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SIMMAN 2013

EXECUTION OF MODEL TESTS WITH KCS and KVLCC2

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Execution of model tests with KCS and KVLCC2

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Abstract

This report is a guidance for interpretation of the results of the towing tank tests performed by Flanders Hydraulics Research for the SIMMAN 2013 workshop. It includes an error analysis on the test results, but not an interpretation of trends.

Manoeuvreergedrag:Open water:Schaalmodelproeven

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List of Symbols

B	beam	m
I_{XX}	moment of inertia about X-axis	kgm²
I_{YY}	moment of inertia about Y-axis	kgm²
I_{ZZ}	moment of inertia about Z-axis	kgm²
KG	vertical centre of gravity	m
K	roll moment	Nm
L_{PP}	ship length between perpendiculars	m
N	yaw moment	Nm
n	propeller rate	rpm
p	roll velocity	°/s
q	pitch velocity	°/s
r	yaw velocity	°/s
T	period	s
t	time	s
TA	draft aft	m
TF	draft fore	m
TM	draft amidships	m
u	longitudinal velocity	m/s
V	total velocity	m/s
v	lateral velocity	m/s
w	vertical velocity	m/s
X	longitudinal force	N
x	longitudinal coordinate	m
Y	lateral force	N
y	lateral coordinate	m
z	vertical coordinate	m
XG	longitudinal centre of gravity	m
β	drift angle	°
δ	rudder angle	°
θ	pitch angle	°
ψ	heading	°
φ	heel angle	°

1 Introduction

1.1 SIMMAN workshop

1.1.1 Purpose [1]

“The purpose of the workshop is to benchmark the capabilities of different ship manoeuvring simulation methods including systems and CFD based methods through comparisons with results for tanker, container ship and surface combatant hull form test cases. Systems based methods will be compared with free-model test data using provided PMM and CMT (circular motion mechanism/rotating-arm) data, whereas CFD based methods will be compared with both PMM/CMT and free-model test data. The comparisons for the free-model tests will be *blind* in the sense that the free-model test data will not be provided prior to the workshop.”

1.1.2 SIMMAN 2013

The next workshop is scheduled for 2013 and will particularly deal with the shallow water manoeuvring behaviour of the tanker and container ship. For that reason the SIMMAN organizers contacted Flanders Hydraulics Research to cooperate on the execution of:

- Captive model tests with the KCS (Appendix 1);
- Free running tests with the KCS (Appendix 2);
- Captive model tests with the KVLCC2 (Appendix 3);
- Free running tests with the KVLCC2 (Appendix 4);
- Captive model tests with the KVLCC2 – bare hull (Appendix 5).

The requirements of each test program have been elaborated in the appendices.

1.2 This report

This report describes the test-setup, the execution of the model tests and the description of the output results and acts as a manual to assess these test results.

1.3 This version

Version 2.1 corrects the measured loading condition of the KVLCC2 based on the reloading of the ship model for tests carried out for the NATO Sea Team [3]. At the same time the SIMMAN year was adapted (not in the appendices, which remain in their original form) and a correction for the mean sinkage computation has been applied.

2 Test set-up

2.1 Experimental facility

2.1.1 General

The tests have been carried out in the towing tank for manoeuvres in shallow water, located at Flanders Hydraulics Research (FHR) and administrated in cooperation with the Maritime Technology Division of Ghent University. The particulars and possibilities of this towing tank have been extensively described in [2]. A short summary will be given below.

2.1.2 Main dimensions

The main dimensions of the towing tank have been listed in Table 1.

Table 1 – Main dimensions towing tank at FHR

Total length	87.5 m
Effective length	68.0 m
Width	7.0 m
Maximum water depth	0.5 m
Length of ship models	3.5 to 4.5 m

2.1.3 Positioning

In captive mode the ship model can be positioned in the three horizontal degrees of freedom. Roll can be restricted or free. Heave and pitch are always free, see Table 2 for more information.

Table 2 – Towing tank: positioning possibilities

		Main carriage	**Lateral carriage**	**Yawing table**
Position	Min	0.00 m	-2.55 m	-130.0 °
	Max	68.00 m	2.55 m	220.0 °
Velocity	Min	0.05 m/s	0.00 m/s	0.0 °/s
	Max	2.00 m/s	1.30 m/s	16.0 °/s
Acceleration	Max	0.40 m/s²	0.70 m/s²	8.0 °/s²
Power Output		4 x 7.2 kW	4.3 kW	1.0 kW

2.1.4 Data acquisition

Data from 48 channels can be logged with a maximal sampling frequency of 40 Hz. The available memory is limited, meaning that the sampling frequency depends on the test duration.

2.2 Ship models

2.2.1 Korea Container Ship (KCS)

FHR does not have a scale model of this ship, so that the ship model built by SVA was borrowed. The main particulars of this ship can be found on the SIMMAN website or in Appendix 1. The hydrostatic dependent particulars are given in Table 3.

Table 3 – Hydrostatic particulars of KCS

Parameter	Unit	C0101	C0102
Draft Fore (TF)	m	10.790 ± 0.005	10.800 ± 0.005
Draft Aft (TA)	m	10.800 ± 0.005	10.800 ± 0.005
Draft Amidships (TM)	m	10.800 ± 0.005	10.800 ± 0.005
Longitudinal centre of gravity (XG)	m	-3.2 ± 0.1	-3.4 ± 0.1
Vertical centre of gravity (KG)	m	11.4 ± 0.1	14.38 ± 0.16
Displacement	m³	52095 ± 30	52022 ± 30
Block coefficient	-	0.651	0.651
I_{XX}	kgm²	13.9 ± 1	24.1 ± 2
I_{YY}	kgm²	429.6 ± 1	408.7 ± 2
I_{ZZ}	kgm²	445.8 ± 1	461.9 ± 1

The setup of the vessel is given by the codes C0101 and C0102, which are explained in paragraph 2.3. Uncertainties are supposed to be normally distributed. It is assumed that each value has a probability of 68% to be within the given interval.

The KCS was fitted with turbulence strips as described by the ITTC quality manual (procedure 7.5-01 -01-01 §3.2.1)[a].

The KCS was already equipped with sand grain strips at the positions stated by the ITTC quality manual.

2.2.2 Korea Very Large Crude Carrier (KVLCC2)

FHR owns a 1/75 scale model of this ship, which was built according to the lines provided by SIMMAN (2[nd] variant). Its main particulars, including propeller data, can consequently be found on the SIMMAN

[a] The model should be fitted with a recognised turbulence stimulator which should be clearly described in the model documentation and the report on the experiments. Suitable hull turbulence stimulators include studs, wires and sand grain strips. [...] Sand strips used for turbulence stimulation will typically comprise backing strips/adhesive of 5 mm to 10 mm width covered with sharp edged sand with grain size around 0.50 mm, with its leading edge situated about 5% LPP aft of the FP. A bulbous bow will additionally have turbulence stimulators situated typically at ⅓ of the bulb length from its fore end.

website or in Appendix 3. The hydrostatic dependent particulars are given in Table 4.

Table 4 – Hydrostatic particulars of KVLCC2

Parameter	Unit	T0Z02/T0Z03/T0Z05	T0Z04
Draft Fore (TF)	m	20.80 ± 0.04	20.80 ± 0.04
Draft Aft (TA)	m	20.79 ± 0.04	20.80 ± 0.04
Draft Amidships (TM)	m	20.80 ± 0.04	20.80 ± 0.04
Longitudinal centre of gravity (XG)	m	10.87 ± 0.06	11.18 ± 0.15
Vertical centre of gravity (KG)	m	20.80 ± 0.06	21.70 ± 0.23
Displacement	m³	312440 ± 100	311600 ± 100
Block coefficient	-	0.81	0.81
I_{XX}	kgm²	41.0 ± 0.7	49.4 ± 1
I_{YY}	kgm²	797.0 ± 2	839.6 ± 1
I_{ZZ}	kgm²	831.0 ± 1	877.5 ± 1

As for the KCS the KVLCC2 was fitted with turbulence stimulation by fitting sand grain strips on the positions given by the ITTC.

2.3 Test naming convention

Each test result is delivered in an ASCII file having the extension .DOC, however it is not a MS office document. Each test is given a structured and unique 15 character name, e.g. C0101A01_C2A000.DOC, separated by an underscore. The digits before the underscore refer to the environmental conditions: ship model, loading condition, water depth, elements built in the towing tank:

- Tests starting with C01 were executed with the KCS model, tests starting with T0Z were executed with the KVLCC2;
- The following 2 digits refer to the loading condition:
    - C0101: PMM loading for ship C01
    - C0102: free running loading for ship C01
    - T0Z02: PMM loading for the fully equipped ship T0Z (T0Z05 at largest water depth, due to new calibration).
    - T0Z03: PMM loading for the bare hull T0Z
    - T0Z04: free running loading for ship T0Z
- The last group of three digits before the underscore refers to the water depth and the elements built in:
    - A: no elements built in
    - 01: digits in ascending order with decreasing under keel clearance, per ship

The digits after the underscore provide information on the test type and test parameters:

- The first letter after the underscore denominates the test type:
    - C: captive stationary test (constant longitudinal velocity)
    - D: free running turning test
    - F: captive harmonic sway test
    - G: captive harmonic yaw test
    - J: captive constant yaw or sway test (constant sway or yaw velocity)
    - M: captive harmonic test (other than sway or yaw)
    - Z: free running zigzag test
- The following digit ascends (0..9, A..Z) with increasing (initial) speed;
- The following digit ascends (0..9, A..Z) with increasing drift angle;
- The following digit ascends (0..9, A..Z) with increasing rudder angle;
- The last two digits increase (00..99) each time a test run is repeated.

2.4 Water depths

The ship models were tested at the water depths listed in Table 5. Some test runs could not be carried out due to the limitations of the free running set-up.

Table 5 – Environmental conditions of tests

Test code	Under keel clearance (% of draft)	Water depth (mm model scale)	Period of execution	Average water temperature (° C)
C0101A01	100	410.0	4/10/2010 – 8/10/2010	18.5
C0101A02	50	307.5	24/09/2010 – 28/09/2010	19.0
C0101A03	20	246.0	29/09/2010 – 4/10/2010	18.0
C0102A01	100	410.0	Not executed[b]	
C0102A02	50	307.5		
C0102A03	20	246.0	28/10/2010	15.5
T0Z05A01	80	499.2	24/11/2010 – 28/11/2010	14.0
T0Z02A02	50	416.0	16/11/2010 – 21/11/2010	14.0
T0Z02A03	20	332.8	9/11/2010 – 14/11/2010	15.0

[b] For free running tests the maximal water level equals 0.50 m – the ship's freeboard – 0.01 m. The minimal water level is 0.285 m – the ship's freeboard.

Test code	Under keel clearance (% of draft)	Water depth (mm model scale)	Period of execution	Average water temperature (° C)
T0Z03A02	50	416.0	3/12/2010	13.0
T0Z03A03	20	332.8	6/12/2010	13.0
T0Z04A01	80	499.2	Not executed	
T0Z04A02	50	416.0		
T0Z04A03	20	332.8	18/10/2010	17.0

2.5 Test parameters

2.5.1 Coordinate system

The coordinate system used during the tests is shown on Figure 1 and is compliant with the requirements as stated in the appendices 1 to 5.

