ITTC Quality System Manual

Recommended Procedures and Guidelines

Procedure

Active Hybrid Model Tests of Floating Offshore Structures with Mooring Lines

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
7.5-02-07-03.4	Active Hybrid Model Tests of Floating Offshore Structures with Mooring Lines

Updated / Edited by	Approved
Ocean Engineering Committee of the 28th ITTC	28th ITTC 2017
Date: 06/2017	Date: 09/2017

Table of Contents

Active Hybrid Model Tests of Floating Offshore Structures with Mooring Lines

1. PURPOSE OF PROCEDURE

The purpose of this procedure is to ensure that active hybrid model tests of floating offshore structures are conducted according to the best available techniques and to provide an indication of where improvements in techniques might be made. Note that floating offshore structures typically apply to oil and gas as well as renewable energy development.

The procedure also aims to ensure that any compromises, inherent in a particular hybrid system model test, are identified and their effect on the measured results is understood. In general, hybrid model tests are employed to combine model tests in a model basin with numerical simulations due to the limitation of a model basin such as water depth and horizontal footprint. It should be also mentioned that the reference to a mooring system can be extended to risers and flexible members such as power cables.

It should be noted that active hybrid systems have been used for renewable energy projects, however they are not much used for offshore projects. Mooring line actuators, which are used in active hybrid systems, can take various forms. A mooring line is effectively a spring that holds the floating platform in position. The purpose of the actuator is to provide a mimic of the mooring/riser force-displacement characteristic as accurately and reliably as possible without having the full-depth model of the mooring/riser in place.

This recommended procedure outlines the requirements and specifications for conducting active hybrid tests. Note that dynamic positioning systems are not covered in this procedure. Details on dynamic positioning system tests can be found in Procedure 7.5-02-07-03.6 Dynamic Positioning System, Model Test Experiments.

1.1 When to use active hybrid model testing

Active hybrid model test techniques are typically used in the following situations: (1) when the physical size of a testing basin does not allow a full-depth model of a mooring/riser system to be accommodated at a reasonable scale; (2) when non-conventional mooring materials are used, for example, elastomeric mooring lines; and (3) when similitude laws cannot be satisfied, for example, Froude's law and Reynolds law are incompatible for floating offshore wind turbine tests. This procedure focuses on situations (1) and (2).

For active hybrid model tests, there is a trade-off between the model scale ratio and the scaling of mooring material properties. In general, it is recommended that the scale ratio, λ, is smaller than 100 for floating offshore platforms. However, if particular details need to be modelled, a lower scale limit may be necessary. For renewable energy systems, the scale ratio can be as small as 20.

2. PARAMETERS TO BE CONSIDERED

2.1 Model parameters

The model should be constructed according to Procedure 7.5-02-07-03.14 Offshore Floating Structure Model Construction.

2.2 Environmental parameters

Parameters related to the simulation of environmental conditions can be found in Procedure 7.5-02-07-03.1 Floating Offshore Platform Experiments.

2.3 Mooring mass and force characteristics

Every effort should be made to correctly model the quasi-static behaviour of mooring lines/risers by using an active hybrid system. A more sophisticated active system may include dynamic effects, for example, due to inertia, hydrodynamic forces and material properties.

2.4 Mooring static offset characteristics

The active system should properly represent the static offset characteristics of the deepwater moorings. The deviation of the horizontal component should be less than 5% and that of the vertical component should not be more than 3%.

2.5 Calibration of force and position measurement devices

The feedback to the active system is provided by sensors measuring the mooring forces and the position and motions of the platform. Since the performance of the active system depends on the accuracy and the response time of these sensors, special care should be taken to choose and calibrate these devices.

2.6 Test duration

Test duration is dependent on the requirements of a specific model test and it should not influence the results of the mooring modelling.

