ITTC Quality System Manual

Recommended Procedures and Guidelines

Procedure

Passive Hybrid Model Tests of Floating Offshore Structures with Mooring Lines

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Disclaimer

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1. PURPOSE OF PROCEDURE

For floating offshore platforms with moorings and risers, it may be challenging to scale the system due to the limit of basin dimensions. This could be applicable to ultra-deep-water systems, or very wide systems. Truncated models are then needed. In most cases, mooring and riser models need to be truncated. Aspects on model tests of general offshore platforms can be found in Procedure 7.5-02-07-03.1 Floating Offshore Platform Experiments.

The purpose of this recommended procedure is to ensure that testing with such truncated model test set-ups, and the integration with subsequent numerical simulations, are conducted according to the best available and well-accepted methods.

The techniques for hybrid tests described in this procedure are limited to those based on integration with passive (off-line) computer simulations only. An alternative approach includes active (on-line) systems, described in Procedure 7.5-02-07-03.4 Active Hybrid Model Tests of Floating Offshore Structures with Mooring Lines. Nowadays, passive hybrid tests are commonly used, while the active hybrid tests are currently adopted for specific applications.

The present procedure is primarily intended for ultra deep-water applications (vertical truncation), while the basic principles could also be applicable to horizontal truncation.

1.1 When to use a Truncated Set-up

For the testing of a floating platform system with mooring lines and/or risers, there may be several possible alternatives:

1. Use of an ultra-small model, for instance, with a scale ratio greater than 100.
2. Passive hybrid tests – truncated set-up in combination with numerical simulations
3. Field tests
4. Use of numerical simulations – only when other methods are not available.

In general, passive hybrid model testing is recommended. The other three alternatives have clear limitations. Alternative 1 will have practical limitations associated to very small dimensions, although it may be realistic in some cases. For instance, if a scale of 1:100 is chosen, a basin depth of 10 m may be able to represent only 1000 m depth. To simulate deeper water depths in the same basin, a greater scale ratio (smaller model size) should be adopted. Alternative 3 may be valuable for research studies, but it is challenging for standard use.

For passive hybrid model tests, there is a trade-off between the model scale ratio and the degree of truncation. In general, it is recommended that the scale ratio, λ, is smaller than 100. However, if particular details need to be modelled, a lower scale limit may be necessary.

1.2 Passive Hybrid Model Testing

Experiments are first run with a truncated set-up. Truncations should be made so that the resulting platform motions and dynamic characteristics like top tensions of mooring lines and risers are like those expected for the full-depth case.

Numerical simulation of the actual truncated experiment is then carried out. The measurements are used to calibrate the numerical model.

Finally, the calibrated data are applied in full-depth simulations, from which final verification results are obtained. A hybrid verification methodology is described in the work of Stansberg *et al*. (2000, 2002) and a description of the procedure was given by Baarholm *et al.* (2006). A similar approach was addressed by Waals and van Dijk (2004).

The use of test results directly from truncated set-ups, without integration with numerical modelling, is generally not recommended for line tensions and riser responses, or for final estimates of platform slow-drift damping due to lines and risers.

As the passive hybrid test method has not been validated by using field test data, it is recommended that it should be regularly documented, and whenever possible, validated by using available data.

2. DESCRIPTION OF PROCEDURE

2.1 Truncation Design

2.1.1 Choice of truncated system

Important aspects to be considered in model testing with a truncated system include:

- When to choose a truncated system
- Critical response parameters for the platform system being tested such as static or dynamic responses, and horizontal or vertical responses.
- Criteria for system truncation
- Degree of system truncation in relation to coupling effects of the platform and its underwater systems
- Possibility of using “equivalent” mooring and riser modelling
- Measurement data needed to calibrate the numerical model
- Effect of airgap and green water
- Effect of vortex induced motion

It is important to check the performance of the truncated model against the properties expected from the design. The truncated system may involve springs, point masses or buoyancy elements, larger than geometrical scaled diameter, and drag chains on the basin floor.

