ITTC Quality System Manual
Recommended Procedures and Guidelines

Guideline

Model Tests of Stationary Multi-Bodies Operating in Close Proximity

7.5	Process Control
7.5-02	Testing and Extrapolation Methods
7.5-02-07	Loads and Responses
7.5-02-07-03	Ocean Engineering
7.5-02-07-03.11	Guideline for Model Tests of Stationary Multi-Bodies Operating in Close Proximity

Edited /Updated	Approved
Ocean Engineering Committee of the 30th ITTC	30th ITTC 2024
Date 04/2024	Date 09/2024

Table of Contents

Guideline for Model Tests of Stationary Multi-Bodies Operating in Close Proximity

1. PURPOSE OF GUIDELINE

The purpose of this guideline is to ensure that model tests of stationary multi-bodies (at least two floating/fixed bodies) in close proximity are conducted according to the best available techniques and to provide an indication of where improvements in techniques might be made.

The primary procedure for a multi-body model test is similar to that for a single body as described in Procedure 7.5-02-07-03.1 Floating Offshore Platform Experiments. Therefore, the objective of the present guideline is to ensure that any compromises, inherent in a particular multi-body interaction model test, are identified and their effect on the measured results is understood.

In general, multi-body interaction model tests are usually performed when the safe operations of offshore platforms and vessels, such as side-by-side offloading and offshore installation involving multiple vessels / platforms, may be compromised, and/or for validation studies.

The main objective of an experiment with multi-bodies in close proximity is to measure positions and motions of the models, free surface elevations in the gap, global loads, line tensions or fender loads, if present.

2. DESCRIPTION OF THE TEST PROCEDURE

Model tests of multi-bodies are subject to wave, current, and wind in terms of environmental conditions. In addition, model tests are often carried out to assess the operational limits of the multi-body configuration. Floating multi-bodies could be moored or dynamically positioned.

2.1 Model test agenda and matrix

Before planning the tests, a statement of the test objectives and a test matrix are required. Judicious use of computational tools can help to reduce the extent of the test matrix. For instance, numerical simulations based on potential flow theory can be used to identify resonant periods or critical gaps around which model test conditions should focus.

2.2 Multi-body models

Models should be scaled according to Froude’s law. The scale ratio is often based on basin dimensions, the relative positions of models and the footprint of the mooring systems, if present. For dynamically positioned bodies, the characteristics of thrusters should be also considered when determining the scale ratio – according to Procedure 7.5-02-07-03.6 Dynamic Positioning Systems Model Test Experiments.

For bodies with mooring lines/risers, full-length line models are preferred, but if basin dimensions and model scale require shortening or truncation, this should be done according to Procedure 7.5-02-07-03.5 Passive Hybrid Model Tests of Floating Offshore Structures with Mooring Lines, or another appropriate method that should be documented.

2.3 Ballasting and loading

Ballasting and loading will be performed for each model individually, and follows the same procedure and guidelines given in Procedure 7.5-02-07-03.1 Floating Offshore Platform Experiments.

2.4 Instrumentation and measurement systems

Multi-body tests may show high-frequency phenomena, especially in the gap. For example, the resonance frequency in the gap could be two or three times the wave frequency of interest for some multi-body configurations. The sampling rate of the measurement system has to be sufficiently high to capture these phenomena.

It is recommended to use a motion measurement system which will not influence the body motions and to provide a synchronised measurement of motions. Optical tracking systems are preferred for multi-body model tests. Care must be taken to minimize the interference of the motion measurements of one model blocking the camera view of the other model.

It is also recommended to use in-line force measurement transducers with a minimum influence on the line tension, according to Procedure 7.5-02-07-03.5 Passive Hybrid Model Tests of Floating Offshore Structures with Mooring Lines.

The wave probes should have adequate high resolution to measure the high-frequency wave elevations in the gap. Wave probes should be sufficiently small in size to avoid any disturbance of the free surface and interference/clashing with the bodies.

A full synchronisation of all the equipment is recommended, including wave, current and wind generators, and data acquisition systems.

2.5 Calibration

The nonlinear behaviour of fenders, transfer/mooring lines, offloading lines, hawsers, and hoses should be modelled and calibrated according to the prototype specifications and Guideline 7.5-02-07-03.16 Model Construction of Offshore Systems.

More details on calibrations of environmental conditions and equipment including moorings/risers and thrusters can be found in Procedure 7.5-02-07-03.1 Floating Offshore Platform Experiments.

2.6 Test procedure and data acquisition

2.6.1 Pre-test considerations

Before each run, measurements should be checked to ensure that residual body motions and wave elevations in the basin are sufficiently small.

2.6.2 Data analysis

Data analysis should be presented in both time series and frequency domain. Details on the analysis procedures can be found in Procedure 7.5-02.07-03.2 Analysis Procedure for Model Tests in Regular Waves and 7.5-02-07-03.14 Analysis Procedure for Model Tests in Irregular Waves.