3. PROCEDURE FOR ACTIVE HYBRID MODEL TESTS

This procedure concentrates on the use of a computer controlled active system to substitute a full-depth mooring system in model tests of floating offshore structures. The active hybrid tests involve the following components:

- A numerical model for dynamic analysis of individual mooring line and/or riser in full scale should be available (e.g., Cao and Tachiev, 2013).
- A physical model of the floating platform should be manufactured at some reasonable scale.
- Actuators should be designed to simulate the mooring forces on the platform model.
- Cables or ropes may be used to link the actuators with the platform model.
- Sensors should be used to measure the mooring forces and displacements/motions of the platform.
- The actuator control system should be in real time.
- Data acquisition systems will collect all the data, including feedback sensor measurements.

3.1 Environmental calibrations

Environmental calibrations of waves, currents and winds should be performed according to Procedure 7.5-02-07-03.1 Floating Offshore Platform Experiments and Guideline 7.5-02-07-01.1 Laboratory Modelling of Multidirectional Irregular Wave Spectra.

3.2 Numerical model for dynamic analysis

The numerical model for dynamic analysis should ideally be three-dimensional and have been validated. For risers, the numerical model should account for the bending effect and the effect of fluid flow in them, if necessary.

3.3 Linking the numerical model to the actuator

The numerical model for dynamic analysis is linked to the control system in the active hybrid model tests.

Note that there are delays due to computations, communications and actuators. The control system should be adequately responsive to the physical phenomenon with the shortest characteristic period.

3.4 Actuators

An actuator is a mechanical system that can be in various forms. The primary characteristic of such a system is essentially a force or displacement applied to the physical platform model.

As an example, the system can be a computer controlled winch that controls the length of a cable or an actuator arm that moves a fixed length of cable or rod.

Actuators should be calibrated to ensure that the control system outputs the desired force-displacement (velocity, acceleration, angular) characteristics.

3.5 Actuator set-up

The point of application of the actuator force is recommended to be at the fairlead for the mooring line or the connection point for risers. A single actuator may be used to simulate the entire mooring and/or riser system. In this case, the point of application of the actuator may be quite different from the actual fairlead or the riser connection point. It should be demonstrated that the active hybrid system provides an adequate representation of the real system.

Care should be taken to position the anchoring point or grounding point of an actuator as it affects the mooring/riser force acting on the platform model. Efforts should also be made to ensure the angle of force application is correct.

For any active hybrid model system, the effect of actuator arrangement on the global system behaviour should be assessed and documented.

3.6 Force and position feedback

The numerical model for dynamic analysis may require the input of velocities and accelerations in addition to the measured mooring forces and displacement/motions of the platform model by sensors.

Special care should be taken to ensure the quality of signals, for example, a signal should have a high signal-to-noise ratio. The effect of other factors, such as friction, phase lag of motions and forces, on the control system, should also be minimised.

The energy dissipation, for example, due to mooring line damping, should be assessed to ensure that the control system accurately represents the actual physical system.

3.7 System verification

The active hybrid system should be verified for static and dynamic performance. The verification should take the form of comparison with accepted data based on one or more standard tests such as tests determining force-displacement curves, decay tests, or tests with a regular wave input. Measurements in the model tests may be compared to numerical simulation results, benchmark experimental data (model or full scale). The level of agreement to be achieved with the reference data should be documented.

3.8 Data collection

In addition to any required data based on the purpose of an active hybrid test, such as mooring line tensions, mooring line extensions and six degree-of-freedom motions of the floating platform, the following quantities should be measured:

- the input signals to the actuator
- actuator forces/moments at the point (or points) of the application on the model
- actuator motions (displacements and rotations) and velocities

4. UNCERTAINTY ANALYSIS

Many parameters cause uncertainties in active hybrid tests. Sources of uncertainties can be found in the work of Qiu et al. (2014).

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

Cao, Y. and Tahchiev, G., 2013, "A Study on an Active Hybrid Decomposed Mooring System for Model Testing in Ocean Basin for Offshore Platforms", ASME 2013 32nd International Conference on Ocean, Offshore and Arctic Engineering.

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.

Ye, M., Duan, M., Li, M., Chen, J., Tian, K., Han, F. and Hu, Z., 2014. "An Active Truncation Method for Simulating Deep-water Riser Installation", Ships and Offshore Structures, Vol. 9, No. 6, 619–632.