The design of a truncated system is facility dependent. A complete documentation of the truncated system, as modelled, is critical for the interpretation of model test results and subsequent simulations.

2.1.2 Truncation criteria

In principle, motion responses (low-frequency and wave-frequency) of the platform with a truncated system should be similar to those of the platform with full-depth mooring.

Hence, for the modelling of a *vertically* truncated deep-water system, the test design should seek to correctly model the following parameters in the given succession of priorities:

1. Total mass of the floating system including hull, topside, full-moorings and risers
2. Total horizontal stiffness and restoring moment of the floating system
3. Quasi-static coupling between important platform responses, for example, the coupling between surge and pitch for a semi-submersible or a spar

4. "Representative" level of mooring and riser system damping in waves and currents, and current force, for example, by adjusting the effective mooring line and riser diameters
5. "Representative" single line tension characteristics for each mooring line and riser (at least quasi-static)

For *horizontally* truncated systems, the same rules may in general be followed, however details may be different depending on the actual problem.

More information on the principles of truncation design can be found in the work of Fylling and Stansberg (2005) and Baarholm *et al.* (2007). Additional principles of truncation design for asymmetric mooring and riser system can be found in the work of Wei *et al.* (2017)

2.1.3 Equivalent modelling by lumped systems

Mooring lines and/or risers may also be "lumped", i.e., a number of similar elements may be modelled as one single element. For example, a group of 12 production risers may be represented by one single model riser. Lumped systems are designed to provide appropriately scaled mass, stiffness, and hydrodynamic properties.

The decisions to truncate/lump moorings and risers can be made separately, but are obviously interrelated if both are to be used in a model test.

2.2 Model Test Program

In general, the test program should be designed to provide data to meet the following objectives:

- Validate that the test environment is repeatable, stationary, and homogeneous throughout the test area and is accurately calibrated to represent the desired metocean test conditions
- Validate that the actual test model has the desired scaled properties during model design
- Ensure to measure the critical floating system responses in metocean environmental conditions which are likely to be experienced during the design life. Extreme and operating conditions are normally of interest. The range of metocean environments tested should be broad enough to cover unexpected floater behaviours in conditions that are likely to be encountered.

For passive hybrid tests, it is particularly important to validate the numerical model of the platform responses (at model scale) that will ultimately be used to analyse the prototype responses. This validation is done at model scale, termed as "Model-of-the-Model" (see Section 2.3).

2.3 Calibration for Off-line Numerical Simulation: "Model-the-Model"

Numerical modelling of the actual truncated model test is first performed and the results are compared to the measurements for validation/calibration purpose. The same numerical tool will be used for the final full-depth simulations.

2.3.1 Numerical model of truncated set-up

A complete numerical model of the truncated set-up should be established to describe the dynamic responses to winds, waves, and currents of a moored system with risers. Time-domain numerical models are preferred since non-linear mooring dynamics can be considered in a more straightforward manner in comparison with frequency-domain models. They are generally regarded as more robust tools for coupled platform/mooring/riser analysis. However, frequency domain models can be calibrated with test data, and have been successfully used to analyse the responses of platform systems in deep water.

A coupled numerical model is recommended in model-the-model as it can simultaneously solve the dynamics of the platform and of its moorings and risers. The forces on the platform should include first-order wave forces and hydrodynamic reaction forces, second-order wave drift forces, second-order wave drift damping, and wind and current forces. The hydrodynamic forces on the moorings and risers should be included in a relative motion formulation. The numerical model should include terms that describe the viscous contributions to damping and to the low-frequency horizontal motions of the platform.

2.3.2 Validation of numerical model

The numerical model of the truncated system is validated by comparing predicted responses (normally from simulated time series, statistics and spectral values) with measured model test data. Typically, this means that hydrodynamic parameters of the platform and for the (truncated) mooring lines and risers are checked and calibrated if needed. In addition, the reconstruction provides a valuable check of the whole numerical tool. Measured wave records and wind/current conditions are normally used as an input.

