ITTC Quality System Manual

Recommended Procedures and Guidelines

Procedure

Floating Offshore Platform Experiments

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Floating Offshore Platform Experiments

1. PURPOSE OF PROCEDURE

The use of model tests is generally recommended to verify and validate the expected global performance of floating offshore platforms. This may involve (1) validation of design assumptions and critical design response parameters, (2) validation of the numerical design tools, and (3) verification of the expected platform performance under design, operating and accidental conditions, and under installation conditions to discover unexpected system behaviours.

Model testing of floating offshore platforms is particularly helpful in the verification and analysis of effects due to extreme environmental conditions, extreme responses, non-linearities, complex mechanisms, and coupling of hull and its mooring system and/or dynamic positioning system.

This procedure is to ensure that floating offshore platform experiments are performed according to the state of the art.

2. PROCEDURE FOR FLOATING OFFSHORE PLATFORM EXPERIMENTS

Model tests of floating offshore platforms use techniques, methodology, and standards from other ITTC Loads and Response procedures. Offshore platforms are subject to wave, current, and wind in terms of environmental conditions. In addition to the prediction of long-term statistics, extreme events are often modelled to ascertain survivability characteristics. The offshore platform could be moored or dynamically positioned, and can be tested in an operational, survival, or transit configuration.

2.1 Test Agenda and Run Matrix

Before planning the tests, a statement of the test objectives and a test matrix are required. Judicious use of computational tools can help reduce the extent of the test matrix.

2.2 Model Geometry

A geometrically similar model of a full-scale design is constructed to a scale at which the tests can be performed according to Froude's similarity law. Small details such as anodes may be neglected, if there is minimal impact on the physical phenomenon measured. Appendages such as mooring lines/risers and thrusters need to be included. The scale ratio is often based on basin dimensions and modelled mooring system that can be fitted into the basin. Full length line models are preferred. If basin dimensions and the chosen model scale require shortening or truncation of the lines, this should be done according to Procedure 7.5-02-07-03.4 Active Hybrid Model Tests of Floating Offshore Structures with Mooring Lines or Procedure 7.5-02-07-03.5 Passive Hybrid Model Tests of Floating Offshore Structures with Mooring Lines. For further details on model construction refer to Guideline 7.5-02-07-03.4 Model Construction of Offshore Systems.

2.3 Ballasting and Loading

The model should be ballasted to the proper waterline, including trim and heel, and match the centre of gravity, and radii of gyration of roll, pitch, and yaw. The mass moments of inertia can be modelled by varying the mass distributions. If structural loads are to be measured, the actual full-scale mass distribution needs to be modelled.

The model's moments of inertia can be determined by direct measurement or by numerical tools to reduce the ballasting time. They can be directly measured by oscillating the model in air. If full-scale natural periods in water are specified, the moments of inertia of solid mass can be obtained using the theoretical added mass. Whenever possible, the calculated natural periods should be validated by in-water testing of the model.

Inclining tests should be performed to measure the metacentric height of the model without a mooring system.

Decay tests should be carried out for the model without a mooring system to determine its natural frequencies.

When the model includes mooring lines, risers or other additional weighing items, their effects on the changes of the centre of gravity, metacentric height and moments of inertia must be considered. Inclining tests and decay tests should also be performed for these configurations.

2.4 Instrumentation

The instrumentation required to measure the responses can be installed on the model. These measurements may include rigid body motions, air gap, impact pressures or loads, accelerations, and mooring line tensions. The instrumentation installed on the model is considered as part of the ballast and needs to be in place when determining the centre of gravity and moments of inertia.

Other instrumentation, e.g., wave probes and optical measurement devices, not associated with the model, should be installed in the tank at this time.

All instrumentation should be in proper working order and calibrated. The location and orientation of all instrumentation should be documented.

2.5 Calibration of Environment

The environment needs to be calibrated prior to the test to ensure the correct environment is going to be tested. The environment is a combination of waves, current, and wind, depending on facility capability and test requirements.

