SHOPERA Benchmark Specification

Part II: The KVLCC2 Case Study

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1 Introduction

The 2012 guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships, MEPC.212(63), represent a major step forward in implementing energy efficiency regulations for ships through the introduction of the EEDI limits for various types of ships. There are, however, serious concerns regarding the sufficiency of propulsion power and steering devices to maintain maneuverability of ships in adverse conditions, hence regarding the safety of ships, if the EEDI requirements are achieved by simply reducing the installed engine power. To address the challenges of this issue by in-depth research studies, a new European research project called SHOPERA (Energy Efficient Safe SHip OPERAtion) [1], funded by the European Commission in the frame of FP7, was launched in October 2013, aiming at developing suitable methods and tools and systematic case studies which will enable the development of improved guidelines and their submission for consideration to IMO-MEPC in 2016. Numerical simulation methods (on simulating the maneuverability of a ship in waves) of varying complexity, such as simplified formulas, potential flow methods, motion simulators and viscous field methods, will be compared with each other and with model tests for selected cases. As the employed methods are of varying complexity and capability, their robustness in predicting is expected to be accordingly of mixed quality. Within this context, an open blind international benchmark study is being organized by SHOPERA using for validation selected tank tests, which were conducted within the SHOPERA project. The aim of this benchmark study is to assess the accuracy/reliability of current numerical simulation methods worldwide and the international State- of-Art in the study field. The SHOPERA benchmark study will be jointly organized by NTUA-SDL and UDE-ISMT. The present study is conducted in the frame the European Project SHOPERA.

This study aims to contribute to the international state of the art in the operation of ships in adverse sea conditions by:

- recording numerical simulation methods employed at international level for the prediction of the added resistance (including drift forces) and maneuverability of ships in waves, and
- assessing the current level of accuracy and efficiency of the relevant numerical prediction methods by comparison with model experimental data.

2 KVLCC2 Tanker

Figure 1: KVLCC2 hull

2.1 Geometry

The KVLCC2 is a VLCC-type vessel, representing the second variant of a modern tanker design developed by the Korean Institute of Ship & Ocean Engineering (KRISO) with bulb bow and U-shaped stern lines, see, [4, 5, 6]). The hull lines have been exclusively developed for testing and benchmarking and no full scale ships of that type exist. The main particular of this vessel for the design loading condition (T = 20.8 m) are given in Table 1 in full scale without appendages. The benchmark model tests for the added resistance and drift forces were conducted in the frame of SHOPERA at the Canal de Experiencias Hidrodinámicas de El Pardo (CEHIPAR) with a model scale of 80, whereas the benchmark maneuvering tests were conducted in the frame of the Japanese JASNAOE project at the National Maritime Research Institute (NMRI) with a model of scale 110.

The coordinate system is right-handed with the x-axis positive towards the bow and the z-axis positive downwards. The origin of the ship bound coordinate system used in the measurements is located at {Lpp/2, CentreLine, BaseLine]. Head wave is denoted by 0°, following wave by 180°, beam wave by 90° from PS.

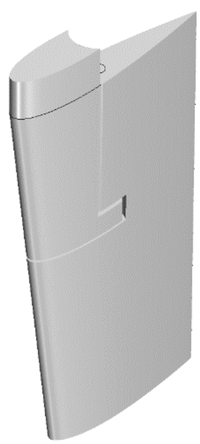

Figure 2: KVLCC2 rudder

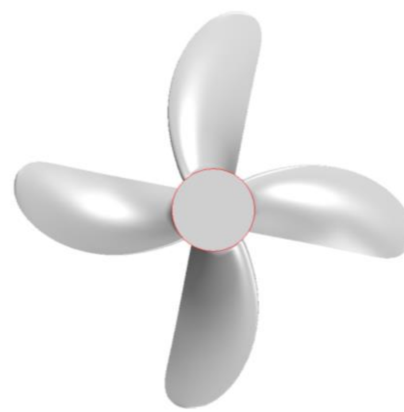

Figure 3: KVLCC2 propeller

Table 1: Main Dimensions of the KVLCC2

L_{pp} [m]	B_{WL} [m]	T [m]	V [m^3]	S [m^2]	CB [-]
320.0	58.0	20.8	312622	27194	0.8098

The KVLCC2 design features a horn rudder of 273.3 m^2 rudder area and a lateral area of 136.7 m^2. The turn rate is 2.34°/s in full scale. At NMRI the turning rate of the ruder was set to 19°/s in model scale. The tanker was equipped with a fixed-pitch 4 bladed propeller of 9.86 m full scale diameter and a pitch ratio of P/D = 0.721. The direction of rotation is right-handed. The propeller characteristics are given in section 2.2.