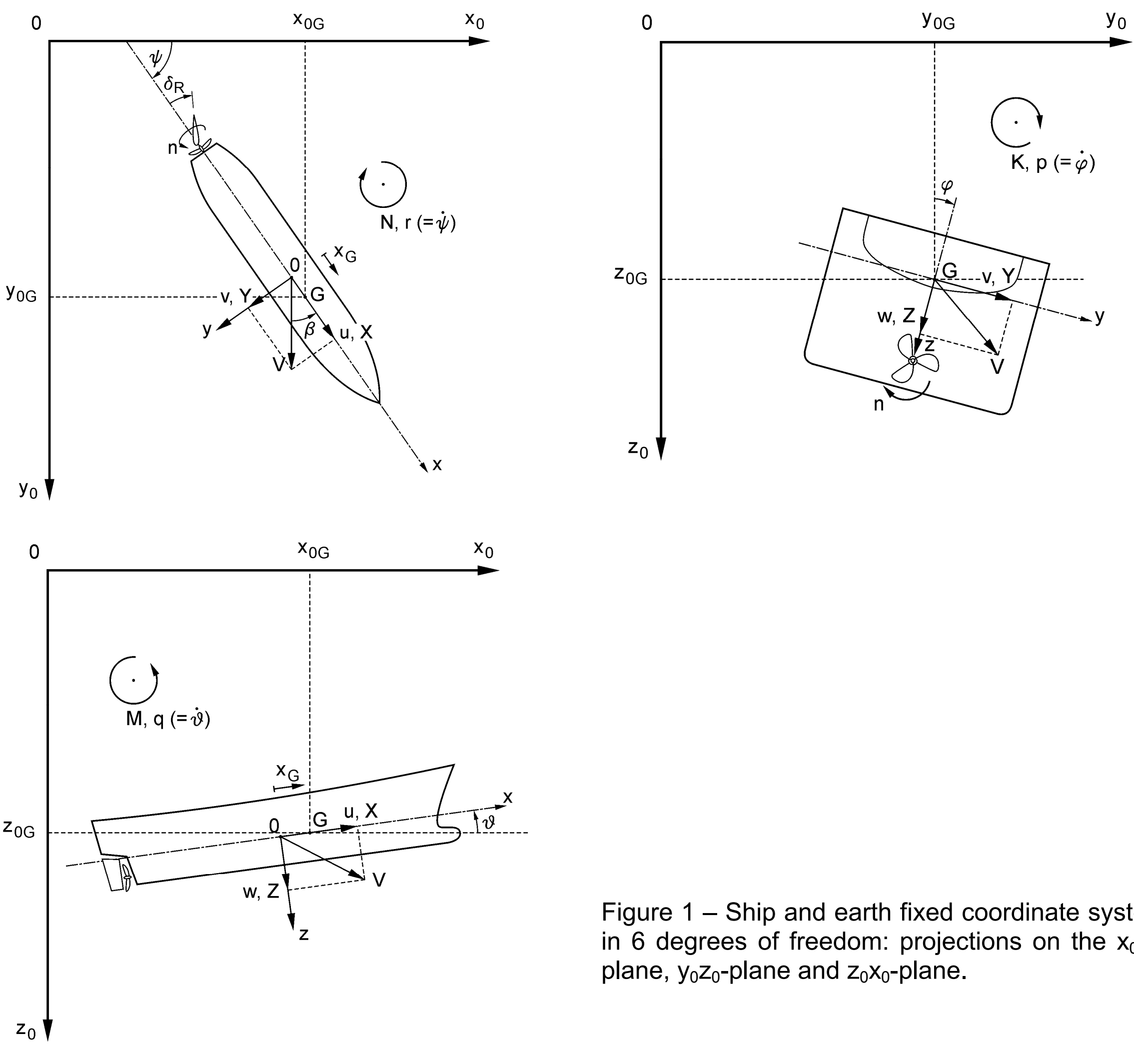


Figure 1 – Ship and earth fixed coordinate system in 6 degrees of freedom: projections on the x_0y_0-plane, y_0z_0-plane and z_0x_0-plane.

2.5.2 Captive stationary tests

Table 6 to Table 8 list the different important parameters of the stationary tests for the three different hull configurations (KCS, KVLCC2 and KVLCC2-bare). The runs with a grey background are repeated ten times throughout the test program. All runs are carried out for the water depths ‘x’ mentioned in 2.4.

The parameters were determined as follows, based upon the requirements:

- Speed was given as a fraction of the design speed, see the Appendixes 1 to 5:
  - 0.62 m/s at 330 rpm (BSHC, see Appendix 1) for KCS;
  - 0.416 m/s at 400 rpm (FHR) for KVLCC2;
  - 0.416 m/s and 0.921 m/s for KVLCC2 – bare hull.
- The same fraction was used to estimate the corresponding propeller rate. The propeller rate is always expressed as a fraction of the maximal propeller rate:
  - 726 rpm for KCS;
  - 866 rpm for KVLCC2.
- The drift angle corresponds to the deviation of the yaw table when navigating ahead;
- Tests with ψ = 90° correspond to pure cross flow tests (pure sway tests).

Table 6 – Parameters of stationary tests with ship C0101

Name	V (m/s)	ψ (°)	Propeller (% of max. rate)	Rudder angle (°)	Sampling frequency (Hz)
C0101A0x_c1z0	0.186	90	11.4	0	20
C0101A0x_c200	0.248	0	15.2	0	40
C0101A0x_c201	0.248	0	15.2	10	40
C0101A0x_c202	0.248	0	15.2	-10	40
C0101A0x_c203	0.248	0	15.2	20	40
C0101A0x_c204	0.248	0	15.2	-20	40
C0101A0x_c205	0.248	0	15.2	30	40
C0101A0x_c206	0.248	0	15.2	-30	40
C0101A0x_c207	0.248	0	15.2	35	40
C0101A0x_c208	0.248	0	15.2	-35	40
C0101A0x_c290	0.248	8	15.2	0	40
C0101A0x_c2a0	0.248	-8	15.2	0	40
C0101A0x_c2b0	0.248	12	15.2	0	40
C0101A0x_c2b1	0.248	12	15.2	10	40
C0101A0x_c2b2	0.248	12	15.2	-10	40
C0101A0x_c2b3	0.248	12	15.2	20	40
C0101A0x_c2b4	0.248	12	15.2	-20	40
C0101A0x_c2b5	0.248	12	15.2	30	40
C0101A0x_c2b6	0.248	12	15.2	-30	40
C0101A0x_c2b7	0.248	12	15.2	35	40
C0101A0x_c2b8	0.248	12	15.2	-35	40
C0101A0x_c2c0	0.248	-12	15.2	0	40
C0101A0x_c2c1	0.248	-12	15.2	10	40
C0101A0x_c2c2	0.248	-12	15.2	-10	40
C0101A0x_c2c3	0.248	-12	15.2	20	40
C0101A0x_c2c4	0.248	-12	15.2	-20	40
C0101A0x_c2c5	0.248	-12	15.2	30	40

Name	V (m/s)	ψ (°)	Propeller (% of max. rate)	Rudder angle (°)	Sampling frequency (Hz)
C0101A0x_c2c6	0.248	-12	15.2	-30	40
C0101A0x_c2c7	0.248	-12	15.2	35	40
C0101A0x_c2c8	0.248	-12	15.2	-35	40
C0101A0x_c2d0	0.248	16	15.2	0	40
C0101A0x_c2e0	0.248	-16	15.2	0	40
C0101A0x_c400	0.496	0	30.5	0	40
C0101A0x_c401	0.496	0	30.5	10	40
C0101A0x_c402	0.496	0	30.5	-10	40
C0101A0x_c403	0.496	0	30.5	20	40
C0101A0x_c404	0.496	0	30.5	-20	40
C0101A0x_c405	0.496	0	30.5	30	40
C0101A0x_c406	0.496	0	30.5	-30	40
C0101A0x_c407	0.496	0	30.5	35	40
C0101A0x_c408	0.496	0	30.5	-35	40
C0101A0x_c470	0.496	4	30.5	0	40
C0101A0x_c471	0.496	4	30.5	10	40
C0101A0x_c472	0.496	4	30.5	-10	40
C0101A0x_c473	0.496	4	30.5	20	40
C0101A0x_c474	0.496	4	30.5	-20	40
C0101A0x_c475	0.496	4	30.5	30	40
C0101A0x_c476	0.496	4	30.5	-30	40
C0101A0x_c477	0.496	4	30.5	35	40
C0101A0x_c478	0.496	4	30.5	-35	40
C0101A0x_c480	0.496	-4	30.5	0	40
C0101A0x_c481	0.496	-4	30.5	10	40
C0101A0x_c482	0.496	-4	30.5	-10	40
C0101A0x_c483	0.496	-4	30.5	20	40
C0101A0x_c484	0.496	-4	30.5	-20	40
C0101A0x_c485	0.496	-4	30.5	30	40
C0101A0x_c486	0.496	-4	30.5	-30	40
C0101A0x_c487	0.496	-4	30.5	35	40
C0101A0x_c488	0.496	-4	30.5	-35	40
C0101A0x_c490	0.496	8	30.5	0	40
C0101A0x_c4a0	0.496	-8	30.5	0	40
C0101A0x_c600	0.62	0	45.5	0	40
C0101A0x_c601	0.62	0	45.5	10	40
C0101A0x_c602	0.62	0	45.5	-10	40
C0101A0x_c603	0.62	0	45.5	20	40
C0101A0x_c604	0.62	0	45.5	-20	40
C0101A0x_c605	0.62	0	45.5	30	40
C0101A0x_c606	0.62	0	45.5	-30	40
C0101A0x_c607	0.62	0	45.5	35	40
C0101A0x_c608	0.62	0	45.5	-35	40
C0101A0x_c610	0.62	0.5	45.5	0	40
C0101A0x_c620	0.62	-0.5	45.5	0	40
C0101A0x_c630	0.62	1	45.5	0	40

Name	V (m/s)	ψ (°)	Propeller (% of max. rate)	Rudder angle (°)	Sampling frequency (Hz)
C0101A0x_c640	0.62	-1	45.5	0	40
C0101A0x_c650	0.62	2	45.5	0	40
C0101A0x_c660	0.62	-2	45.5	0	40
C0101A0x_c670	0.62	4	45.5	0	40
C0101A0x_c680	0.62	-4	45.5	0	40