2.5.1 Calibration of Current

At the projected location of the model, a homogeneous current must be calibrated over the full width or a sufficiently large part of the width of the basin.

The uniform current velocity should be measured at a depth corresponding to half of the draft of the fully loaded model and at sufficient number of locations abreast of the projected location of the model.

At the projected location of the model, the distribution of the horizontal velocity in the vertical direction should be measured in the tests of a model with mooring lines/risers, as the velocity profile affects the loads on the mooring lines/risers.

2.5.2 Calibration of Waves

For the calibration of unidirectional waves, a minimum of two wave probes should be installed. One is placed at the projected model location, and then removed during the actual testing; another one, the reference probe, will be used for the wave phasing with regard to the measured signals.

The locations of wave probes relative to the model need to be reported for the calibration tests as well as during the tests. This will allow the correction of signals or phases to the reference position.

The reference wave probes used during the tests should be placed as far as possible from the model to reduce the influence of the model on their measurements.

The repeatability of the wave conditions should be carefully checked before the removal of probes relative to the model and their next installation in the basin.

For the calibration of multidirectional waves an array of wave probes should be installed. Refer to Procedure 7.5-02-07-03.14 Analysis Procedure of Model Tests in Irregular Waves for further details.

For tests involving wave-current interaction, the wave spectrum should be calibrated in the presence of the calibrated current for test duration. Note that current is typically calibrated prior to wave-current calibration.

Multidirectional/multimodal spectra should be calibrated in a similar way to that of typical spectra by considering the capability of a facility and the requirement of a client. Details of multidirectional/multi-modal wave modelling can be found in Procedure 7.5-02-07-01.1 Laboratory Modelling of Multidirectional Irregular Wave Spectra.

The target of the wave calibration is the spectral shape as specified by the client. Alternatively, acceptance criteria can be a percentage deviation from the targeted significant wave height and peak period from spectral and zero crossing analysis.

Documentation of additional characteristics should include at least:

- wave height distribution;
- wave elevation distribution;
- spectral shape of the wave grouping;
- wave grouping distribution;
- wave directions for multidirectional waves.

2.5.3 Calibration of Wind

The velocities of the air flow and its spectral contents need to be measured at the location of the model before it is installed to ensure the accuracy of the wind. The repeatability of the generated wind should be checked, and documentation on wind calibration should be prepared.

2.5.4 Calibration of External Forces

In order to simulate specific loads acting on the model, it may be necessary to generate external forces, which may include forced motion systems (e.g., actuators and hexapod), loads on superstructures, on-board moving weights (e.g., cranes, active ballasting and heave compensation devices), thrusters, and fans.

The forces must be calibrated prior to the tests in terms of its magnitude and frequencies. Setup and results should be documented, including pictures.

The calibration of mechanical actuators is preferably performed without the model in the basin or in a dedicated area. Mechanical setup, displacements, forces, and moments should be measured and reported carefully.

The calibration of a mean wind force acting on the model can be performed by adjusting the velocity of the air flow while measuring the mean horizontal forces and the overturning moments on the model. A loading curve with respect to wind speed is then obtained to determine the target values. The wind velocity is usually measured for at least 30 minutes in full scale at the projected location of the offshore platform, at a level of 10 m (full-scale) above the water level. The measurement of the loads may require a dedicated mechanical setup involving a separate jig or stand.

2.6 Positioning of the Model

The model should be positioned at the test location with minimum wave reflection and distortion. All mooring and restraint lines should have been calibrated and installed by this time. Restraint lines should be soft, elastic lines that allow motions, but restrain excessive drifting. The spring stiffness of the restraint lines should be based on the natural period consideration, i.e., the restraint system's natural period should be at least one order of magnitude greater than the lowest wave period and model natural periods.

The power/data umbilical should be installed at this time with minimum restraint on the motions of the model. As an alternative, wireless data transfer systems may be used.

2.6.1 Installation of the mooring system

Each individual mooring line should be free from possible coil before installation. Possible plastic deformation of the mooring line and the model chain(s) under expected loading should be avoided.

