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Prepared by	Approved
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Floating Offshore Platform Experiments

1 PURPOSE OF PROCEDURE

To ensure that floating offshore platform experiments are performed according to the state of the art.

2. PROCEDURE FOR FLOATING OFFSHORE PLATFORM EXPERIMENTS

Sea keeping 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 prediction of long term statistics, often extreme events are modelled to ascertain survivability characteristics. The offshore platform could be moored or dynamically positioned. It 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 Run Matrix are required. Judicious use of computations can help reduce the extent of the test run 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 can be neglected, as long as there is minimal impact on the physical phenomenon measured. Appendages need to be included. Often, the scale ratio is based on basin depth and amount of mooring system that can be fitted into the basin without significantly truncating the mooring lines. Truncation of lightly loaded lines is acceptable, but heavily loaded lines should be modelled to the full length.

2.3 Ballasting and Loading

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

The model moments of inertia and gyration can be determined by direct measurement or by calculation. Oscillating the model in air directly measures the moments of inertia and gyration. If full-scale natural periods in water are specified, the moments of inertia of solid mass can be obtained using the theoretical added mass.

2.4 Instrumentation

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

Also other instrumentation, e.g., wave probes, 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 was tested. The environment is a combination of waves, current, and wind, depending on facility capability.

2.5.1 Calibration of Current

At the projected location of offshore platform, a homogeneous current has to 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 offshore platform and at sufficient number of locations abreast of the projected location of the model.

At the projected location of the offshore platform, a current distribution over the vertical may be measured.

2.5.2 Calibration of Waves

For the calibration of long-crested waves a minimum of two wave probes should be installed. One placed at the projected offshore platform location, and removed during the actual testing; the other one placed abreast of the former one in order to be used for the wave phasing with regard to the measured signals.

The wave spectrum should be calibrated in the presence of the adjusted current for a duration corresponding to the test duration.

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

Documentation of additional characteristics should be made for at least:

- Wave height distribution
- Wave elevation distribution
- Spectral shape of the wave grouping
- Wave grouping distribution

2.5.3 Calibration of the Mean Wind Force

Usually with batteries of fans in place in the basin, a homogeneous wind velocity over a sufficient large area of the test set-up is adjusted. The nominal wind velocity at the projected location of the offshore platform should be measured and adjusted at a level of 10 m (full-scale) above the water level by means of a propeller-anemometer for instance.

With the installed model in the basin, the fans should be run for at least a half an hour full-scale, and the mean force is measured. Measuring the mean horizontal forces and vertical moment on the model may require a separate jig or stand. The measured force is compared with the target wind force. If necessary, the RPM of the fans are adjusted to obtain the specified mean wind force without overloading the fan.

2.6 Positioning of the Model

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

The power/data umbilical should be installed at this time and impose the minimum restraint on the motions of the model.

2.6.1 Installation and static load-deflection curve of the mooring system

Each individual line should be free from possible coil in the mooring leg before being laid out. Additionally, there should be no possible plastic deformation of the spring and in the model chain(s) under expected loading.

To verify individual mooring line load-displacement curve, each line will be pulled out in the basin and connected to the exact location of the anchor point. Then by means of a dummy platform for each individual line the chain force versus the horizontal displacement of the "platform" in the direction of the line has to be determined and compared with the theoretical one (static load-displacement curve for the individual lines) and documented. Normally the (small ring-shaped) force transducer in the chain is incorporated in the top end of the line close to the turret attachment point. Alternatively, underwater load cells at the anchor points could be used.

After all lines have been adjusted, they will be connected to the offshore platform during the positioning of the model in the basin. Then the pretensions are measured and documented.

Finally the static load-deflection curve of the total system has to be measured (assuming a symmetrical system). For these measurements the model will be horizontally shifted in a stepwise manner. During the static load-displacement measurements the individual chain forces, the horizontal force as measured by the transducer incorporated in the platform and displacements (as measured with a model tracking system) will be recorded. The model will be shifted a distance that corresponds to the breaking load of the heaviest loaded line. The measured and theoretical results will be documented.

