ITTC Quality System Manual
Recommended Procedures and Guidelines

Guideline

Benchmark Data for Validation of Manoeuvring Predictions

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Disclaimer

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Benchmark Data for Validation of Manoeuvring Predictions

1. PURPOSE OF GUIDELINE

The purpose of this document is to give guidelines for the Benchmark Data for Validation of Manoeuvring Predictions.

2. INTRODUCTION

The guideline 4.0-01 is a general guideline illustrating the basic understanding of benchmarking activity, explaining the overall processes of benchmarking and listing common rules to be kept by participating organisations during benchmarking activity.

The present guideline highlights the processes relevant for benchmarking within the field of manoeuvrability. The last section of the guideline provides a list of the benchmark database available and may serve as an aid in selection of benchmark cases.

3. PROCEDURE OF BENCHMARKING

3.1 General information

The model tests should generally be carried out according to the Recommended Procedures given by the latest ITTC Manoeuvring Committee:

- Captive model tests: 7.5-02-06-02
- Free running model tests: 7.5-02-06-01

The following sections summarizes steps, additional requirements and possible pitfalls, which require high attention when doing benchmark tests. Data collection, analysis and sharing information are all elements of the benchmarking process.

The objective of the benchmark tests must be clearly defined from the start. Careful planning is required to ensure the requested results are accurately recorded and with sufficient details. Right from the start the test cases/test programme should be defined and documented to make sure the test set is clearly defined, and that focus is kept on the essentials. It must be carefully considered what data are needed and if necessary, the test program should be narrowed to ensure the work required is carried out.

Once started, the process must be documented. With detailed process documentation it is possible to analyse deviations and capture outliers. It is recommended to carry out uncertainty assessment according to the latest Recommended Procedures by the ITTC (see 3.3) to assure the quality/repeatability of the tests and that the data set can be used for CFD validation.

3.2 Data Collection

Before starting the data collection, key measures and definitions must be established and clearly documented. Furthermore, it must be decided:

- What kind of data is needed?
- How are the data collected?
- How will they be evaluated?

A possible pitfall during the planning process is too many parameters or irrelevant parameters.

Key measures and definitions which should be considered and documented are as follows:

- All applied coordinate systems, e.g. ship, rudder, global etc.
- Applied units. It is recommended to keep all variables in SI units.
- Main particulars of both hull, propeller and rudder if present.
- Loading condition.
- Turbulence stimulation, preferably photo documentation of all applied stimulation.
- Rudder rate.
- Self-propulsion point.
- Initial conditions.
- Tank conditions i.e. water temperature, water viscosity, size of tank, bottom type (in case of shallow water).
- Equipment descriptions, e.g. type, setup, positions etc.
- Selected set of channels/signals.
- Applied filters.
- Logging frequency.
- Autopilot if present.
- Procedure of carriage speed. Is the speed constant or is the carriage following the model?

The above list is a minimum list of high attention areas.

3.3 Uncertainty Assessment

As stated earlier, it is highly recommended to carry out uncertainty assessment.

Uncertainty assessment will assure the quality and repeatability of the tests and will qualify them to be used for the purpose of verification.

If a full uncertainty study is too comprehensive, it is recommended to reduce the UA scope and focus on single representative data points rather than neglecting it. Presence of uncertainty estimates is a great enhancement of the data set.

When carrying out the uncertainty assessment, please refer to the recommended procedures: 7.5-02-06-04 and 7.5-02-06-05.

3.4 Analysis

Besides the planning and the data collection, the analysis phase is possibly the most important and difficult one.

It is necessary to carry out a thorough analysis of the data, identifying all discrepancies, outliers and errors and moreover identifying the root cause to these. Make sure that the data collected is only and precisely what is required. It is highly recommended to apply quality control to data and information.

Important areas, which must be included in the analysis documentation are as follows:

- Post processing actions (applied filtering, subtraction of centrifugal force etc.).
- Detailed process description. Describe the background from raw measured data to delivered data. A process documentation with detailed process descriptions will also make it possible to analyse deviations and outliers.
- Format of delivered data. Is it e.g. raw measured data, Fourier coefficients, mean data or are the given data the out of phase or the in-phase values? Any applied data reduction equation and fairing must be documented.

Please refer to the recommended procedures 7.5-02-06-01 and 7.5-02-06-02 for further details regarding data analysis of free running model tests and captive models tests respectively.

3.5 Publication of data

Sharing the data is the final step of the benchmarking process. When sharing the data, all data and information requested for a complete dataset must be provided. Be honest and complete.

All geometries used (hull, appendages and propeller) must be well defined with clear definitions of scales and units.