The static load-displacement curve for each individual line should be validated and documented. Dynamics of each mooring line may be checked before connected to the model.

After the static and dynamics characteristics of each line have been validated, all the lines will be connected to the model. The line pretensions and the model position should be measured and documented.

The static load-displacement curve of the whole system must be measured. The model will be horizontally pulled in a quasi-static manner and the line forces and the model displacements will be recorded. To check if there is a hysteresis effect in the static load-displacement curve, from the maximum offset to the initial position of the model, the pulling force will be quasi-statically reduced. The measured load-displacement curve and its comparison with theoretical results should be documented.

In addition, care should be taken to ensure the characteristics of the mooring system, such as line stiffness and anchor points, remain unchanged during the tests.

2.7 Collection of Data

The sample rate should be high enough to capture the physical phenomenon being measured, e.g., 25 Hz is inadequate for impact loads, but acceptable for pitch motions. The sample rate should be more than twice the highest frequency of interest. Generally, the data are low pass or band pass hardware filtered. The cut-off frequencies should not eliminate desired data. The sample rate should be consistent with the hardware filters to avoid step functions in the data.

Data acquisition systems should be calibrated and verified to ensure the quality of measurements, i.e., precision and accuracy. Efforts should be made to synchronize the measured signals and data. Furthermore, the test runs must be long enough to collect a statistically valid sample.

2.8 Data Analysis

In determining the motions for regular wave analysis, the average amplitude and period of at least 10 cycles should be obtained. See Procedure 7.5-02-07-03.2 Analysis Procedure for Model Tests in Regular Wave. Alternatively, a spectral analysis following the procedures outlined below for irregular waves could be followed to obtain the amplitude and period characteristics of waves and responses.

Energy spectra of waves and relevant responses should be produced through spectral analysis. In addition to the spectral analysis, statistical analysis should be performed to calculate the mean, maximum, minimum, and the mean of the 1/3 highest values. Details can be found in Procedure 7.5-02-07-03.13 Analysis Procedure for Model Tests in Irregular Waves.

Analysis procedures should be thoroughly documented to ensure reproducibility.

2.9 Presentation of Results

Results can be presented in dimensional or non-dimensional form. Dimensional results can be in model scale or full scale (preferably); however, this must be clearly documented.

The results of statistical analyses can be presented in histograms to depict probability density, and as cumulative probability distribution plots for selected responses.

Tabular presentation of all results should be made in addition to plots. Tabular data should also include statistical data such as maximum, minimum, mean, standard deviation, and mean 1/3 highest values for each channel for each run.

Care needs to be taken to demonstrate the problems associated with transient phenomena either during the tests or during the analysis.

In the presentation of data, it is recommended to include the uncertainty analysis results corresponding to a specified confidence level.

2.10 Pre-Test Considerations

2.10.1 Sign Convention

In consultation with the client, sign conventions should be established for the basin, model, and appropriate instrumentation. These should be documented graphically and in writing. In the absence of specific instruction, a right-hand-rule convention should be used.

The basin-fixed global coordinate system and the model-fixed coordinate system should be described and documented. For example, the origin can be located at the midship section of a ship-like platform model, with positive z upwards, and positive x from the stern to the bow. The vertical origin could be chosen on the waterplane at a specified draft.

2.10.2 Instrumentation Verification

Following the model and instrumentation installation, and prior to experiment commencement, the performance and sign convention of all transducers and gauges will be verified by applying a known load or displacement. The process will be recorded through the data acquisition and stored for quality assurance purposes. This verification process will indicate whether the transducer/gauge is functioning according to the calibration and conforming to the defined sign convention. Adjustments should be made to the non-conforming devices, prior to testing.

2.10.3 Calm Water Acquisition

Prior to running a wave test, a data acquisition should be done in calm water with measurements from all channels. This will provide a record of “zero” levels for all pre-experiment transducers and may be useful in identifying electronic drift later in the experiment. It will serve as an additional transducer check and provide a record of basin standing wave conditions. Additional calm water runs can be acquired throughout the experiment, preferably at the beginning of each day.