2.6.3 Presentation of results

Results can be presented in dimensional or non-dimensional form. Dimensional results can either in model or full scale; however, this must be clearly documented. Typical measurements are described in Procedure 7.5-02-07-03.1 Floating Offshore Platform Experiments. So, for tests of multi-bodies, the results should include:

- 6-DOF rigid body motions for each body
- Mass and moment of inertia properties of each model
- Relative body motions
- Accelerations at specified locations
- Free surface elevations in the gap
- Free surface elevations in other locations
- Kinematic coefficient of viscosity in the gap
- Coefficient of surface tension in the gap

- Tensions in lines (mooring lines, offloading lines, hoses, etc.)
- Fender loads
- Wave conditions
- Wind velocity
- Current velocity
- Method of extrapolation of the results from model scale to full scale - when applicable.

3. PARAMETERS

Most parameters are the same as those for a single body model test. Details on the parameters can be found in Procedure 7.5-02-07-03.1 Floating Offshore Platform Experiments, including:

- test conditions
- models' dimensions
- basin dimensions
- wave calibration
- wave periods and heights
- wave headings
- current calibration
- wind calibration
- mooring calibration
- measurement equipment
- test duration
- number of repeat runs
- use of different gauges

3.1 Scaling

Multi-body model tests may involve several similitude laws such as geometrical and dynamic similitudes. The linkages between bodies also need to be modelled in scale according to their mechanical properties, for example, the stiffness of the fenders, hawsers and hoses. Notice that forces due to linkages are often very nonlinear and viscous effects on damping can be critical. For example, the tension force due to fenders is zero while the compression force can be nonlinear with the distance.

The gap width is critical for the definition of the scale. The gap should be large enough to avoid effects associated to water surface tension, such as capillary waves and meniscus. Surface tension effects may start to become important in very small-scale model tests where they are not significant at full scale. This is one factor, for example, which ultimately limits the scale ratio that can be used to define the gap when testing models in close proximity. Gaps significantly smaller than 0.1 m (in model scale) should be avoided to prevent surface tension effects (BMT, 2000). Furthermore, the gap width affects the fenders' damping and the viscous effects.

The model test results can be converted to the full scale according to Froude scaling. However, the highly nonlinear behaviour and viscous effects in gaps need to be carefully considered.

3.2 Model geometry

The models should be as detailed as possible if their elements influence the physical phenomena or if they are important for the measurements. These elements include appendages, fenders, offloading hoses, hawsers, cables, articulated arms, connecting bridges, thrusters, and mooring lines/risers, if present. The telescoping bridges (gangways) should have low friction that does not affect the platform motions. The telescoping gangways can be equipped with a metric grid for visual verification of the relative distance (between the platforms) measured by the optical system.

3.3 Body-to-body connection systems

If multi-bodies are connected, inertial properties, motions, loads and extensions of connecting systems, such as body-to-body mooring lines and connecting bridges, should be modelled.

Modelling the mooring stiffness in Yaw is important in multi-body tests because the Yaw motions affect the relative distance between the floating platforms (especially if the two platforms yaw out of phase). The Yaw stiffness also depends on the mooring pretensions, which should be maintained at their targets throughout the test campaign. The VIM Yaw motions may also reduce the relative distance between the platforms.

3.4 Fenders

Fenders are needed if contact occur between bodies. In this case, the stiffness and damping of fenders, including their nonlinear behaviour, must be accurately modelled by using rubber type or polymer elements and/or mechanical systems. Fenders should be calibrated before the tests.

If a fender affects the flow in the gap, its geometry should also be modelled as accurately as possible.

Details on fenders modelling can be found in Guideline 7.5-02-07-03.16 Model Construction of Offshore Systems.

3.5 Offloading systems

For offloading systems such as hoses and articulated arms, their stiffness and lumped mass distribution should be modelled. In-line tensions should be measured.

3.6 Other structures

If a structure has a substantial effect on the motion of or the load on one (or more) body, it should be modelled. Examples include superstructures and topsides under wind loading and/or subsea structures in the splash zone.

3.7 Environmental parameters

Tests should be carried out in the metocean conditions (wind, waves and current) in which the platforms may be required to operate. Shielding and shadowing effects are of special importance. Details on these parameters can be found in Procedure 7.5-02-07-03.1 Floating Offshore Platform Experiments.

4. UNCERTAINTY ANALYSIS

Many parameters cause uncertainties in multi-body model tests. Details on the sources of uncertainties can be found in the works of Qiu et al. (2014, 2017).

Furthermore, uncertainty analysis should be performed in accordance with Procedure 7.5-02-01-01 Guide to the Expression of Uncertainty in Experimental Hydrodynamics.

5. REFERENCES

BMT, 2000, “Review of model testing requirements for FPSO’s”. Offshore Technology Report, 123, BMT Fluid Mechanics Ltd for the Health and Safety Executive.

ITTC, 2008, “Guide to the Expression of Uncertainty in Experimental Hydrodynamics”, ITTC Procedure 7.5-02-01-01.

Qiu, W., Sales, J.J., Lee, D., Lie, H., Magarovskii, V., Mikami, T., Rousset, J.M., Sphaier, S., Wang, X., 2014, “Uncertainties Related to Predictions of Loads and Responses for Ocean and Offshore Structures”, Ocean Engineering, Vol. 86, pp. 58-67.

Qiu, W., Rousset, J.M., Peng, H., Horel, B., 2017, “Benchmark Tests of Two Body Interaction in Waves”, Proceedings of the ASME 36th International Conference on Ocean, Offshore and Arctic Engineering, Trondheim, Norway.