The final documentation should be summarized in a public report or adequate article. Data, including the documentation, must be available via workshops or a publicly accessible location on the institute's own website.

4. BENCHMARK DATABASE

Advancements in the development of CFD and EFD provide the necessary tools for realisation of simulation-based design. To be able to predict manoeuvring behaviour, reliable predictions or simulation methods are required. Therefore, it is important to make a dedicated verification and validation effort related to the simulation methods and hereby assess the accuracy of the methods.

The 24th and 25th ITTC Manoeuvring Committee identified this need and initiated the SIMMAN workshops, which have focus on verification and validation of ship manoeuvring simulation methods. The benchmark data collected for the SIMMAN workshops and other similar workshop (e.g. MASHCON) creates the need to maintain a current evaluation of databases for validation with regards to status and future uses and requirements. This effort will ease the effort of upcoming workshops and provide a listing of present available benchmark data for validation of manoeuvring predictions.

The present database will be updated continuously. Present benchmark sets may be excluded in the future if they proof to be irrelevant, whereas new data can be included. Elimination or inclusion of data will be based on recommendations from the steering committees of the workshops, who will also be responsible for the QA and availability of the data.

Section 4.2 to 4.6 will provide an overview of the available benchmark hull forms covering tankers, container vessels, surface combatant hull forms, bulk carriers and underwater vehicles (UV) and section 4.7 summarize available restricted water cases. A summary table listing all available data including references to the data are also provided.

4.1 SIMMAN

The purpose of the SIMMAN workshops is to benchmark the capabilities of manoeuvring prediction methods through comparisons with towing tank results for different hull form test cases.

The 24th ITTC Manoeuvring Committee recommended to adopt a new set of benchmark data, where four different ship hulls were selected: two versions of a full-form tanker named KVLCC1 and KVLCC2, a container ship named KCS and a naval combatant named 5415. Though none of these ships exist in full-scale, they all represent modern hull forms of the respective types and full geometrical data for hull, propeller, rudder and other appendages is publicly available. In connection with the first "Workshop on Verification and Validation of Ship Manoeuvring Simulation Models" in 2008 (SIMMAN 2008), a large model test campaign was performed, comprising PMM, CMT (circular motion tests) and free model tests for each of the four hulls (Stern et al., 2011).

At the second workshop, SIMMAN 2014, the benchmark data sets were updated, and shallow water test cases included. Due to only minor differences in the manoeuvring characteristics between KVLCC1 and KVLCC2, the KVLCC1 was removed from the list of applied hulls narrowing down the amount of test cases.

The total amount of test cases comprised free running manoeuvres (turning circles and zig-zag manoeuvres) and captive PMM type tests in deep and shallow water for all hulls except 5415 which only covered deep water.

At the workshop, for each test case, the predicted forces/moments and trajectories from a variety of manoeuvring prediction methods were compared and validated against the model test results, Quadvlieg et al. (2017). For the KCS it was clear, that the 3DOF methods are not adequate for manoeuvring predictions. For ships with low GM inclusion of heel seems to be important, i.e., methods with minimum 4DOF are necessary in order to predict the manoeuvres correctly.

Only very few submissions were available for the shallow water cases, and they showed a larger variation than the deep water cases indicating that shallow water is not an easy test case and that more effort within this area is required.

At the third workshop, SIMMAN 2020, the benchmark data sets of KVLCC2 and KCS were updated according to the recommendations of SIMMAN 2014. The 5415M used in both SIMMAN 2008 and 2014 was replaced by the surface combatant ONR Tumblehome model 5613 (ONRT) to include new test cases for the participants. The benchmark data sets of the ONRT were all new model tests and included both captive tests and free running model tests.

Besides the calm water data, free running model tests in waves were introduced for both the KCS and the ONRT. The tests were turning circles carried out in regular waves for at least three turns each, i.e., minimum 1080 degree change of heading (Quadvlieg et al., 2023).

Data from all SIMMAN workshops are open and available, but it is recommended to use the benchmark data from SIMMAN 2014 and SIMMAN 2020 listed in the summary table.

4.2 Tanker

KVLCC2:

The KRISO 300K VLCC 2 (KVLCC2) was conceived to provide data for both explication of flow physics and CFD validation for a modern 300 K tanker hull form with bulbous bow and transom stern (ca. 1997). No full-scale ship exists.

4.3 Container vessel

KCS:

The KRISO Container Ship (KCS) was conceived to provide data for both explication of flow physics and CFD validation for a modern container ship with bulb bow and stern (ca. 1997). The conditions include bare hull and fixed model. No full-scale ship exists.