2.10.4 Channel Priority

In consultation with the client, the instrumentation will be prioritized. This will aid test staff, in the event of a gauge malfunction, to prioritize the repairs.

2.10.5 Transducer Re-zeroing

Instrumentation that requires re-zeroing should be identified in consultation with the client. Re-zeroing can be carried out prior to testing each day, as required.

2.10.6 Shakedown Run / Online Analysis

Prior to commencing the test programme, a sample wave should be run to verify the performance of the model, mooring, and instrumentation. The measurements will be used to fine-tune the online analysis command procedure. The online analysis will consist of time trace plots of all measurement channels along with basic statistics for each one. The online analysis should be performed and checked following each test run. This is to ensure that instrumentation functions as expected.

2.10.7 Acquisition from calm water

When the test program commences, it is important that the data acquisition for each run starts from calm water. This will serve as an additional check on the performance of instrumentation and will ensure that indication of zero-drift is occurring.

3. PARAMETERS

3.1 Parameters to be taken into account

The following parameters should be considered:

- test conditions
- model dimensions
- model mass and inertial properties
- model natural frequencies
- basin dimensions
- wave calibration
- wave periods and heights
- wave headings
- current calibration
- wind calibration
- mooring calibration
- method of restraint
- drift forces
- measurement equipment
- test duration
- number of repeat runs
- use of different gauges

3.2 Recommended Parameters

To obtain reliable results from offshore platform experiments, the test procedures must be followed carefully. The following points are recommended to ensure the accuracy of the experiments.

3.2.1 Test Conditions

Tests should be carried out in the metocean conditions (wind, waves and current) in which the platform may be required to operate.

Enough tests should be carried out to provide adequate data ensuring good resolution at frequencies of interest.

3.2.2 Model Dimensions

The scale of the model should be as large as practical. Care should be taken to consider effects of wall and reflected radiated/diffracted waves. Numerical analysis, for example using the potential-flow theory, can be performed to determine the size and the position of the model and to minimize these effects.

3.2.3 Water Depth

Scaling of the water depth is important in many cases due to hydrodynamic effects and for correct modelling of the mooring system.

3.2.4 Wave Calibration

The wave height (spectrum) should be measured at the location of the offshore structure model before it is installed in the basin to ensure the accuracy of the generated waves. The repeatability of the generated waves should be checked.

3.2.5 Wave Periods and Wave Heights

Wave periods and heights should be chosen based on the purpose of the tests. For example, to obtain a complete representation of linear model responses in the frequency domain, one may need to choose several wave periods and wave heights by keeping given wave steepness constant. In that case, care should be taken to minimize uncertainty especially for very small wave heights associated to short waves.

The nonlinear response of the model is often dependent on the wave height and therefore it is recommended that the tests should be run for several increasing wave heights at selected wave periods.

3.2.6 Wave Headings

When performing tests in oblique seas, the range of wave headings between 0 and 360 degrees should be selected in accordance with the stated test objectives.

3.2.7 Current Calibration

The velocities of the flow and its directions at various depths need to be measured at the location of the offshore structure model. This should be done before the model is installed to ensure the accuracy of the generated current. The repeatability of the generated current should be checked, and documentation on current calibration should be prepared. Spectral shape or standard deviation should be verified as well.

3.2.8 Wind Calibration

The velocities of the air flow and its spectral contents should be measured at the location of the model before it is installed to ensure the accuracy of the wind. The gust spectrum is the variability about the mean wind speed based on load measurements. The repeatability of the generated wind should be checked, and documentation on wind calibration should be prepared.

3.2.9 Mooring Calibration

It is generally desirable to model the non-linear behaviour of the mooring system. This can be done using a scaled model of the mooring system or reproducing the load-displacement curve of the mooring system. Whatever the approach is used, the mooring system and the load-displacement curve should be fully documented.