Table 7 – Parameters of stationary tests with ship T0Z02/T0Z05

Name	V (m/s)	ψ (°)	Propeller (% of max. rate)	Rudder angle (°)	Sampling frequency (Hz)
T0Z02A0x_c1z0	0.125	90	16.8	0	20
T0Z02A0x_c200	0.208	0	25.2	0	40
T0Z02A0x_c201	0.208	0	25.2	10	40
T0Z02A0x_c202	0.208	0	25.2	-10	40
T0Z02A0x_c203	0.208	0	25.2	20	40
T0Z02A0x_c204	0.208	0	25.2	-20	40
T0Z02A0x_c205	0.208	0	25.2	30	40
T0Z02A0x_c206	0.208	0	25.2	-30	40
T0Z02A0x_c207	0.208	0	25.2	35	40
T0Z02A0x_c208	0.208	0	25.2	-35	40
T0Z02A0x_c290	0.208	8	25.2	0	40
T0Z02A0x_c291	0.208	8	25.2	10	40
T0Z02A0x_c292	0.208	8	25.2	-10	40
T0Z02A0x_c293	0.208	8	25.2	20	40
T0Z02A0x_c294	0.208	8	25.2	-20	40
T0Z02A0x_c295	0.208	8	25.2	30	40
T0Z02A0x_c296	0.208	8	25.2	-30	40
T0Z02A0x_c297	0.208	8	25.2	35	40
T0Z02A0x_c298	0.208	8	25.2	-35	40
T0Z02A0x_c2a0	0.208	-8	25.2	0	40
T0Z02A0x_c2a1	0.208	-8	25.2	10	40
T0Z02A0x_c2a2	0.208	-8	25.2	-10	40
T0Z02A0x_c2a3	0.208	-8	25.2	20	40
T0Z02A0x_c2a4	0.208	-8	25.2	-20	40
T0Z02A0x_c2a5	0.208	-8	25.2	30	40
T0Z02A0x_c2a6	0.208	-8	25.2	-30	40
T0Z02A0x_c2a7	0.208	-8	25.2	35	40
T0Z02A0x_c2a8	0.208	-8	25.2	-35	40
T0Z02A0x_c2b0	0.208	12	25.2	0	40
T0Z02A0x_c2c0	0.208	-12	25.2	0	40
T0Z02A0x_c300	0.3328	0	37.8	0	40
T0Z02A0x_c301	0.3328	0	37.8	10	40
T0Z02A0x_c302	0.3328	0	37.8	-10	40
T0Z02A0x_c303	0.3328	0	37.8	20	40
T0Z02A0x_c304	0.3328	0	37.8	-20	40

Name	V (m/s)	ψ (°)	Propeller (% of max. rate)	Rudder angle (°)	Sampling frequency (Hz)
T0Z02A0x_c305	0.3328	0	37.8	30	40
T0Z02A0x_c306	0.3328	0	37.8	-30	40
T0Z02A0x_c307	0.3328	0	37.8	35	40
T0Z02A0x_c308	0.3328	0	37.8	-35	40
T0Z02A0x_c370	0.3328	4	37.8	0	40
T0Z02A0x_c371	0.3328	4	37.8	10	40
T0Z02A0x_c372	0.3328	4	37.8	-10	40
T0Z02A0x_c373	0.3328	4	37.8	20	40
T0Z02A0x_c374	0.3328	4	37.8	-20	40
T0Z02A0x_c375	0.3328	4	37.8	30	40
T0Z02A0x_c376	0.3328	4	37.8	-30	40
T0Z02A0x_c377	0.3328	4	37.8	35	40
T0Z02A0x_c378	0.3328	4	37.8	-35	40
T0Z02A0x_c380	0.3328	-4	37.8	0	40
T0Z02A0x_c381	0.3328	-4	37.8	10	40
T0Z02A0x_c382	0.3328	-4	37.8	-10	40
T0Z02A0x_c383	0.3328	-4	37.8	20	40
T0Z02A0x_c384	0.3328	-4	37.8	-20	40
T0Z02A0x_c385	0.3328	-4	37.8	30	40
T0Z02A0x_c386	0.3328	-4	37.8	-30	40
T0Z02A0x_c387	0.3328	-4	37.8	35	40
T0Z02A0x_c388	0.3328	-4	37.8	-35	40
T0Z02A0x_c390	0.3328	8	37.8	0	40
T0Z02A0x_c3a0	0.3328	-8	37.8	0	40
T0Z02A0x_c400	0.416	0	46.2	0	40
T0Z02A0x_c401	0.416	0	46.2	10	40
T0Z02A0x_c402	0.416	0	46.2	-10	40
T0Z02A0x_c403	0.416	0	46.2	20	40
T0Z02A0x_c404	0.416	0	46.2	-20	40
T0Z02A0x_c405	0.416	0	46.2	30	40
T0Z02A0x_c406	0.416	0	46.2	-30	40
T0Z02A0x_c407	0.416	0	46.2	35	40
T0Z02A0x_c408	0.416	0	46.2	-35	40
T0Z02A0x_c410	0.416	0.5	46.2	0	40
T0Z02A0x_c420	0.416	-0.5	46.2	0	40
T0Z02A0x_c430	0.416	1	46.2	0	40
T0Z02A0x_c440	0.416	-1	46.2	0	40
T0Z02A0x_c450	0.416	2	46.2	0	40
T0Z02A0x_c460	0.416	-2	46.2	0	40
T0Z02A0x_c470	0.416	4	46.2	0	40
T0Z02A0x_c480	0.416	-4	46.2	0	40

Table 8 – Parameters of stationary tests with ship T0Z03

Name	V (m/s)	ψ (°)	Propeller (% of max. rate)	Rudder angle (°)	Sampling frequency (Hz)
T0Z03A0x_c400	0.416	0	n/a	n/a	40
T0Z03A0x_c470	0.416	4	n/a	n/a	40
T0Z03A0x_c480	0.416	-4	n/a	n/a	40
T0Z03A0x_c900	0.921	0	n/a	n/a	40
T0Z03A0x_c970[c]	0.921	4	n/a	n/a	40
T0Z03A0x_c980[c]	0.921	-4	n/a	n/a	40

2.5.3 Captive harmonic sway tests

During harmonic sway tests the lateral carriage executes moves according to:

$$y = y_a \cos\left(\frac{2\pi}{T_y} t\right) \tag{2.1}$$

The corresponding sway velocity is then

$$v = -\frac{2\pi\, y_a}{T_y} \sin\left(\frac{2\pi}{T_y} t\right) \tag{2.2}$$

A given dimensionless maximal sway velocity depends consequently on both the sway amplitude and the sway period. At FHR harmonic sway tests are typically carried out with a sway period of 200 mm, so that the period has been adapted to match the requirements:

$$v' = \frac{v_{MAX}}{V} = \frac{2\pi\, y_a}{VT_y} \Rightarrow T_y = \frac{0.4\pi}{v' V} \tag{2.3}$$

The number of periods during the stationary condition has to be a multiple of 0.5 and has been chosen to have a maximal longitudinal test distance. Table 9 and

Table 10 give an overview of the parameters during the harmonic sway tests.

Table 9 – Parameters of harmonic sway tests with ship C0101

Name	V (m/s)	y_a (m)	T_y (s)	Number of periods	Propeller (% of max. rate)	Sampling frequency (Hz)
C0101A0x_f600	0.62	0.2	50.7	1.5	45.5	40
C0101A0x _f610	0.62	0.2	25.3	3.0	45.5	40

Table 10 – Parameters of harmonic sway tests with ship T0Z02

Name	V (m/s)	y_a (m)	T_y (s)	Number of periods	Propeller (% of max. rate)	Sampling frequency (Hz)
T0Z02A0x_f600	0.416	0.2	75.5	1.5	46.2	40
T0Z02A0x _f610	0.416	0.2	37.8	3.0	46.2	40

[c] Failed at 20% under keel clearance due to excessive forces

2.5.4 Captive harmonic yaw tests

During a harmonic yaw test the yawing table moves as follows:

$$\psi = \psi_m - \psi_a \cos\left(\frac{2\pi}{T_\psi} t\right) \tag{2.4}$$

The corresponding yaw velocity is

$$r = \frac{2\pi\psi_a}{T_\psi} \sin\left(\frac{2\pi}{T_\psi} t\right) \tag{2.5}$$

Giving a maximal velocity

$$r_{max} = \frac{2\pi\psi_a}{T_\psi} = \frac{r'V}{L_{PP}} \tag{2.6}$$

Common values were chosen for the yaw amplitude ψ_a so that the period could be deduced from the above equation. The number of periods needs to be a multiple of 0.5 and has been chosen as large as possible. The runs with a grey background in Table 11 to

Table 13 are repeated ten times throughout the test program.

Table 11 – Parameters of harmonic yaw tests with ship C0101

Name	V (m/s)	ψ_m (°)	ψ_a (°)	T_ψ (s)	Number of periods	Propeller (% of max. rate)	Rudder angle (°)	Sampling frequency (Hz)
C0101A0x_g200	0.248	0	15	41.4	4+1[d]	15.2	0	40
C0101A0x_g205	0.248	0	15	41.4	4+1	15.2	30	40
C0101A0x_g206	0.248	0	15	41.4	4+1	15.2	-30	40
C0101A0x_g2b0	0.248	12	15	41.4	4+1	15.2	0	40
C0101A0x_g2c0	0.248	-12	15	41.4	4+1	15.2	0	40
C0101A0x_g400	0.496	0	15	41.4	2	30.5	0	40
C0101A0x_g403	0.496	0	15	41.4	2	30.5	20	40
C0101A0x_g404	0.496	0	15	41.4	2	30.5	-20	40
C0101A0x_g470	0.496	4	15	41.4	2	30.5	0	40
C0101A0x_g480	0.496	-4	15	41.4	2	30.5	0	40
C0101A0x_g600	0.62	0	2.5	38.6	1.5	45.5	0	40
C0101A0x_g601	0.62	0	5	38.6	1.5	45.5	0	40
C0101A0x_g602	0.62	0	7.5	38.6	1.5	45.5	0	40
C0101A0x_g603	0.62	0	10	38.6	1.5	45.5	0	40

Table 12 – Parameters of harmonic yaw tests with ship T0Z02/T0Z05

Name	V (m/s)	ψ_m (°)	ψ_a (°)	T_ψ (s)	Number of periods	Propeller (% of max. rate)	Rudder angle (°)	Sampling frequency (Hz)
T0Z02A0x_g200	0.208	0	10	37.5	5+2	25.2	0	40
T0Z02A0x_g205	0.208	0	10	37.5	5+2	25.2	30	40
T0Z02A0x_g206	0.208	0	10	37.5	5+2	25.2	-30	40

[d] x+y: x periods with ψ_a = *value* followed by y periods with ψ_a = 0°

Name	V (m/s)	ψ_m (°)	ψ_a (°)	T_ψ (s)	Number of periods	Propeller (% of max. rate)	Rudder angle (°)	Sampling frequency (Hz)
T0Z02A0x_g290	0.208	8	10	37.5	5+2	25.2	0	40
T0Z02A0x_g2a0	0.208	-8	10	37.5	5+2	25.2	0	40
T0Z02A0x_g300	0.333	0	10	46.8	3	37.8	0	40
T0Z02A0x_g303	0.333	0	10	46.8	3	37.8	20	40
T0Z02A0x_g304	0.333	0	10	46.8	3	37.8	-20	40
T0Z02A0x_g370	0.333	4	10	46.8	3	37.8	0	40
T0Z02A0x_g380	0.333	-4	10	46.8	3	37.8	0	40
T0Z02A0x_g400	0.416	0	2.5	56.2	1.5	46.2	0	40
T0Z02A0x_g401	0.416	0	5	56.2	1.5	46.2	0	40
T0Z02A0x_g402	0.416	0	5	37.5	3	46.2	0	40
T0Z02A0x_g403	0.416	0	10	56.2	1.5	46.2	0	40

Table 13 – Parameters of harmonic yaw tests with ship T0Z03

Name	V (m/s)	ψ_m (°)	ψ_a (°)	T_ψ (s)	Number of periods	Propeller (% of max. rate)	Rudder angle (°)	Sampling frequency (Hz)
T0Z03A0x_g400	0.416	0	10	28.1	4	n/a	n/a	40
T0Z03A0x_g900[e]	0.921	0	25	31.8	1.5	n/a	n/a	40

2.5.5 Captive constant yaw tests

The captive constant yaw tests are carried out to simulate the effect of pure rotation. The parameters of these tests are given in Table 14 and Table 15.