The loading condition are shown in Table 2.

Table 2: Loading Condition of the KVLCC2

T_f [m]	T_a [m]	M [kg]	LCG [m]*	VCG [m]*	GM [m]	rx [m]	ry [m]	rz[m]
20.8	20.8	320438	171.1	18.56	5.71	23.2	80	80

*CAD-file coordinate system

2.2 Propeller open water characteristic

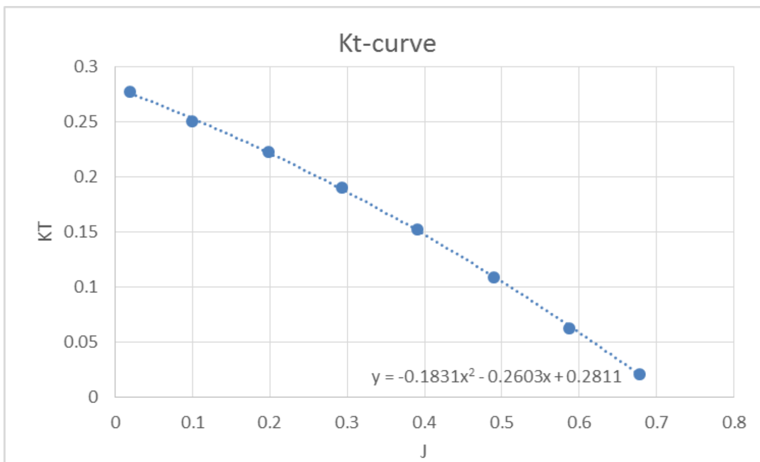

Figure 4: K_T curve of the model propeller

2.3 SHOPERA Benchmark Test Cases

The selected SHOPERA benchmark test cases of the KVLCC2 hull in head and oblique waves, as well as maneuvering tests, are specified in the following. All tests were conducted under deep water conditions. The actual depth of the basin was 5m.

2.3.1 Added Resistance

Both the added resistance tests and the drift force tests were carried out by CEHIPAR. The scale is 1:80 and the model was towed using a soft mooring based on springs. To this purpose two beams extended a certain distance forward of the bow and aft of the stern giving two attachment points for the mooring lines. Two lines on each points. The other ends of the mooring lines were fixed to two posts subjected to the carriage and in the plane of the midship section. Therefore the mooring lines formed a diamond with 6 meters diagonals approximately (see Figure 5).