DTC:

The Duisburg Test Case (DTC) is a hull design of a typical modern Post-Panamax container vessel, developed at ISMT at the University of Duisburg-Essen (el Moctar et al., 2012). The ship is a single screw vessel with a bulbous bow and a large bow flare. It is equipped with a fixed-pitch five-bladed propeller with right rotation and a twisted rudder with a Costa bulb. No full-scale ship exists.

HTC:

The Hamburg Test Case (HTC) is a model of the 153.7 m container ship built by Bremer Vulkan in 1986 as Ville de Mercure (IMO 8513792). The full-scale ship is appended with bilge keels and bow thruster, but please note model tests have been carried out both with and without these appendages. No full-scale ship exists.

4.4 Combatant

5415:

Model 5415 was conceived as a preliminary design for a Navy surface combatant (ca. 1980). The hull geometry includes both a sonar dome and transom stern. Propulsion is provided through twin open-water propellers driven by shafts supported by struts. No full-scale ship exists.

ONRT:

The ONR Tumblehome (ONRT) model 5613 is a preliminary design of a modern surface combatant, which is publicly accessible for fundamental research. The ship model is appended with skeg and bilge keels. The model has a wave piercing hull design with 10° tumblehome sides and transom stern. No full-scale ship exists.

4.5 Bulk Carrier

JBC:

The Japan Bulk Carrier (JBC) is a cape size bulk carrier equipped with a stern duct as an energy saving device. The National Maritime Research Institute (NMRI), Yokohama National University and the Ship Building Research Centre of Japan (SRC) are jointly involved in the design of a ship hull, a duct and a rudder. No full-scale ship exists.

4.6 Multi Hull

DC372:

The Delft Catamaran 372 (DC372) is a waterjet propeller fast catamaran. The catamaran was designed at Delft University, with dimensions based on new buildings from the decade of 1990s as described in Van't Veer (1998). The catamaran is characterised by symmetrical demi hulls and a transom with zero wetted area when floating on a flat-water surface at zero speed. No full-scale ship exists.

4.7 Underwater Vehicle

DARPA:

The DARPA (Defence Advanced Research Projects Agency) Suboff is a recommended submarine hull form for benchmark tests. It is an axisymmetric body with fairwater, symmetric stern appendages, two ring wings and ring wing support struts originally designed for the DARPA Suboff Project. The overall model geometry for the two Suboff models, DTRC model nos. 5470 and 5471 are identical. The two models differ only in the location of the surface pressure taps. No full-scale ship exists.

BB2:

The submarine Brendon's Boat 2 (BB2) is a modified version of the BB1 hull form, a three deck 4000t (submerged) SSK class submarine introduced by Joubert (2006). To improve directional stability BB2 features larger aft control surfaces and a more forward located sail with increased thickness compared to BB1. No full-scale ship exists.

4.8 Manoeuvring in Restricted Water

Bank effects:

Two sets of benchmark data covering various bank effects are available from the MASHCON conferences.

The first set covers both surface piercing banks and banks with platform submergence composed of a sloped part from the bottom to the platform. The tests are carried out in a captive setup using a single screw 800 TEU container carrier.

The second set covers data for two ships approaching and leaving locks. The free sailing data is carried out with a 12000 TEU container vessel at a scale of 1:80. For the captive data set a 1:75 scale bulk carrier has been used.

Ship-to-ship interaction:

Two sets of data results from captive ship-to-ship interaction tests are available from the 2nd and the 6th MASHCON conference. The first set covers five static tests and one dynamic rudder test carried out with an Aframax tanker as the service ship and the KVLCC2 as the ship to be lightered.

The second data covers the effects of a passing ship (KCS) at a moored Neo Panamax container and a moored Aframax tanker at close distance and/or high speed.

	Scale	Environment	Appendages	PMM	CMT	FRMT
Tanker						
KRISO 300K VLCC2 (KVLCC2)						
1.1 HMRI (2013) SIMMAN 2014 + 2020 Sung et al. (2014)	46.426	∞	app	√		
1.2 MARIN (2007) SIMMAN 2014 + 2020 Quadvlieg and Brouwer (2011)	45.714	∞	app			√
1.3 HSVA (2006) SIMMAN 2014	45.714	∞	app			√
1.4 CTO (2007) SIMMAN 2014	45.714	∞	app			√
1.5 NMRI (2006) SIMMAN 2014	110.000	∞	app		√	
1.6 BSHC (2013) SIMMAN 2014 +2020	45.714	1.2, 1.5, 1.8	app, bh	√		
1.7 MARIN (2013) SIMMAN 2014 + 2020 Tonelli and Quadvlieg (2015)	75.000	1.2	app			√
1.8 FHR (2010) SIMMAN 2014 + 2020 Eloot et al. (2015)	75.000	1.2, 1.5, 1.8	app, bh	√		√
Container Vessel						
KRISO 3600 TEU (KCS)						
2.1 JMU (2012) (wo. propeller) SIMMAN 2020 Yoshimura et. al (2013)	105.000	∞	app-wop	√		
2.2 MARIN (2009) SIMMAN 2014 + 2020	37.890	∞	app			√
2.3 FORCE (2009) SIMMAN 2014	52.667	∞	app	√		
2.4 NMRI (2005) (3DOF) SIMMAN 2014	75.500	∞	app		√	
2.5 KRISO (2014) SIMMAN 2020	31.600	1.2	app	√		