Table 14 – Parameters of constant yaw tests with ship C0101

Name	V (m/s)	r (°/s)	Propeller (% of max. rate)	Sampling frequency (Hz)
C0101A0x_j000	0	2	0	40

Table 15 – Parameters of constant yaw tests with ship T0Z02/T0Z05

Name	V (m/s)	r (°/s)	Propeller (% of max. rate)	Sampling frequency (Hz)
T0Z02A0x_j000	0	2	0	40

2.5.6 Captive multi-modal tests

Multi-modal tests are used to decrease the number of tests with a ship model. During such a test one or more parameters can be harmonically varied. In the multi-modal tests carried out for the SIMMAN workshop the rudder angle has been varied:

$$\delta = \delta_a \sin\left(\frac{2\pi}{T_\delta} t\right) \tag{2.7}$$

The multi-modal tests presented in Table 16 and Table 17 cover a range of stationary tests with each time a different rudder angle and the ideally identical output of both test types can be compared.

[e] Failed at 20% under keel clearance due to excessive forces

Table 16 – Parameters of multi-modal tests with ship C0101

Name	V (m/s)	ψ (°)	Propeller (% of max. rate)	δ_a (°)	T_δ (s)	Sampling frequency (Hz)
C0101A0x_m200	0.248	0	15.2	35	200	40
C0101A0x_m2b0	0.248	12	15.2	35	200	40
C0101A0x_m2c0	0.248	-12	15.2	35	200	40
C0101A0x_m400	0.496	0	30.5	35	100	40
C0101A0x_m470	0.496	4	30.5	35	100	40
C0101A0x_m480	0.496	-4	30.5	35	100	40
C0101A0x_m600	0.62	0	45.5	35	69	40

Table 17 – Parameters of multi-modal tests with ship T0Z02/T0Z05

Name	V (m/s)	ψ (°)	Propeller (% of max. rate)	δ_a (°)	T_δ (s)	Sampling frequency (Hz)
T0Z02A0x_m200	0.208	0	25.2	35	200	40
T0Z02A0x_m2b0	0.208	8	25.2	35	200	40
T0Z02A0x_m2c0	0.208	-8	25.2	35	200	40
T0Z02A0x_m300	0.333	0	37.8	35	150	40
T0Z02A0x_m370	0.333	4	37.8	35	150	40
T0Z02A0x_m380	0.333	-4	37.8	35	150	40
T0Z02A0x_m400	0.416	0	46.2	35	100	40

2.5.7 Free running turning circles

Due to the limited dimensions of the towing tank only the first part of the free running turning circles shown in Table 18 and

Table 19 can be carried out. The tests with a grey background are repeated ten times.

Table 18 – Parameters of turning circles with ship C0102

Name	V (m/s)	Propeller (% of max. rate)	Rudder angle (°)	Sampling frequency (Hz)
C0102A0x_d607	0.62	45.5	35	40
C0102A0x_d608	0.62	45.5	-35	40

Table 19 – Parameters of turning circles with ship T0Z04

Name	V (m/s)	Propeller (% of max. rate)	Rudder angle (°)	Sampling frequency (Hz)
T0Z04A0x_d407	0.416	46.2	35	40
T0Z04A0x_d408	0.416	46.2	-35	40

2.5.8 Free running zigzag tests

Zigzag tests are carried out with parameters mentioned in Table 20 and Table 21. Again a grey background indicates a test is repeated ten times.

Table 20 – Parameters of zigzag tests with ship C0102

Name	V (m/s)	ψ (°)	Propeller (% of max. rate)	Rudder angle (°)	Sampling frequency (Hz)
C0102A0x_z651	0.62	2.5	45.5	10	40
C0102A0x_z652	0.62	2.5	45.5	-10	40
C0102A0x_z673	0.62	5	45.5	20	40
C0102A0x_z674	0.62	5	45.5	-20	40

Table 21 – Parameters of zigzag tests with ship T0Z04

Name	V (m/s)	ψ (°)	Propeller (% of max. rate)	Rudder angle (°)	Sampling frequency (Hz)
T0Z04A0x_z451	0.416	2.5	46.2	10	40
T0Z04A0x_z452	0.416	2.5	46.2	-10	40
T0Z04A0x_z473	0.416	5	46.2	20	40
T0Z04A0x_z474	0.416	5	46.2	-20	40

3 Processing the results

3.1 Captive tests

3.1.1 General

The results of the captive tests are written in an ASCII file which contains:

- The environmental parameters: time, ship model, built in structures, etc.
- Time series of ship positions and measured data (channels): forces acting on ship model, sinkage, etc.

The maximal frequency of the time series is 40Hz.

3.1.2 Stationary tests

For stationary tests the average of the measurements is calculated per channel. This is done for the stationary condition between 30% and 95% of the time of this stationary condition.

3.1.3 Harmonic sway or yaw tests

The results of the harmonic sway and yaw tests are obtained through Fourier analysis of the time series. The first ¼ period after acceleration and the last ¼ period before deceleration are excluded from the Fourier analysis. For each test 24 data points are shown per channel.

3.1.4 Multi modal tests

As for the captive harmonic sway or yaw tests 24 data points are shown per channel and per (smallest) period. In this case Fourier analysis has not been applied but averaging per maximal 7 measurement points (or 7 x 0.025 = 0.175 seconds).

3.1.5 Constant yaw tests

The results of the constant yaw tests are presented as an average (at 4 Hz) of the time series during the stationary condition.

3.2 Free running tests

The free running test results are presented as time series with an average calculated per s. The results are only shown during free running mode. For the zigzag tests the results are accompanied by significant parameters of the zigzag trajectory:

- Period
- Time till 1st heading deviation (HD)
- Travelled distance till 1st HD
- Time between 1st HD and max heading (MH)
- Travelled distance between 1st HD and MH
- Time between 2nd HD and max heading (MH)
- Travelled distance between 2nd HD and MH
- Max. heading 1
- Max. heading 2

4 Presentation of the results

4.1 General

The processed results are delivered in MS Office 2003 Excel format and can be found in Appendixes 6 to 10. Each excel file contains a page called “Environment” and a results page per tested under keel clearance (by name).

4.2 Environment page

The environment page lists the characteristics of the used ship model, the under keel clearances and the results of the calibrations. Upon all data 68% confidence intervals have been determined, assuming a normal distribution of the uncertainties. Also the technical resolution and maximal values of the force gauges (for captive tests) and squat is given.

4.3 Results pages

4.3.1 Captive tests

The results are presented in the following order (rows in excel):

- Grouped by test type (stationary STATX0, harmonic sway PMMY2, harmonic yaw PMMPSI2, multi-modal MULTI0, constant yaw);
- Per test type alphabetically;
- For repeated tests, to assess the repeatability, chronologically and followed by statistical parameters.

For each test or each data point within a test the following data is presented (columns in excel) – not for constant yaw tests:

- Name (A);
- Type (B);
- Flag (C)[f];
- Tank longitudinal coordinate (D);
- Tank lateral coordinate (E);
- Heading angle of rotation table (F);
- Ship longitudinal velocity (G);
- Ship lateral velocity (H);

- [f] The flag gives an indication on the accuracy of positions and speeds. A zero value is the most accurate. The flag’s value increases with 1 when:
    - The difference between desired lateral position and measured lateral position is more than 0.0001 m
    - The difference between desired heading and measured heading is more than 0.01°
    - The difference between desired longitudinal speed and measured longitudinal speed is more than 0.0001 m/s
    - The difference between desired lateral speed and measured lateral speed is more than 0.0001 m/s
    - The difference between desired yaw speed and measured yaw speed is more than 0.01 °/s

- Ship yaw velocity (I);
- Ship longitudinal acceleration (J);
- Ship lateral acceleration (K);
- Ship yaw acceleration (L);
- Total longitudinal force acting on the ship (M);
- Total lateral force acting on the ship (N);
- Total yaw moment acting on the ship (O);
- Mean sinkage (P);
- Trim (Q);
- For ships equipped with rudder and propeller:
    - Given propeller rate (R);
    - Measured propeller rate (S);
    - Thrust (T);
    - Propeller torque (U);
    - Given rudder angle (V);
    - Measured rudder angle (W);
    - Tangential rudder force (X)[9];
    - Normal rudder force (Y);
    - Rudder torque (Z);
    - Roll moment (AA);
    - Drift angle (AB);
    - Longitudinal carriage speed (AC).
- For the bare hull:
    - Roll moment (R);
    - Drift angle (S);
    - Longitudinal carriage speed (T).

The results of the constant yaw tests are presented as follows:

- Name (A);
- Time (C);
- Tank longitudinal coordinate (D);
- Tank lateral coordinate (E);
- Heading angle of rotation table (F);
- Fore component of longitudinal force (G);
- Fore component of lateral force (H);

[9] The force components acting on the rudder have not been measured correctly for the KCS.

- Aft component of longitudinal force (I);
- Aft component of lateral force (J);
- Measured propeller rate (K);
- Thrust (L);
- Propeller torque (M);
- Sinkage fore (N);
- Sinkage aft (O);
- Measured rudder angle (P);
- Roll moment (T).

For the constant yaw tests some post processing is still needed to have the actual values:

1. The offset values (printed in bold) for the force components and sinkage have to be subtracted from the measured data;
2. The total longitudinal force = $X_f + X_a$;
3. The total lateral force = $Y_f + Y_a$;
4. The total yaw moment can be calculated using the application points of Y_f and Y_a given on the environment page (YF, YA respectively);
5. The mean sinkage:

$$Sinkage\_mean = \frac{Sinkage\_fore \cdot |XHA| + Sinkage\_aft \cdot |XHV|}{|XHA| + |XHV|} \tag{4.1}$$

   The positions of the sinkage measurements, XHV and XHA, can be found on the environment page.

6. The trim can analogously be calculated using the positions of the sinkage measurements given on the environment page (XHV, XHA respectively).