2.4 Full-depth Numerical Simulation

A numerical model of the full-depth platform system is established by use of the same numerical tool as for the truncated system. Parameters obtained from the validated or calibrated truncated numerical model are used in the final full-depth simulations. In using this approach, it is recommended that the truncated system is as “similar” as possible to the full-depth system, following the criteria from subsection 2.1.2 above.

Comparisons between predicted responses for the full-depth platform system and the responses originally expected for the system design will then provide a basis for verifying the performance and adequacy of the design. The verified model must be adjusted to incorporate the prototype geometry, prototype properties, coefficients for drag and damping, and actual (non-truncated and non-simplified) moorings and risers.

3. KEY PARAMETERS

- Model scale
- Physical platform parameters such as geometry, mass, moments of inertia, centres of gravity and hydrostatic data
- Details of the numerical representation of platform geometry
- A description of the software for hydrodynamic analysis
- Total horizontal stiffness and restoring moment from moorings and risers
- Total vertical stiffness from moorings and risers
- Truncated set-up properties including position and stiffness of springs, position of point masses, etc.
- Drift forces and moments, quadratic transfer functions
- Viscous damping of the platform
- Damping due to mooring lines and risers
- Mooring line and risers properties including axial stiffness, bending stiffness (for

risers), underwater weight, diameter, pretension, drag coefficients, truncation, finite element model parameters, and lumped model parameters if any.
- Environmental conditions including waves, current and wind.

4. VALIDATION

The technique itself includes a validation or calibration of the numerical model through each test as an integrated part of the methodology.

A two-step procedure will always introduce additional uncertainties. In order to reduce these, and thereby increase the general reliability of the method, new particular validation cases - where truncated test cases (with numerical model integration) are benchmarked against full-depth tests - are always of great value. A related option is to carry out two-scale experiments. Model test data for more simplified cases also enhance the reliability of validation such as regular wave tests and free decay tests.

In addition, sub-tools such as specific numerical codes used for the platform hydrodynamics and for the moorings / risers should be validated independently.

5. UNCERTAINTY ANALYSIS

Many parameters cause uncertainties in truncated mooring tests. Typical sources of uncertainties can be found in Qiu *et al.* (2014).

Additional references can be found in the Procedure 7.5-02-01-01 Guide to the Expression of Uncertainty in Experimental Hydrodynamics.

6. REFERENCES

Baarholm R., Fylling, I.J., Stansberg C.T. and Øritsland O., 2006, “Model Testing of Deepwater Floater Systems: Truncation and Software Verification Methodology”, Proceedings of the ASME 25th International Conference on Ocean, Offshore and Arctic Engineering, Hamburg, Germany.

Baarholm, R., Stansberg, C.T., Fylling, I.J., Lee, M.Y., and Ma, W., 2007, “A robust procedure for deep-water model testing”, The 17th International Offshore and Polar Engineering Conference, Lisbon, Portugal

Fylling, I.J. and Stansberg, C.T., 2005, “Model testing of deep-water floating production systems: strategy for truncation of moorings and risers”, 17th Deep Oil Technology Conference, Rio de Janeiro, Brazil.

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

Stansberg, C.T., Øritsland, O., and Kleiven, G., 2000, “VERIDEEP: Reliable methods for laboratory verification of mooring and station keeping in deep water”, Offshore Technology Conference, Houston, Texas

Stansberg, C.T., Ormberg, H., and Øritsland, O., 2002, “Challenges in deep water experiments: hybrid approach”, Journal of Offshore Mechanics and Arctic Engineering, Vol. 124(2), pp. 90-96.

Waals, O.J. and van Dijk, R. R., 2004, “Truncation methods for deep water mooring systems for a catenary moored FPSO and a semi taut moored semisubmersible", Deep Offshore Technology Conference, New Orleans, LA

Wei, H., Xiao, L., Tian, X., Kou, Y., 2017. "Four-level Screening Method for Multi-Variable Truncation Design of Deepwater Mooring System", Marine Structures, Vol. 51, pp. 40–64.