	Scale	Environment	Appendages	PMM	CMT	FRMT
KRISO 3600 TEU (KCS) cont.						
2.6 MARIN (2019) SIMMAN 2020	37.890	1.2	app			√
2.7 FHR (2010) SIMMAN 2014	52.667	1.2, 1.5, 2.0	app	√		
2.8 BSCH (2008 + 2011) SIMMAN 2014	52.667	1.2, 2.0, 2.5	app			√
2.9 Hiroshima University (2018) SIMMAN 2020	75.240	wave(∞)	app			√
2.10 IIHR (2017) SIMMAN 2020	75.240	wave(∞)	app			√
Duisburg Test Case (DTC)						
3.1 FHR (2015) 5th MASHCON Van Zwijnsvoorde et al. (2019) 4th MASHCON Eloot et al. (2016)	89.110	1.2, 2.0, wave(1.2), wave(2.0)	app, bh	√		√
Hamburg Test Case (HTC)						
4.1 HSVA (2007) VIRTUE Vogt et al. (2007)	24.000	∞	app, bh	√* P	√*	
4.2 MARIN (2011) Toxopeus (2011)						√
Combatant						
DTMB model 5415 (5415)						
5.1 MARIN (2007) (5415M) SIMMAN 2014 Toxopeus et al. (2011)	35.480	∞	app	√	√	√
5.2 FORCE (2004) SIMMAN 2014 Simonsen (2004)	35.480	∞	bh	√		
5.3 IIHR (2005) SIMMAN 2014 Yoon et al. (2015a) Yoon et al. (2015b)	46.588	∞	bh	√P		

	Scale	Environment	Appendages	PMM	CMT	FRMT
DTMB model 5415 (5415) cont. 5.4 INSEAN (2005) SIMMAN 2014 Benedetti et al. (2006)	24.830	∞	bh	√		
ONR Tumblehome model 5613 (ONRT) 6.1 Seoul National University (2018) SIMMAN 2020 Seo et al. (2018)	48.936	∞	app	√		
6.2 IIHR (2013) SIMMAN 2020 Sanada et al. (2018)	48.936	∞, wave(∞)	app			√
Bulk Carrier						
Japan Bulk Carrier (JBC) 7.1 Akishima Laboratories (2015) Tokyo 2015 Kishimoto et al. (2016)	101.818	∞	app	√		√
Multi Hull						
Delft Catamaran (JBC) 8.1 BSCH (2007) Zlatev et al. (2009)	27.571	2.5	bh	√		
8.2 BSCH (2010) Milanov et al. (2011)	27.571	∞, 2.0, 1.5	app	√		
Underwater Vehicles						
DARPA Suboff (DARPA) 9.1 David Taylor Research Center (1990) Roddy (1990) Groves et al. (1989)	1.000	∞	bh, app-wop	√		
Brendon's boat 2 (BB2) 10.1 MARIN (2015) Overpelt et al. (2015)	18.348	∞	app			√

	Scale	Environment	Appendages	PMM	CMT	FRMT
Manoeuvring in Restricted Water						
Bank Effects						
11.1 FHR (2006) (Banks)	NA	1.1, 1.35, 2.0	app	√		
Lataire et al. (2009b)		1.1, 1.2				
11.2 FHR (2008) (Locks)	80.000		app	√		√
Vantorre et al. (2012)	75.000					
Ship-ship interaction						
12.1 FHR (2009)	75.000	1.9, 3.09, 3.93	app	√		
Lataire et al. (2009a)						
Lataire et al. (2011)						
12.2 FHR (2022)	80.000	1.1, 1.2, 1.5	bh	√		
Zwijnsvoorde et al. (2022)						

5. LIST OF SYMBOLS

app Appended hull
app-wop Appended hull without propeller
bh Bare hull
h Water depth
P Including PIV (Particle Image Velocimetry) measurements
T Draught
T/h Shallow water depth ratios; 1.1, 1.2, 1.35…
∞ Deep water
√ Data available
$\underline{\surd}$ Data under procurement

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