From this extreme position of the platform, the pulling force will be stepwise reduced and the same signals as before will be measured. This static load-displacement curve may show possible hysteresis effects in the mooring legs. The results should be documented.

Additionally, decay tests should be made on the platform with and without mooring to determine natural frequencies. An inclining experiment should be performed to measure metacentric height. The results should be documented.

2.7 Collection of Data

Once the model is ballasted, instrumented, calibrated, and in position, the test matrix can be carried out. The data should be collected digitally whenever possible. The sample rate should be high enough to capture the physical phenomenon being measured, e.g., 20 Hz is inadequate for impact loads, but acceptable for pitch. The sample rate should be at least 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.

Furthermore, the test runs must be long enough to collect a statistically valid sample. Typically, one to three hours full-scale irregular seas is an acceptable duration limits, see section 3.2.13. Repeated runs are suggested.

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. 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. See Procedure 4.9-03-05-03.2 Analysis Procedure for Regular Wave Tests.

Energy spectra of waves and relevant responses should be produced through spectral analysis using either the indirect method of Fourier transformation of the autocorrelation function, or the direct method of splitting the record into suitable blocks and subjecting these to Fast Fourier Transform.

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. Techniques utilised to smooth spectral shapes, such as block overlapping, should be documented in the presentation of the results. When reporting statistics of wetness, the number of events and number of encounters should be reported independently, as well as the overall statistics.

2.9 Presentation of Results

Responses should be presented in a non-dimensional form. Linear motions may be divided by wave amplitude, and angular motions by wave slope. Phase angles should be given in degrees and increases in resistance and propulsion parameters may be presented in non-dimensional forms defined in Reference 1. Accelerations should be made non-dimensional by $L/(g\varsigma_a)$, where L is the characteristic length. The results should be plotted to a base of $\omega\,(L/g)^{1/2}$ or $\omega_e\,(L/g)^{1/2}$.

For tests in irregular waves, the energy spectra of wave and motions should be shown plotted against $\omega_e\,(L/g)^{1/2}$ or $\omega\,(L/g)^{1/2}$.

The results of statistical analyses should 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 maximum, minimum, mean, standard deviation, and mean 1/3 highest values for each channel for each run.

3. PARAMETERS

3.1 Parameters to be Taken into Account

The following parameters should be taken into account:

- Test Conditions
- Model Dimensions
- Basin Dimensions
- Wave Calibration
- Wave Periods and Heights
- Wave Headings
- Current Calibration
- Wind Calibration
- Mooring Calibration
- Method of Restraint
- Drift Forces
- Measuring Equipment
- Test Duration
- Number of Repeat Runs
- Accuracy of the Different Gauges
- Presentation of Results

3.2 Recommendations of ITTC for Parameters

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

<u>3.2.1 Test Conditions.</u> Tests should be carried out in environments appropriate to the sea conditions in which the platform may be required to operate. In the absence of specific wave

spectrum data, an ITTC spectrum should be used.

A sufficient number of tests should be carried out to provide adequate data for a minimum range of wavelengths from $0.5L_M$ to 2.0 L_M and ensure good resolution of resonant areas.

3.2.2 Model Dimensions. The scale of the model should be as large as is practical. Offshore model testing does not have wall interference in the traditional sense. Large models can generate reflections that contaminate the incoming wave. Beach reflections and model radiation contaminate of the incoming wave as well. Such contamination is more a problem for regular wave testing. Reflection contamination for irregular seas testing is considered part of the randomness and accounted for during calibration.

3.2.3 Basin Dimensions. A wide test area is needed to avoid reflection between the model and basin walls. A scaling of the water depth is important in many cases due to hydrodynamic effects and for correct modelling of load-excursion characteristics of compliant platform motions in the horizontal plane.

