S_{C_p}^{V_e}$	0.0004	0.0002	0.0004	0.0003	0.0002	0.0000
$S_{C_p}^{dispersion}$	0.0027	0.0028	0.0034	0.0017	0.0017	0.0045
$B_{C_p}^+$	0.0011	0.0010	0.0013	0.0008	0.0027	0.0004
$B_{C_p}^-$	0.0019	0.0013	0.0020	0.0012	0.0028	0.0004
S_{C_p}	0.0027	0.0028	0.0034	0.0018	0.0017	0.0045
$U_{C_p}^+$	0.0055	0.0058	0.0070	0.0036	0.0043	0.0089
$U_{C_p}^-$	0.0057	0.0058	0.0072	0.0037	0.0043	0.0089
C_p	-0.1192	-0.0684	-0.1168	-0.0715	-0.0469	0.0005

FORCE



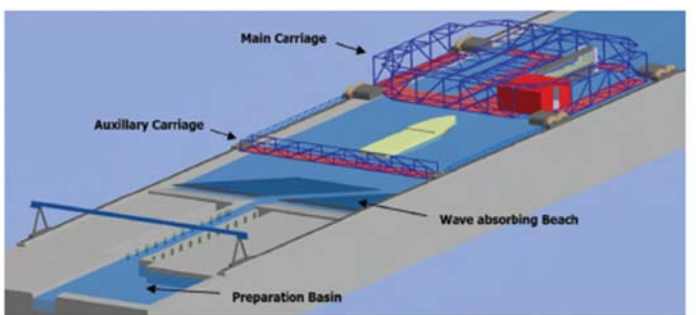
EFD and CFD for KCS heaving and pitching in regular head waves

By Claus D. Simonsen¹, Janne F. Otzen¹ and Fred Stern²

¹FORCE Technology, Denmark and ²IHR, University of Iowa, USA

27th Symposium on Naval Hydrodynamics, Seoul, Korea, 5-10 October 2008

EFD: Setup and UA



- Test conducted in FORCE Technology's towing tank L=200m, B=12m and D=5.5m
- The model is free to heave and pitch. Locked in surge
- UA is based on precision limits and bias limits

$$U_{\bar{X}}^2 = B_{\bar{X}}^2 + P_{\bar{X}}^2$$

- Precision limits are based on 12 repeat tests, while bias limits are estimated based on data reduction equations and a careful study of the measurement system



Geometry and conditions



Test in Regular Waves w/o Propeller				
Froude	wave/ship length	steepness	height m	freq. enc Hz
-	-	-	-	-
0.26 *	-	-	-	-
0.26 *	1.15	60	0.084	0.90
0.26	0.50	60	0.036	1.63
0.26	1.15	120	0.042	0.90
0.26	1.33	60	0.097	0.81
0.26	1.50	60	0.109	0.75
0.26	2.00	60	0.146	0.62
0.26	1.15	30	0.167	0.90
0.26	1.15	40	0.126	0.90
0.26	1.15	50	0.100	0.90
0.33	-	-	-	-
0.33	0.50	60	0.036	1.83
0.33	1.15	60	0.084	0.99
0.33	1.33	50	0.116	0.89
0.33	1.33	60	0.097	0.89
0.33	1.50	60	0.109	0.82
0.33	2.00	60	0.146	0.67
0.40	-	-	-	-
0.40	0.50	60	0.036	2.04
0.40	1.15	60	0.084	1.08
0.40	1.33	60	0.097	0.97
0.40	1.50	60	0.109	0.89
0.40	2.00	60	0.146	0.72
0.26	0.71	60	0.052	1.26
0.26	0.44	60	0.032	1.79
0.26	0.28	60	0.020	2.52
0.26	0.92	90	0.045	1.05

- The study is based on a test matrix designed to investigate large motions around resonance conditions
- In analogy to a mass-spring-damper system with forced motion, two things influence the ship's response:
 - Resonance, $f_e = f_n = 0.90\text{Hz}$
 - Size of excitation force, $\lambda/L_{pp} = 1.33$
- The two conditions do only coincide for one speed, so it is interesting to see if the response has a maximum at this condition
- The experiment also included uncertainty assessment. In table * denotes conditions considered for UA work