4.3.2 Free running tests

Each results page contains a number of repetitions of the same test, separated by an empty row. Tests are given in a chronological order. For each test the following data are presented (columns in excel):

- Time (A);
- Travelled free running distance (B);
- Tank longitudinal coordinate (C);
- Tank lateral coordinate (D);
- Heading angle of rotation table (E);
- Roll angle of the ship (F);
- Ship longitudinal velocity (G);
- Ship lateral velocity (H);
- Ship yaw velocity (I);
- Ship roll velocity (J);
- Measured propeller rate (K);
- Thrust (L);
- Propeller torque (M);

- Sinkage fore (N);
- Sinkage aft (O);
- Measured rudder angle (P);
- Measured water temperature (Q);
- Contact value (R), 1 means no contacts between ship and environment occurred.

Some post processing is still needed to have the actual values:

1. The mean sinkage = 0.5 (Sinkage fore + Sinkage aft);
2. The trim can be calculated using the positions of the sinkage measurements given on the environment page (XHV, XHA respectively).

For zigzag tests the results are followed by the significant parameters mentioned in paragraph 3.2 (from column T on).

4.4 Assessment of repeatability

The results of the repeated tests are assessed for each column (captive tests) or significant parameter (free running tests):

- Average value;
- Standard deviation: the excel function is used. If a normal distribution is assumed this corresponds with the 68% confidence interval;
- Relative error: the quotient of the standard deviation with the average;
- Delta: the difference between the largest and the smallest value, which can be considered as the nearly 100% confidence interval.

For all captive stationary and all captive harmonic tests the results are summarized with:

- The average standard deviation measured per column over all the test results in one single environment;
- The maximal delta measured per column over all the test results in one single environment.

5 Analysis of the uncertainties

In this chapter the uncertainties are analysed based on the results of the repeated tests.

5.1 Captive tests

5.1.1 KCS

The technical possible resolutions are listed in Table 22.

Table 22 – Technical resolution of captive tests with KCS

Value	Resolution	Unit
X_f and X_a	0.02	N
Y_f	0.08	N
Y_a	0.07	N
K	0.01	Nm
Thrust	0.03	N
Torque	0.664	Nmm
Sinkage fore	0.033	mm
Sinkage aft	0.033	mm
XV	0.002	m
XA	0.004	m
XHV	0.001	m
XHA	0.001	m

Using the propagation formulae in error analysis one can calculate the minimal 68% confidence interval on the forces and sinkages:

- Longitudinal force: 0.03 N;
- Lateral force: 0.11 N;
- Yawing moment: 0.11 Nm;
- Roll moment: 0.01 Nm;
- Sinkage: 0.05 mm;
- Trim: 0.05 mm/m.

It was assumed that the error on the position of the application points can be neglected. The actual theoretical error depends on the amplitude of the measured force or sinkage. The averaged standard deviations are listed in Table 23.

Table 23 – Average standard deviations of captive tests with KCS

Value	Unit	Minimal	Actual					
			Stationary			Harmonic		
			A01	A02	A03	A01	A02	A03
Longitudinal force	N	0.03	0.25	0.14	0.48	0.28	0.15	**0.54**
Lateral force	N	0.11	0.15	0.08	0.24	0.27	0.35	**0.69**
Yawing moment	Nm	0.11	0.23	0.13	0.24	0.40	0.53	**0.88**
Roll moment	Nm	0.01	0.07	0.02	0.04	**0.11**	0.02	0.06
Sinkage	mm	0.05	0.11	0.09	0.10	**0.15**	0.12	**0.15**
Trim	mm/m	**0.05**	0.03	0.02	0.01	**0.05**	0.03	0.02

Only the values for the trim are within the proposed 68% confidence interval. The values for lateral force and yawing moment are rather large, but still this corresponds to more or less 5% of the measured value. A problem is the longitudinal force, with error rates up till 100%. This has several reasons:

- The measured values are overall small, because tests were conducted under self propulsion conditions;
- In between the conditions A01 and A03 the linear guidance for the sinkage of the vessel was regulated. This had a severe effect on the offset of the longitudinal force yielding a shift of this force. For the repeated tests the first condition after the regulation has been underlined.

The values printed in bold give an approximate and conservative confidence for the measured values. The values for the longitudinal force have to be interpreted with caution due to a shift that occurred during the tests.

However, there are other uncertainties that are related to the hull form of the vessel:

- The bottom of the ship model cannot be considered flat. This can be due to the absorption of water by the wood. The hypothesis can be supported by the fact that the inner hull has been painted before due to the presence of must.
- Due to these deformations the rudder collided with the hull form at certain rudder angles, so that the rudder forces are not trustful.

5.1.2 KVLCC2

As for the KCS Table 24 gives the average standard deviations for the KVLCC2.

Table 24 – Average standard deviations of captive tests with KVLCC2

Value	Unit	Minimal	Actual					
			Stationary			Harmonic		
			A01	A02	A03	A01	A02	A03
Longitudinal force	N	0.03	0.05	0.06	**0.10**	0.08	0.05	**0.10**
Lateral force	N	0.11	0.03	0.05	0.17	0.20	0.24	**0.47**
Yawing moment	Nm	0.11	0.07	0.08	0.14	0.30	0.31	**0.58**
Roll moment	Nm	0.01	0.03	0.03	**0.04**	0.03	0.03	**0.04**
Sinkage	mm	0.05	0.04	0.03	0.03	**0.06**	0.03	0.04
Trim	mm/m	**0.05**	0.02	0.01	0.01	0.01	0.01	0.01

The standard deviations increase with decreasing under keel clearance, which is related to the larger forces measured and are larger for harmonic tests. One should bear in mind that for the latter Fourier analysis was conducted which can increase the uncertainties. The values in bold give a conservative approach for the confidence of the measurements.

5.2 Free running tests

The output of the turning tests is given complimentary, because no significant course deviation could be obtained. Each zigzag test has been repeated a number of times. The results are given in Table 25 and Table 26. The used codes are given in

G	5.0	0.6	4.2	0.6	3.2	0.1	3.3	0.1
H	-3.8	0.6	5.3	0.5	-8.7	0.5	9.7	0.3
I	9	1	-8.2	1	12.9	0.8	-13.2	0.4

Table 27. Especially the period and the distance travelled of the zigzag manoeuvre with the KVLCC2 are subject to large deviations.

Table 25 – Results of zigzag tests with KCS

Code	10/2.5		-10/2.5		20/5		-20/5	
	Value	Confidence	Value	Confidence	Value	Confidence	Value	Confidence
A	36.7	0.8	35.6	0.3	40.0	0.2	40.0	0.2
B	6.0	0.3	6.7	0.2	6.9	0.1	7.0	0.1
C	3.7	0.2	4.1	0.1	4.2	0.1	4.3	0.1
D	4.8	0.2	5.1	0.1	5.5	0.1	6.2	0.2
E	3.0	0.1	3.2	0.1	3.3	0.1	3.7	0.1
F	6.5	0.3	5.5	0.2	6.7	0.1	6.1	0.1
G	4.0	0.2	3.4	0.1	3.7	0.1	3.4	0.1
H	-5.1	0.2	5.4	0.2	-11.0	0.2	12.0	0.3
I	7.6	0.4	-6.6	0.3	13.9	0.2	-12.7	0.2

Table 26 – Results of zigzag tests with KVLCC2

Code	10/2.5		-10/2.5		20/5		-20/5	
	Value	Confidence	Value	Confidence	Value	Confidence	Value	Confidence
A	58	3	58	4	54	2	55.8	0.9
B	11	1	8.6	0.8	9.8	0.3	8.9	0.2
C	4.7	0.4	3.6	0.3	4.0	0.1	3.7	0.1
D	5	1	9	1	6.7	0.6	7.6	0.5
E	2.1	0.5	3.7	0.5	2.7	0.2	3.0	0.2
F	13	1	11	2	8.8	0.4	9.0	0.3
G	5.0	0.6	4.2	0.6	3.2	0.1	3.3	0.1
H	-3.8	0.6	5.3	0.5	-8.7	0.5	9.7	0.3
I	9	1	-8.2	1	12.9	0.8	-13.2	0.4

Table 27 – Codes of zigzag test parameters

Code	Parameter	Unit
A	Period	s
B	Time till 1st heading deviation (HD)	s
C	Travelled distance till 1st HD	m
D	Time between 1st HD and max heading (MH)	s
E	Travelled distance between 1st HD and MH	m
F	Time between 2nd HD and max heading (MH)	s
G	Travelled distance between 2nd HD and MH	m
H	Max. heading 1	°
I	Max. heading 2	°

6 List of references

[1] http://www.simman2008.dk

[2] VAN KERKHOVE G., VANTORRE, M., DELEFORTRIE, G. Advanced Model Testing Techniques for Ship Behaviour in Shallow and Confined Water. Proceedings of AMT 2009, Nantes, France, 2009.

[3] Eloot, K.; Delefortrie, G.; Peeters, P.; Mostaert, F. (2012). Large drift angle: KVLCC2: Subreport 2 – Static model test with 30 degrees drift angle. Version 1_1. WL Rapporten, 00_094. Flanders Hydraulics Research: Antwerp, Belgium.

Appendix 1: Model Test Specification KCS: PMM

Model Test Specification

Hull	**KCS**
Test type	**Captive (PMM)**
Water depth	**Shallow**
Appendages	**Appended**

SUMMARY

Captive PMM tests shall be conducted in shallow water with a model of the KCS container ship. The data will be used as basis for simulation models for use in the SIMMAN 2012 Workshop. Free model tests in shallow water with the same model shall also be carried out and used as blind data for validation of the simulation models.

MODEL GEOMETRY

Identification: SVA model no. M1203S001

Scale: 1:52.667

Hull: Dimensions of the KCS hull in this scale are as follows:

L_{pp}	[m]	4.367
B	[m]	0.611
T	[m]	0.205
∇	[m^3]	0.356
S	[m^2]	3.436
C_B	[-]	0.651
LCB	[%Lpp]	-1.480

(LCB positive forward of midships)

Propeller: The KCS model is equipped with SVA stock propeller no. VP1193, righthanded, with following particulars:

type	CP
blades	5
d [m]	0.150
P/D at 0.7R	1.000
Ae/A0	0.700
hub ratio	0.227
rotation	right

Rudder: The KCS is equipped with one semi balanced horn rudder with corresponding head box. Rudder particulars:

S_{rudder}	[m^2]	0.0415
lat. area	[m^2]	0.0196
lat. area movable	[m^2]	0.0163
helm rate	[deg/s]	16.8

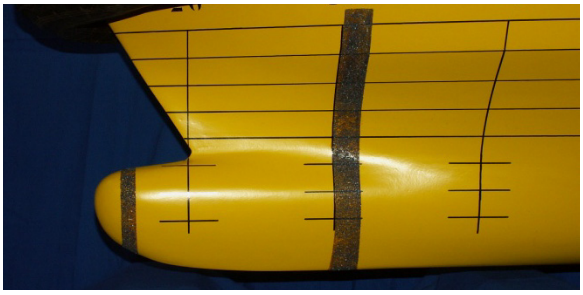
Bilge keels: None.

Turbulence stimulation: Turbulence stimulation is provided by sand on section 19 as well as on the bulb.