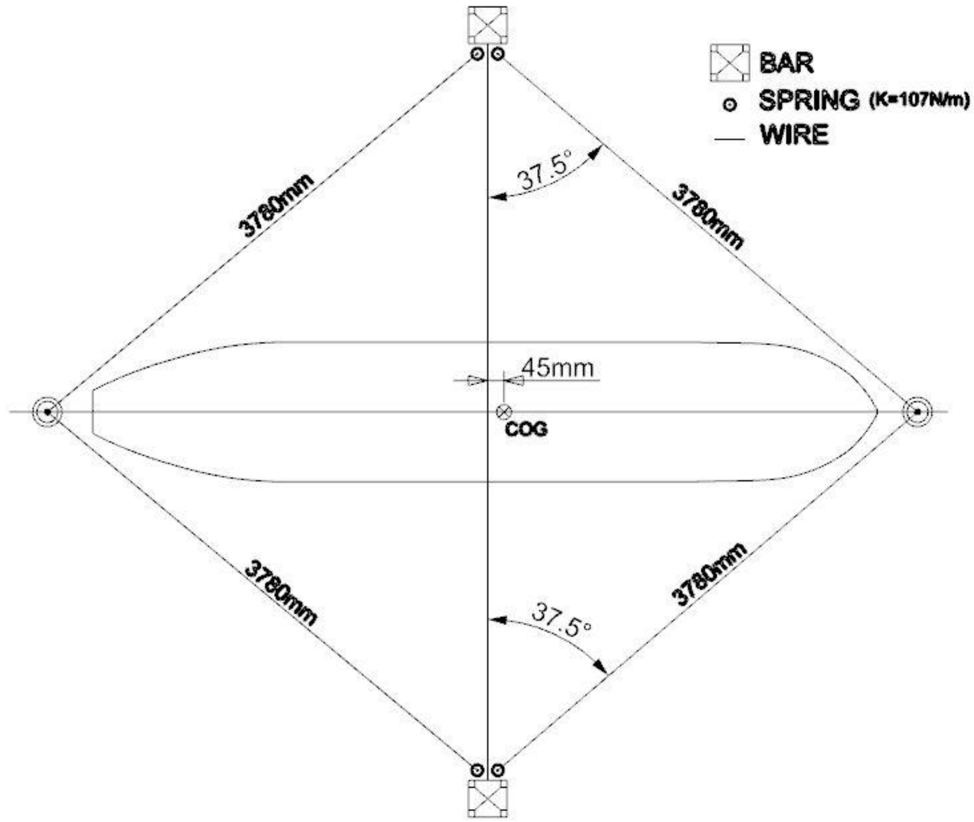

Figure 5: Attachment of the KVLCC2 model at CEHIPAR model tests

The benchmark test cases for the added resistance in harmonic/regular waves are specified in Table 3 to Table 5. A test case in irregular waves is defined in Table 6. Zero degrees angle means head waves.

Table 3: KVLCC2 test conditions for added resistance tests with zero speed in regular waves

Run number	H [m]	T [s]	Encounter angle [°]	v[knots]
E37	1.54	6.28	0	0
E38	2.41	7.85	0	0
E39	4.50	10.47	0	0
E40	4.50	11.42	0	0
E41	4.50	12.57	0	0
E42	4.50	15.71	0	0

Table 4: KVLCC2 test conditions for added resistance tests with 6 knots in regular waves

Run number	H [m]	T [s]	Encounter angle [°]	v[knots]
342	1.54	6.28	0	6
343	2.41	7.85	0	6
344	4.5	10.47	0	6
345	4.5	11.42	0	6

346	4.5	12.57	0	6
347	4.5	15.71	0	6

Table 5: KVLCC2 test conditions for added resistance tests with 12 knots in regular waves

Run number	H [m]	T [s]	Encounter angle [°]	v[knots]
348	1.54	6.28	0	12
349	2.41	7.85	0	12
350	4.5	10.47	0	12
351	4.5	11.42	0	12
352	4.5	12.57	0	12
353	4.5	15.71	0	12

Table 6: KVLCC2 test conditions for added resistance tests in irregular waves

Run number	H_s [m]	T_p [s]*	Encounter angle [°]	v [knots]
372	2.0	6.5	0	6
373	5	9.5	0	6
374	7.5	11.5	0	6

Tp= sea spectrum's peak period. The measured spectrum is available on the website www.shopera.org

2.3.2 Drift Forces

The mooring arrangement is specified in section 2.3.1. The two sets of benchmark calculations are specified: drift forces and yaw moment at zero speed, with the test cases shown in Table 7.

Table 7: KVLCC2 test conditions for drift force and yaw moment tests at zero speed

Run number	H [m]	T [s]	Encounter angle [°]	v [knots]
E07	1.54	6.28	150	0
E08	2.41	7.85	150	0
E09	4.50	10.47	150	0
E10	4.50	11.42	150	0
E11	4.50	12.57	150	0
E12	4.50	15.71	150	0
E13	1.54	6.28	120	0
E14	2.41	7.85	120	0
E15	4.50	10.47	120	0
E16	4.50	11.42	120	0
E17	4.50	12.57	120	0
E18	4.50	15.71	120	0
E19	1.54	6.28	90	0
E20	2.41	7.85	90	0
E21	4.50	10.47	90	0
E22	4.50	11.42	90	0
E23	4.50	12.57	90	0