EFD: measuring quantities



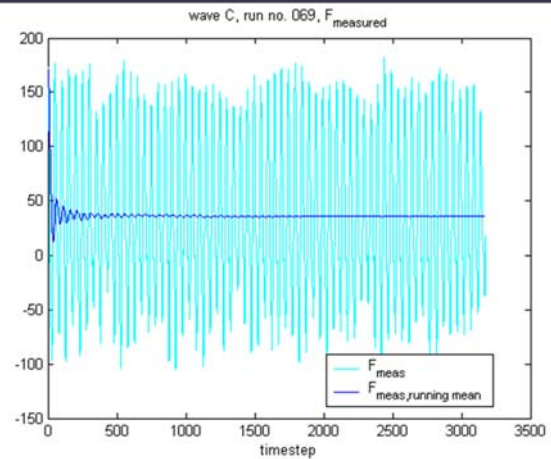
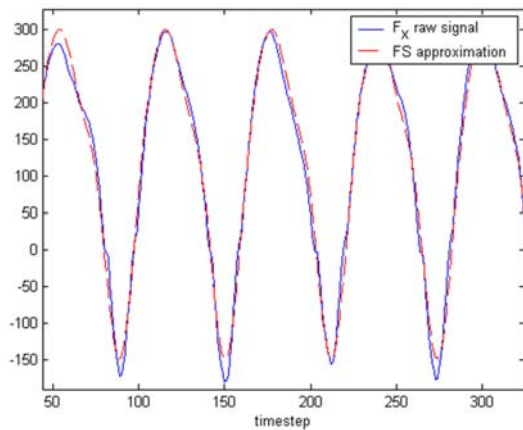
		Quantity	Unit
1	U_c	Speed	m/s
2-3	Z_{for}, Z_{aft}	Sinkage, for and after	mm
4-5	$F_{X,for}, F_{X,aft}$	X-Force, for and aft	N
6	T	Thrust	N
7	Q	Torque	Nm
8	N	Propeller rpm	rpm
9-10	$\dot{w}_{aft}, \dot{w}_{aft}$	Acceleration at FP and AP	m/s ²
11	ζ_s	Wave, stationary probe	m
12	ζ_e	Wave of encounter	m

Table 3: Overview of measured quantities.

EFD: Results, time series



- Time series for the measured motion and resistance are approximated by 3rd order Fourier Series
- Running means were calculated to check statistical convergence and make sure that sufficient logging time was used in the run



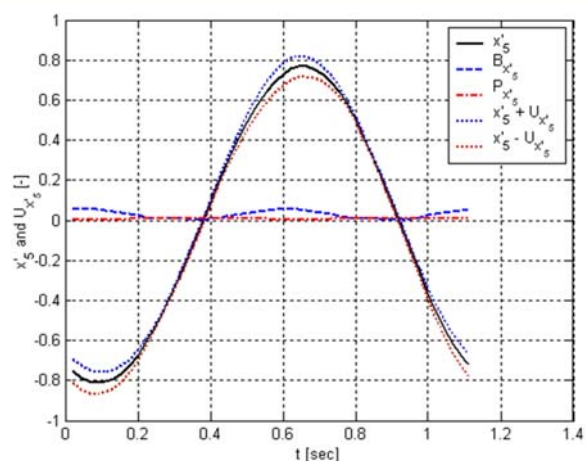
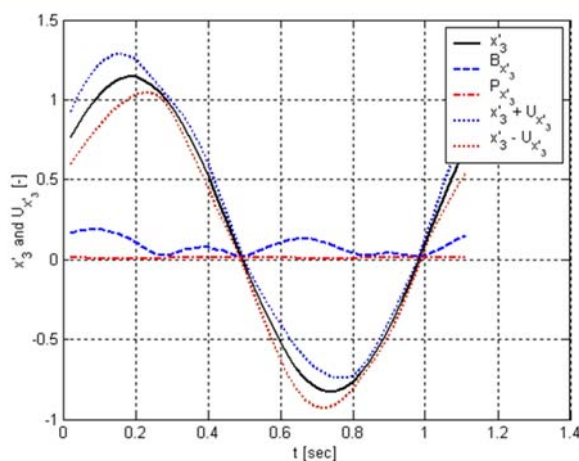
EFD: Results, time series



- The time series for the motions are represented on non-dim form by

$$X'_3 = \frac{x_3}{\zeta_{I1}}$$

$$X'_5 = \frac{x_5}{k\zeta_{I1}}$$



Thanks !