3.2.10 Method of Restraint

In many cases, soft mooring lines adequately model the restraint conditions. However, depending on the purpose of the tests, where space and depth permit, it is generally preferred to utilize realistic restraints that possess the correct non-linear characteristics of the mooring lines.

Safety lines should be used to prevent the model from damaging in extreme conditions. They should be left slack during runs and only pulled taut when the model is in danger. Transducers should be installed in the safety lines to mark "taut" events.

3.2.11 Drift Force

Drift forces result from cumulative wave action on a body in terms of second-order slowly varying forces and moments (Fonseca et al., 2017). During a test, drift forces and moments are measured in terms of the thruster forces or tensions on mooring lines (scaled system or soft restraint).

The duration of each test run should be sufficiently long to properly analyze the long-period responses. Additionally, data affected by transient behaviour should be discarded from the steady-state analysis.

While constant heading is desired for theoretical calculation/validation, the restraining mooring and safety lines need to be designed to allow yaw rotation about the equilibrium heading (Potthoff and Moctar, 2016, Liu et al., 2017).

Depending on the wavemaker and the generated spectral bandwidth of a sea state, wave sequences may show statistics exceeding given threshold values, which leads to the definition of a wave group, i.e., a wave sequence within a record whose characteristics, such as height and energy, exceed a given threshold value based on a theoretical wave spectrum. These sequences should be identified, quantified, and documented as they can have significant influence on slow drift oscillations. Typical grouping parameters include the spectral peakedness parameter (Q_p), the groupiness factor (GF) and the Hilbert envelope statistics. The definition of the spectral peakedness parameter can be found in the work by Goda (1976). The groupiness factor GF can be defined as the ratio of the standard deviation of smoothed instantaneous wave energy history (SIWEH) to the time average of SIWEH. Details on these parameter calculations can be found in Saunier et al. (2011).

3.2.12 Measurement Equipment

Generally, all six degrees of freedom of motion are recorded as well as mooring forces, accelerations, relative motions, and structural loads. Care should be taken when models are tested in their natural frequency range and measurements are made with mechanical connectors. In the case of such measurements, the use of non-contact measuring systems is preferable.

Development of systems that reduce or eliminate cable connections between instruments on the model and the recording system is encouraged.

Wave probes for measuring air gap should be able to withstand occasional splashing. Additionally, they should maintain its signal in steep and breaking waves.

Tests should be recorded visually by video, preferably in a way allowing scaling of time.

Photographs of the test set-up are also helpful for data analysis.

3.2.13 Test Duration

The physical phenomenon is an important factor in determining the test duration. For example, duration of about 10 cycles is normally sufficient to determine first-order motion transfer functions in regular waves, while drift force measurements require much longer duration.

For irregular waves, duration of 20-30 minutes in full scale is generally sufficient to collect a statistically valid sample for wave frequency responses. A three-hour duration in full-scale is an industry standard. Longer durations are required when measuring rarely occurring events and slowly-varying forces.

3.2.14 Number of Repeat Runs

To demonstrate the repeatability of the testing techniques selected conditions should be repeated non-sequentially. Repeat runs are subject to cost and schedule constraints.

3.2.15 Use of Different Gauges

Gauges should be carefully chosen considering the following parameters: range, precision, accuracy, and dynamic properties such as band width and modal frequencies. Precision and accuracy should be documented for uncertainty analysis. Their masses and dimensions should also be considered, especially when used in a small model.

3.2.16 Other Considerations

Tests may be performed to capture rarely occurring events, extreme conditions, and other highly nonlinear phenomena as well as for fatigue analysis. Considerations should be made on the choice of test duration and wave realization in terms of random phases and frequencies. Rarely occurring events are those with low probability or phenomena that have design implications, e.g., the 100-year storm. The structure should be able to survive such events and it is important to know the platform loading and response. See Procedure 7.5-02-07-02.3 Experiments on Rarely Occurring Events.

Long duration tests can also be carried out for further fatigue analysis.

4. VALIDATION

4.1 Uncertainty Analysis

Many parameters cause uncertainties in floating offshore platform tests. Details on the 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

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