E24	4.50	15.71	90	0
E25	1.54	6.28	60	0
E26	2.41	7.85	60	0
E27	4.50	10.47	60	0
E28	4.50	11.42	60	0
E29	4.50	12.57	60	0
E30	4.50	15.71	60	0
E31	1.54	6.28	30	0
E32	2.41	7.85	30	0
E33	4.50	10.47	30	0
E34	4.50	11.42	30	0
E35	4.50	12.57	30	0
E36	4.50	15.71	30	0

2.3.3 Turning circle and Zig-Zack maneuvers*

The model for the maneuvering test was built at a scale of 1:110. Turning tests with $\delta = 35°$ and $-35°$, and 10/10 and -10/-10 zig-zag maneuver tests should be carried out in short-crested irregular waves. The approach speed U_0 and propeller revolution n_P in the tests.as well as the wave conditions are shown in Table 8. This condition is corresponding to Sea State 6. As the wave spectrum, the following spectrum $\Phi_{\zeta\zeta}$ was used as:

$$\Phi_{\zeta\zeta}(\omega,\theta) = S_{\zeta\zeta}(\omega)G(\theta)$$

Where

$$S_{\zeta\zeta}(\omega) = \frac{8.1\,x\,10^{-3}\,g^2}{\omega^5}\exp\left\{-\frac{3.11}{H_s^2\,\omega^4}\right\}$$

$$G(\theta) = \frac{2}{\pi}\cos^2(\theta)$$

g is the acceleration gravity. The frequency spectrum $S_{\zeta\zeta}$ is the ITTC spectrum, and $\cos^2$-function was used as the wave angular distribution function $G(\theta)$.

Head wave direction was selected in the ship approach condition as the main wave direction. All tests in irregular waves were repeated 5 times with changing randomly the phase relation among the element waves generated.

Table 8: KVLCC2 test conditions for maneuvering tests

Run number	**maneuver**	**H_s [m]**	**T_p [s]***	**Encounter angle [°]**	**v [knots]**	**n [rps]**
TC1	Turning Circle (δ= 35°)	6	9.46	0	5	8.3
TC2	Turning Circle (δ= -35°)	6	9.46	0	5	8.3
ZZ1	Zig-Zag 10/10 to PS	6	9.46	0	5	8.3
ZZ2	Zig-Zag 10/10 to SB	6	9.46	0	5	8.3

3 Data for Submission

The participants of the benchmark workshop are asked to describe the method/software used and the computational procedure and setup. A grid and time discretization study is required. Convergence behavior shall be documented. A document template will be issued by the benchmark organizers.

Data to be delivered should include

1. Dimensional (model scale) motions (6 degrees of freedom) *
2. Dimensional (model scale) hydodynamic forces (3) and moments (3) *
3. The time series of all conducted simulations for at least ten encounter periods (regular waves).
4. Submission files shall include the added resistance, heave and pitch for regular head waves. The results of the computations in oblique regular waves shall include the longitudinal and transverse forces, the yaw moment and all associated motions.
5. The maneuvering simulation time series shall include the trajectories*, rudder and heading angle.

*Definitions and templates will be prepared and distributed by the benchmark organizers in due time.

4 Time Plan

- Release of specifications for the DTC benchmark: December 15, 2015
- Release of specifications for the KVLCC2 benchmark: December 21, 2015
- Release of template for benchmark results: January 25, 2016
- Submission of results: March 7, 2016
- Feedback on results and possible update/resubmission: March 21, 2016
- Analysis of results: April 8, 2016
- Presentation of results: April 15, 2016
- Release of benchmark report: May 30, 2016

5 Benchmark Contacts

Participation to the benchmark study can be requested through the SHOPERA web site or directly by email to the study coordinators:

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References

[1] „Proceedings of the Gothenburg Workshop on CFD in Ship Hydrodynamics," 2010.

[2] „Proceedings of the Workshop on Verification and Validation of Ship Manoeuvring Simulation Methods - SIMMAN 2008," 2008.

[3] „SHOPERA," 2013-2016. Available: www.shopera.org.