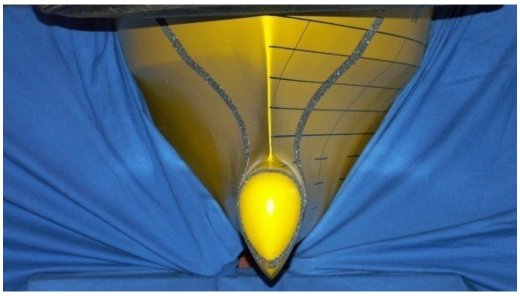
Comment: The model and conditions must be identical to those in the subsequent free model tests.

This model has been tested before at SVA (free, 2006), CEHIPAR (PMM, 2006), BSHC (free, 2007) and FORCE (PMM, 2009).

Model photos



bow side view



bow front view

rudder and propeller arrangement side view

rudder and propeller arrangement rear view

TEST CONDITIONS

Loading condition

The model shall be tested on even keel at draught of 0.205 m (10.8 m full scale). The mass and moment of inertia in yaw must be measured. Nominal values are as follows:

m	[kg]	356
i_{xx}/B	[-]	n.a.
i_{zz}/L_{pp}	[-]	0.25
GM	[m]	n.a.

NB. These are nominal values; used values to be specified.

Water depths:

The tests shall be performed at 3 water depths ranging from very shallow (UKC = 20%) up to moderate (UKC = 100%):

Depth	h/Tm	UKC (%)	h (m)	Fnh
h1	1.20	20%	0.246	0.399
h2	1.50	50%	0.308	0.357
h3	2.00	100%	0.410	0.309

(Depths have been chosen to match some cases from BSHC tests).

Nominal speeds and RPM: The nominal approach speed will be the same for all water depths:

Nom. speed ship	[kn]	8.75 (*1)
Nominal speed U_0	[m/s]	0.62
Froude no. Fn	[-]	0.095
Nominal revs. N_0	[RPM]	(*2)

(*1) Speed chosen to match free model tests at BSHC.

(*2) RPM shall be set to model self-propulsion point at each water depth (for reference BSHC used 330 RPM for this speed at h/T=1.2).

Self-propulsion point: Model (No friction deduction force applied)

RPM strategy: Constant RPM

Degrees of "freedom": 4 DOF, i.e. measure longitudinal force X, transverse force Y, yaw moment N and roll moment K.

Set-up: Free to trim and sink, otherwise constrained.

TEST PROGRAM

The basic scope of tests <u>for each water depth</u> is given in the following table:

	Speed U/U_0 (non-dim.)	Prop. Revs. (non-dim.)	Rudder Angle δ (deg)	Drift Angle β (deg)	Sway Vel. v' (non-dim)	Yaw Vel. r' (non-dim)
STATIC TESTS						
static rudder	1.00	1.00	± 0, ***[10]***, 20, 30, 35	0	-	-
	0.80	1.00	± 0, 10, 20, 30, 35	0	-	-
	0.40	1.00	± 0, 10, 20, 30, 35	0	-	-
static drift	1.00	1.00	0	± 0, 0.5, 1,	-	-

				2, ***[4]***		
	0.80	1.00	0	± 0, 4, 8	-	-
	0.40	1.00	0	± 0, 8, 12, 16	-	-
drift & rudder	0.80	1.00	± 0, 10, 20, 30, 35	± 4	-	-
	0.40	1.00	± 0, 10, 20, 30, 35	± 12	-	-
DYNAMIC TESTS						
pure sway	1.00	1.00	-	-	0.04, 0.08	-
pure yaw	1.00	1.00	-	-	-	0.05, 0.10, 0.15, ***[0.20]***
	0.80	1.00	-	-	-	0.35
	0.40	1.00	-	-	-	0.70
yaw & drift	0.80	1.00	-	± 4	-	0.35
	0.40	1.00	-	± 12	-	0.70
yaw & rudder	0.80	1.00	± 20	-	-	0.35
	0.40	1.00	± 30	-	-	0.70

[value]: These tests shall be repeated N times to provide data for uncertainty analysis. N should be at least 3, but preferably 10.

Note: The yaw-induced roll angle is minor in shallow water. BSHC free zig-zag and turning tests with KCS at nominal GMT showed max roll angle of 2.5 deg for water depths up to h/T=2. Therefore tests with heel/roll are not included.

Additional tests for harbour manoeuvring data (if possible):

	Speed U/U_0 (non-dim.)	Prop. Revs. (non-dim.)	Rudder Angle δ (deg)	Drift Angle β (deg)	Sway Vel. v' (non-dim)	Yaw Vel. r' (non-dim)
pure cross-flow	0.30	1.00	0	90	-	-
pure rotation	0.00	0.00	0	0	-	∞

Note: Amplitudes and frequencies of PMM motion should be selected based on facility experience.

MEASUREMENT SYSTEM

Facility:	Towing tank for manoeuvres in shallow water at Flanders Hydraulics Research (co-operated with the Maritime Technology Division of Ghent University).
Water temperature:	To be specified.
Measurements:	The following quantities shall be measured (at least): Captive tests: X- and Y-forces, N- and K-moment, sinkage fore and aft, carriage speed, rudder angle, drift angle, amplitudes and frequencies of PMM motion, propeller thrust, torque and RPM, rudder forces (if possible).
Sampling frequency:	To be specified.

DATA PROCESSING

Coordinate system:	The coordinate system is fixed in the ship model. Origin for captive motion: intersection between the water line plane and the centre line plane at amidships. The x-axis is positive in the forward direction, the y-axis is positive towards starboard side and the z-axis is positive downwards. Angles, moments and directions of rotation follow the general right hand rule.
Filtering of raw data:	All raw signals should be filtered to remove measurement noise.
Total hydrodynamic forces:	After filtering, the total forces and moments shall be derived by combining the measured forces from each of the gauges and the inertial forces originating from the mass of the model and the moving part of the measurement system should be subtracted to give the pure hydrodynamic forces. Alternatively the total forces can be given along with sufficient information to derive the hydrodynamic forces.
Motion variables:	The definition of the independent motion variables (x_0, y_0, psi, beta, u, v, r, udot, vdot, rdot) in relation to the PMM motion should be given.

OUTPUT DATA

The results should be delivered in Ascii format files with processed data in model scale using physical SI-units. For static tests the data should be given as mean values, while for dynamic tests a time series of one or more PMM cycles is necessary. An example of output channels for a dynamic PMM test is given below:

No.	Designation	Dimension	Description
1	t	s	Time
2	X	N	Hydrodynamic longitudinal force
3	Y	N	Hydrodynamic transverse force
4	N	Nm	Hydrodynamic yaw moment
5	K	Nm	Hydrodynamic roll moment
6	Uc	m/s	Carriage speed
7	sink	m	Sinkage, mean
8	trim	deg	Trim, mean
9	T	N	Propeller thrust
10	Q	Nm	Propeller torque
11	n	RPM	Propeller revolutions
12	beta	deg	Drift angle
13	delta	deg	Rudder angle
14	xo	m	Global position, x-direction
15	yo	m	Global position, y-direction
16	psi	deg	Heading
17	u	m/s	Surge velocity
18	v	m/s	Sway velocity
19	r	deg/s	Yaw velocity
20	udot	m/s^2	Surge acceleration
21	vdot	m/s^2	Sway acceleration
22	rdot	deg/s^2	Yaw acceleration

UNCERTAINTY ANALYSIS

The model test facility is encouraged to carry out uncertainty analysis on the measurements.

Appendix 2: Model Test Specification KCS: free running

Model Test Specification

Hull	**KCS**
Test type	**Free sailing**
Water depth	**Shallow**
Appendages	**Appended**

SUMMARY

Free model tests shall be conducted in shallow water with a model of the KCS container ship. The data will be used as basis for validation of simulation models in the SIMMAN 2012 Workshop. Captive PMM tests in shallow water with the same model shall also be carried out and used as input data for the simulation models.

MODEL GEOMETRY

Identification: SVA model no. M1203S001

Scale: 1:52.667

Hull: Dimensions of the KCS hull in this scale are as follows:

L_{pp}	[m]	4.367
B	[m]	0.611
T	[m]	0.205
∇	[m^3]	0.356
S	[m^2]	3.436
C_B	[-]	0.651
LCB	[%Lpp]	-1.480

(LCB positive forward of midships)

Propeller: The KCS model is equipped with SVA stock propeller no. VP1193, righthanded, with following particulars:

type	CP
blades	5
d [m]	0.150
P/D at 0.7R	1.000
Ae/A0	0.700
hub ratio	0.227
rotation	right

Rudder: The KCS is equipped with one semi balanced horn rudder with corresponding head box. Rudder particulars:

S_{rudder}	[m^2]	0.0415
lat. area	[m^2]	0.0196
lat. area movable	[m^2]	0.0163
helm rate	[deg/s]	16.8

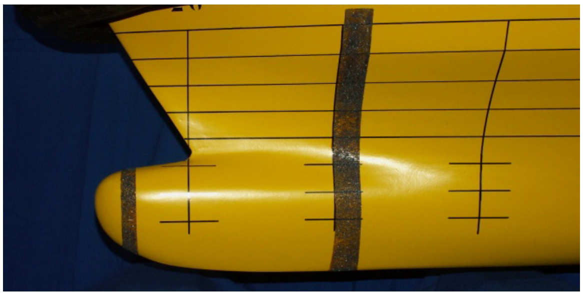
Bilge keels: None.

Turbulence stimulation: Turbulence stimulation is provided by sand on section 19 as well as on the bulb.

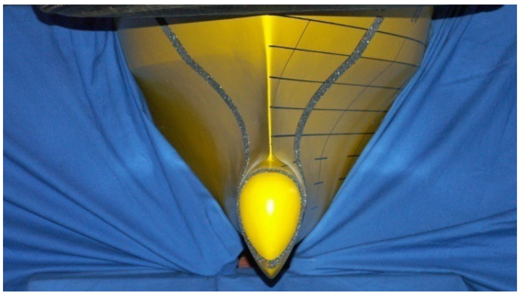
Comment: The model and conditions must be identical to those in the PMM model tests.

This model has been tested before at SVA (free, 2006), CEHIPAR (PMM, 2006), BSHC (free, 2007) and FORCE (PMM, 2009).

Model photos



bow side view



bow front view

rudder and propeller arrangement side view

rudder and propeller arrangement rear view

TEST CONDITIONS

Loading condition The model shall be tested on even keel at draught of 0.205 m (10.8 m full scale). The mass and moment of inertia in roll and yaw must be measured. Nominal values are as follows:

m	[kg]	356
i_{xx}/B	[-]	0.40
i_{zz}/L_{pp}	[-]	0.25
GM	[m]	0.011

NB. These are nominal values which should be matched as closely as possible. Used values to be specified.

Water depths: The tests shall be performed at 3 water depths ranging from very shallow (UKC = 20%) up to moderate (UKC = 100%):

Depth	h/Tm	UKC (%)	h (m)	Fnh
h1	1.20	20%	0.246	0.399
h2	1.50	50%	0.308	0.357
h3	2.00	100%	0.410	0.309

(Depths have been chosen to match some cases from BSHC tests).

Nominal speeds and RPM: The nominal approach speed will be the same for all water depths:

Nom. speed ship	[kn]	8.75 (*1)
Nominal speed U_0	[m/s]	0.62
Froude no. Fn	[-]	0.095
Nominal revs. N_0	[RPM]	(*2)

(*1) Speed chosen to match free model tests at BSHC.

(*2) RPM shall be set to model self-propulsion point at each water depth (for reference BSHC used 330 RPM for this speed at h/T=1.2).

Self-propulsion point: Model (No friction deduction force applied)

RPM strategy: Constant RPM

Degrees of freedom: 6 DOF,

Set-up: Free.

TEST PROGRAM

The basic scope of tests for each water depth is given in the following table:

Type	**Rudder angle (deg)**	**Heading change (deg)**	**Starting to**	**Comment**
zig-zag	10	2.5	port	
zig-zag	10	2.5	starboard	
zig-zag	20	5	port	
zig-zag ***(*)***	20	5	starboard	
turning circle ***(*)***	35	-	port	first quarter of circle only
turning circle	35	-	starboard	first quarter of circle only

(*) Note: these tests shall be repeated N times to provide data for uncertainty analysis. N should be at least 3, but preferably 10.

MEASUREMENT SYSTEM

Facility: Towing tank for manoeuvres in shallow water at Flanders Hydraulics Research (co-operated with the Maritime Technology Division of Ghent University).

Water temperature: To be specified.

Measurements: The following quantities shall be measured (at least):

x- and y-position in Earth fixed coordinate system, heading angle, rudder angle, roll angle, propeller thrust, torque and RPM.

Sampling frequency: To be specified.

DATA PROCESSING

Coordinate systems: The ship coordinate system is fixed in the model. The x-axis is positive in the forward direction, the y-axis is positive towards starboard side and the z-axis is positive downwards. Angles, moments and directions of rotation follow the general right hand rule. An similar Earth-fixed coordinate system is used for the global positions.

Filtering of raw data: All raw signals should be filtered to remove measurement noise.

OUTPUT DATA

The results should be delivered in Ascii format files with processed data in model scale using physical SI-units. For free model tests the full time series should be given (including a short period before the first rudder execute to document the initial conditions).

An example of output channels for a free model test is given below:

Column.	Designation	Dimension	Description
1	t	s	time
2	x	m	x-position in earth-fixed coordinate system
3	y	m	y-position in earth-fixed coordinate system
4	phi	deg	roll angle
5	psi	deg	heading angle
6	u	m/s	longitudinal velocity component of ship
7	v	m	lateral velocity component of ship
8	p	deg/s	roll rate
9	r	deg/s	yaw rate
10	delta	deg	rudder angle
11	n	rpm	propeller revolutions
12	thrust	N	propeller thrust
13	torque	Nm	propeller torque

UNCERTAINTY ANALYSIS

The model test facility is encouraged to carry out uncertainty analysis on the measurements.

Appendix 3: Model Test Specification KVLCC2: PMM

Model Test Specification

Hull	**KVLCC2**
Test type	**Captive (PMM)**
Water depth	**Shallow**
Appendages	**Appended**

SUMMARY

Captive PMM tests shall be conducted in shallow water with a model of the KVLCC2 tanker. The data will be used as basis for simulation models for use in the SIMMAN 2012 Workshop. Free model tests in shallow water with the same model shall also be carried out and used as blind data for validation of the simulation models.

MODEL GEOMETRY

Identification: FHR model

Scale: 1:75

Hull: Dimensions of the KVLCC2 hull in this scale are as follows:

L_{pp}	[m]	4.2667
B	[m]	0.7733
T	[m]	0.2773
∇	[m^3]	0.7410
S	[m^2]	4.8345
C_B	[-]	0.8098
LCB	[%Lpp]	3.48

(LCB positive forward of midships)

Propeller: The KVLCC2 is equipped with one fixed-pitch propeller with particulars as follows:

type	FP
blades	4
d [m]	0.131
P/D at 0.7R	0.721
Ae/A0	0.431
hub ratio	0.155
rotation	Right

NB. These are nominal values; particulars of used propeller to be specified.

Rudder: The KVLCC2 is equipped with one semi balanced horn rudder:

lat. area including horn	[m^2]	0.0243
helm rate	[deg/s]	20.3

Bilge keels: None.

Turbulence stimulation: Used method to be specified.

Comment: The model and conditions must be identical to those in the subsequent free model tests.

Model photos
(not included in spec)

TEST CONDITIONS

Loading condition The model shall be tested on even keel at draught of 0.277 m (20.8 m full scale). The mass and moment of inertia in yaw must be measured. Nominal values are as follows:

m	[kg]	741
i_{xx}/B	[-]	n.a.
i_{zz}/L_{pp}	[-]	0.25
GM	[m]	n.a.

NB. These are nominal values; used values to be specified.

Water depths: The tests shall be performed at 3 water depths ranging from very shallow (UKC = 20%) up to the maximum possible depth (0.5m):

Depth	h/Tm	UKC (%)	h (m)	Fnh
h1	1.20	20%	0.333	0.230
h2	1.50	50%	0.416	0.206
h3	1.80	80%	0.500	0.188

Nominal speeds and RPM: The nominal approach speed will be the same for all water depths:

Nom. speed ship	[kn]	7.0
Nominal speed U_0	[m/s]	0.416
Froude no. Fn	[-]	0.064
Nominal revs. N_0	[RPM]	(*)

(*) RPM shall be set to model self-propulsion point at each water depth.

Self-propulsion point: Model (No friction deduction force applied)

RPM strategy: Constant RPM

Degrees of freedom: 3 DOF, i.e. measure longitudinal force X, transverse force Y and yaw moment N.

Set-up: Free to trim and sink, otherwise constrained.

TEST PROGRAM

The basic scope of tests <u>for each water depth</u> is given in the following table:

	Speed U/U_0 (non-dim.)	Prop. Revs. (non-dim.)	Rudder Angle δ (deg)	Drift Angle β (deg)	Sway Vel. v' (non-dim)	Yaw Vel. r' (non-dim)
STATIC TESTS						
static rudder	1.00	1.00	± 0, ***[10]***, 20, 30, 35	0	-	-
	0.80	1.00	± 0, 10, 20, 30, 35	0	-	-
	0.50	1.00	± 0, 10, 20, 30, 35	0	-	-
static drift	1.00	1.00	0	± 0, 0.5, 1, 2, ***[4]***	-	-
	0.80	1.00	0	± 0, 4, 8	-	-
	0.50	1.00	0	± 0, 8, 12	-	-
drift & rudder	0.80	1.00	± 0, 10, 20, 30, 35	± 4	-	-
	0.50	1.00	± 0, 10, 20, 30, 35	± 8	-	-
DYNAMIC TESTS						
pure sway	1.00	1.00	-	-	0.04, 0.08	-
pure yaw	1.00	1.00	-	-	-	0.05, 0.10, 0.15***, [0.20]***
	0.80	1.00	-	-	-	0.30
	0.50	1.00	-	-	-	0.60
yaw & drift	0.80	1.00	-	± 4	-	0.30
	0.50	1.00	-	± 8	-	0.60
yaw & rudder	0.80	1.00	± 20	-	-	0.30
	0.50	1.00	± 30	-	-	0.60

[value] Note: these tests shall be repeated N times to provide data for uncertainty analysis. N should be at least 3, but preferably 10.

Additional tests for harbour manoeuvring data (if possible):

	Speed U/U_0 (non-dim.)	Prop. Revs. (non-dim.)	Rudder Angle δ (deg)	Drift Angle β (deg)	Sway Vel. v' (non-dim)	Yaw Vel. r' (non-dim)
pure cross-flow	0.30	1.00	0	90	-	-
pure rotation	0.00	0.00	0	0	-	∞

MEASUREMENT SYSTEM

Facility: To be specified.

Water temperature: To be specified.

Measurements: The following quantities shall be measured (at least):

Captive tests: X- and Y-forces, N- and K-moment (if relevant), sinkage fore and aft, carriage speed, rudder angle, drift angle, roll angle (if relevant), amplitudes and frequencies of PMM motion, propeller thrust, torque and RPM.

Free model tests: x- and y-position in earth fixed coordinate system, heading angle, rudder angle, roll angle, propeller thrust, torque and RPM.

Sampling frequency: To be specified.

DATA PROCESSING

Coordinate system: The coordinate system is fixed in the ship model. Origin for captive motion: intersection between the water line plane and the centre line plane at amidships. The x-axis is positive in the forward direction, the y-axis is positive towards starboard side and the z-axis is positive downwards. Angles, moments and directions of rotation follow the general right hand rule.

Filtering of raw data: All raw signals should be filtered to remove measurement noise.

Total hydrodynamic forces: After filtering, the total forces and moments shall be derived by combining the measured forces from each of the gauges and the inertial forces originating from the mass of the model and the moving part of the measurement system should be subtracted to give the pure hydrodynamic forces.

Motion variables: The definition of the independent motion variables (x_0, y_0, psi, beta, u, v, r, udot, vdot, rdot) in relation to the PMM motion should be given.

OUTPUT DATA

The results should be delivered in Ascii format files with processed data in model scale using physical SI-units. For static tests the data should be given as mean values, while for dynamic tests a time series of one or more PMM cycles is necessary. An example of output channels for a dynamic PMM test is given below:

No.	Designation	Dimension	Description
1	t	s	Time
2	X	N	Hydrodynamic longitudinal force
3	Y	N	Hydrodynamic transverse force
4	N	Nm	Hydrodynamic yaw moment
5	K	Nm	Hydrodynamic roll moment
6	Uc	m/s	Carriage speed
7	Sink-f	m	Sinkage forward
8	Sink-a	m	Sinkage aft
9	T	N	Propeller thrust
10	Q	Nm	Propeller torque
11	n	RPM	Propeller revolutions
12	beta	deg	Drift angle
13	delta	deg	Rudder angle
14	phi	deg	Roll angle
15	xo	m	Global position, x-direction
16	yo	m	Global position, y-direction
17	psi	deg	Heading
18	u	m/s	Surge velocity
19	v	m/s	Sway velocity
20	r	deg/s	Yaw velocity
21	udot	m/s^2	Surge acceleration
22	vdot	m/s^2	Sway acceleration
23	rdot	deg/s^2	Yaw acceleration

UNCERTAINTY ANALYSIS

The model test facility is encouraged to carry out uncertainty analysis on the measurements.

Appendix 4: Model Test Specification KVLCC2: free running

Model Test Specification

Hull	**KVLCC2**
Test type	**Free sailing**
Water depth	**Shallow**
Appendages	**Appended**

SUMMARY

Free model tests shall be conducted in shallow water with a model of the KVLCC2 tanker. The data will be used as basis for validation of simulation models in the SIMMAN 2012 Workshop. Captive PMM tests in shallow water with the same model shall also be carried out and used as input data for the simulation models.

MODEL GEOMETRY

Identification: FHR model

Scale: 1:75

Hull: Dimensions of the KVLCC2 hull in this scale are as follows:

L_{pp}	[m]	4.2667
B	[m]	0.7733
T	[m]	0.2773
∇	[m^3]	0.7410
S	[m^2]	4.8345
C_B	[-]	0.8098
LCB	[%Lpp]	3.48

(LCB positive forward of midships)

Propeller: The KVLCC2 is equipped with one fixed-pitch propeller with particulars as follows:

type	FP
blades	4
d [m]	0.131
P/D at 0.7R	0.721
Ae/A0	0.431
hub ratio	0.155
rotation	Right

Rudder: The KVLCC2 is equipped with one semi balanced horn rudder:

lat. area including horn	[m^2]	0.0243
lat. area movable part	[m^2]	0.0199
helm rate	[deg/s]	20.3

Bilge keels: None.

Turbulence stimulation: Used method to be specified.

Comment: The model and conditions must be identical to those in the PMM model tests.

Model photos
(not included in spec)

TEST CONDITIONS

Loading condition

The model shall be tested on even keel at draught of 0.277 m (20.8 m full scale). The mass and moment of inertia in roll and yaw must be measured. Nominal values are as follows:

m	[kg]	741
i_{xx}/B	[-]	0.40
i_{zz}/L_{pp}	[-]	0.25
GM	[m]	0.076

NB. These are nominal values which should be matched as closely as possible. Used values to be specified.

Water depths:

The tests shall be performed at 3 water depths ranging from very shallow (UKC = 20%) up to the maximum possible depth (around 0.5m):

Depth	h/Tm	UKC (%)	h (m)	Fnh
h1	1.20	20%	0.333	0.230
h2	1.50	50%	0.416	0.206
h3	1.80	80%	0.500	0.188

NB. Obtained values for deepest depth to be specified.

Nominal speeds and RPM:

The nominal approach speed will be the same for all water depths:

Nom. speed ship	[kn]	7.0
Nominal speed U_0	[m/s]	0.416
Froude no. Fn	[-]	0.064
Nominal revs. N_0	[RPM]	(*)

(*) RPM shall be set to model self-propulsion point at each water depth.

Self-propulsion point: Model (No friction deduction force applied)

RPM strategy: Constant RPM

Degrees of freedom: 6 DOF,

Set-up: Free.

TEST PROGRAM

The basic scope of tests for each water depth is given in the following table:

Type	Rudder angle (deg)	Heading change (deg)	Starting to	Comment
zig-zag	10	2.5	port	
zig-zag	10	2.5	starboard	
zig-zag	20	5	port	
zig-zag ***(*)***	20	5	starboard	
turning circle ***(*)***	35	-	port	first quarter of circle only
turning circle	35	-	starboard	first quarter of circle only

(*) Note: these tests shall be repeated N times to provide data for uncertainty analysis. N should be at least 3, but preferably 10.

MEASUREMENT SYSTEM

Facility: Towing tank for manoeuvres in shallow water at Flanders Hydraulics Research (co-operated with the Maritime Technology Division of Ghent University).

Water temperature: To be specified.

Measurements: The following quantities shall be measured (at least):

x- and y-position in Earth fixed coordinate system, heading angle, rudder angle, roll angle, propeller thrust, torque and RPM.

Sampling frequency: To be specified.

DATA PROCESSING

Coordinate systems: The ship coordinate system is fixed in the model. The x-axis is positive in the forward direction, the y-axis is positive towards starboard side and the z-axis is positive downwards. Angles, moments and directions of rotation follow the general right hand rule. An similar Earth-fixed coordinate system is used for the global positions.

Filtering of raw data: All raw signals should be filtered to remove measurement noise.

OUTPUT DATA

The results should be delivered in Ascii format files with processed data in model scale using physical SI-units. For free model tests the full time series should be given (including a short period before the first rudder execute to document the initial conditions).

An example of output channels for a free model test is given below:

Column.	Designation	Dimension	Description
1	t	s	time
2	x	m	x-position in earth-fixed coordinate system
3	y	m	y-position in earth-fixed coordinate system
4	phi	deg	roll angle
5	psi	deg	heading angle
6	u	m/s	longitudinal velocity component of ship
7	v	m	lateral velocity component of ship
8	p	deg/s	roll rate
9	r	deg/s	yaw rate
10	delta	deg	rudder angle
11	n	rpm	propeller revolutions
12	thrust	N	propeller thrust
13	torque	Nm	propeller torque

UNCERTAINTY ANALYSIS

The model test facility is encouraged to carry out uncertainty analysis on the measurements.

Appendix 5: Model Test Specification KVLCC2 – bare hull: PMM

Model Test Specification

Hull	**KVLCC2**
Test type	**Captive (PMM)**
Water depth	**Shallow**
Appendages	**Bare**

SUMMARY

Captive PMM tests shall be conducted in shallow water with a bare hull model of the KVLCC2 tanker.

MODEL GEOMETRY

Identification: FHR model

Scale: 1:75

Hull: Dimensions of the KVLCC2 hull in this scale are as follows:

L_{pp}	[m]	4.2667
B	[m]	0.7733
T	[m]	0.2773
∇	[m^3]	0.7410
S	[m^2]	4.8345
C_B	[-]	0.8098
LCB	[%Lpp]	3.48

(LCB positive forward of midships)

Propeller: none

Rudder: none

Bilge keels: None.

Turbulence stimulation: Used method to be specified.

Comment: The model is identical to the one used for appended hull PMM tests, only with the rudder and propeller dismounted and fixed inside the model.

Model photos
(not included in spec)

TEST CONDITIONS

Loading condition The model shall be tested on even keel at draught of 0.277 m (20.8 m full scale). The mass and moment of inertia in yaw must be measured. Nominal values are as follows:

m	[kg]	741
i_{xx}/B	[-]	n.a.
i_{zz}/L_{pp}	[-]	0.25
GM	[m]	n.a.

NB. These are nominal values; used values to be specified.

Water depths: The tests shall be performed at 2 water depths:

Depth	h/Tm	UKC (%)	h (m)	Fnh
h1	1.20	20%	0.333	0.230
h2	1.50	50%	0.416	0.206

Nominal speeds and RPM: The two nominal approach speeds are the same for both water depths:

Nom. speed ship	[kn]	7.0	15.5
Nominal speed U_0	[m/s]	0.416	0.921
Froude no. Fn	[-]	0.064	0.142
Nominal revs. N_0	[RPM]	n.a.	n.a.

Self-propulsion point: n.a.

RPM strategy: n.a.

Degrees of "freedom": 4 DOF, i.e. measure longitudinal force X, transverse force Y, yaw moment N and roll moment K.

Set-up: Free to trim and sink, otherwise constrained.

TEST PROGRAM

The basic scope of tests <u>for each water depth and speed</u> is given in the following table:

	Speed U/U_0 (non-dim.)	Prop. Revs. (non-dim.)	Rudder Angle δ (deg)	Drift Angle β (deg)	Sway Vel. v' (non-dim)	Yaw Vel. r' (non-dim)
static drift	1.00	-	-	0, 4	-	-
pure yaw	1.00	-	-	-	-	0.40

MEASUREMENT SYSTEM

Facility: Towing tank for manoeuvres in shallow water at Flanders Hydraulics Research (co-operated with the Maritime Technology Division of Ghent University).

Water temperature: To be specified.

Measurements: The following quantities shall be measured (at least):

X- and Y-forces, N- and K-moment, sinkage fore and aft (or mean sinkage and trim), carriage speed, drift angle, amplitudes and frequencies of PMM motion.

Sampling frequency: To be specified.

DATA PROCESSING

Coordinate system: The coordinate system is fixed in the ship model. Origin for captive motion: intersection between the water line plane and the centre line plane at amidships. The x-axis is positive in the forward direction, the y-axis is positive towards starboard side and the z-axis is positive downwards. Angles, moments and directions of rotation follow the general right hand rule.

Filtering of raw data: All raw signals should be filtered to remove measurement noise.

Total hydrodynamic forces: After filtering, the total forces and moments shall be derived by combining the measured forces from each of the gauges and the inertial forces originating from the mass of the model and the moving part of the measurement system should be subtracted to give the pure hydrodynamic forces. Alternatively the total forces can be given along with sufficient information to derive the hydrodynamic forces.

Motion variables: The definition of the independent motion variables (x_0, y_0, psi, beta, u, v, r, udot, vdot, rdot) in relation to the PMM motion should be given.

OUTPUT DATA

The results should be delivered in Ascii format files with processed data in model scale using physical SI-units. For static tests the data should be given as mean values, while for dynamic tests a time series of one or more PMM cycles is necessary. An example of output channels for a dynamic PMM test is given below:

	Designation	Dimension	Description
1	t	s	Time
2	X	N	Hydrodynamic longitudinal force
3	Y	N	Hydrodynamic transverse force
4	N	Nm	Hydrodynamic yaw moment
5	K	Nm	Hydrodynamic roll moment
6	Uc	m/s	Carriage speed
7	sink	m	Sinkage, mean
8	trim	deg	Trim, mean
9	beta	deg	Drift angle
10	xo	m	Global position, x-direction
11	yo	m	Global position, y-direction
12	psi	deg	Heading
13	u	m/s	Surge velocity
14	v	m/s	Sway velocity
15	r	deg/s	Yaw velocity
16	udot	m/s^2	Surge acceleration
17	vdot	m/s^2	Sway acceleration
18	rdot	deg/s^2	Yaw acceleration

Appendix 6: KCS: PMM results

Digitally available upon request.

Appendix 7: KCS: free running results

Digitally available upon request.

Appendix 8: KVLCC2: PMM results

Digitally available upon request.

Appendix 9: KVLCC2: free running results

Digitally available upon request.

Appendix 10: KVLCC2 – bare hull: PMM results

Digitally available upon request.

Appendix 11: Customer's comments

11.1 Comment

E-mail dated 25/01/2011:

I have read your report for the tests with KCS and KVLCC2. It is very comprehensive and gives a detailed documentation of the tests you have performed and will thus be most valuable for those who may use the test data for validation at SIMMAN and further ahead.

However, there is one issue that I need you to clarify concerning the propeller RPM during the tests. On page 7 you state that the "same fraction (as for the speed) was used to estimate the corresponding propeller rate" for the speeds below the design speed. But in our specification of the captive tests we had stated "constant RPM", see for example pages A3 and A13 for KCS and KVLCC2 respectively, where the fraction for propeller revolutions is 1.00 for all speed fractions in the test program. As I interpret your Tables 6 to 17 you have run the tests at some reduced fraction of the RPM corresponding to the design speed. The idea of keeping fixed RPM was to make the captive data directly usable for making simulations to compare with the free model tests, where the RPM should also be fixed (as you have done if I read your Tables 18 to 21 correctly). Please let me know if I interpret your report correctly on this point.

Kristian

11.2 Answer

The above interpretation is correct. The PMM tests were conducted at a speed-rpm relationship corresponding to the self propulsion point, i.e. each speed has its own fixed propeller rate. The program took into account the remark *(*) RPM shall be set to model self-propulsion point at each water depth* on e.g. p A12. A misunderstanding of the remark led to the execution of useful tests but with the wrong propeller rate.

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