3.2.4 Wave Calibration. The wave height (spectrum) has to be measured at the location of the offshore structure model before it is installed to ensure the accuracy of the generated waves. Other probes, up wave and abreast the model during testing prove measurements of phasing and spatial variation as well as elevation. The repeatability of the generated waves should be checked, and documentation on wave calibration should be prepared.

3.2.5 Wave Periods and Wave Heights. In order to obtain a complete representation of the motion response amplitudes in the frequency domain, one may need to carry out as many as 20 runs depending on the purpose of the tests. The behaviour of offshore structures in waves is in general affected by non-linear phenomena. The response of non-linear systems is dependent on the wave height and therefore it is recommended that such systems should be checked for a number of wave heights at selected wave periods, including the natural rigid-body periods.

3.2.6 Wave Headings. When performing tests in oblique seas, the range of encounter angles between 0 and 360 degrees should be selected appropriately in accordance with the stated test objectives. Smaller ranges of encounter angle are appropriate for models with planes of symmetry.

3.2.7 Current Calibration. The current magnitude and direction at various depths has 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 wind field magnitude and spectral content has to be measured at the location of the offshore structure model before it is installed to ensure the accuracy of the wind. This is done by a direct load/moment measurement using the model at the mean wind speed. 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 mooring system load deflection curve. Whatever the approach, the mooring system and load deflection 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 utilise realistic restraints that possess the correct non-linear characteristics of the mooring lines.

Safety lines are prudent to prevent the model from breaking other lines in large seas. They should be left slack during runs and only pulled taut when the model is in danger.

3.2.11 Drift Force. Drift forces result from cumulative wave action on a body as mean forces and moments and as second order slowly varying forces and moments. During a test, drift forces and moments are measured by the thruster forces or tensions on mooring lines (scaled system or soft restraint).

The main consideration is making runs of long duration to collect enough data to properly analyze this long period response. Additionally, data affected by transient behaviour should be discarded from steady state analysis.

While constant heading is desired for theoretical calculation validation, the equilibrium heading angle is often desired information as well. As such the restraining mooring and safety lines need to allow yaw rotation to the equilibrium heading. This may require rearranging the restraint configuration.

Wave groupiness parameters should be measured and documented as they can have a large influence on slow drift oscillations. Also wave groupiness characteristics can be a function of the wave maker.

3.2.12 Measuring Equipment. Generally, all six degrees of motion are recorded as well as mooring forces, accelerations, relative motions and structural loads. Particular care has to 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 signal in steep and breaking waves.

Tests should be recorded visually, either by film or video, preferably in a way allowing scaling of time. Photographs of the test set up are also helpful for data analysis.

<u>3.2.13 Test Duration.</u> A run length of about 10 cycles is normally sufficient for determining first-order motion transfer functions, while drift force measurements require much longer run length due to transients.

For irregular seas runs, a run length of 20-30 minutes full-scale is generally sufficient to collect a statistically valid sample. Longer times are required if measuring rarely occurring events. Three hours full-scale is an industry standard for extremes.

<u>3.2.14 Number of Repeat Runs.</u> To demonstrate the repeatability of the testing techniques selected frequencies should be repeated non-sequentially. Repeat runs are desired subject to cost and schedule constraints.

<u>3.2.15 Accuracy of the Different Gauges.</u> Typically, different gauges have different accuracy and that accuracy is proportional to price. An uncertainty analysis will indicate which gauges would be cost effective to upgrade to improve overall accuracy most.

<u>3.2.16 Presentation of Results</u>. When presenting results from measurements the accuracy of the different gauges should be stated and the calibration procedures should be described.

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

When presenting the results the sign of the phase angle is defined by the requirement that the response shall be expressed by

$$x(t) \approx \mu + \sum_{j=1}^{M} A_j \cos\left(j\omega_e t + \varphi_j \right)$$

i.e. response lagging behind lead signal gives negative phase angle.

4. RARELY OCCURRING EVENTS

Rarely occurring events are those low probability events or phenomenon 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 response and loading. See Procedure 7.5-02-07-02.3 Experiments on Rarely Occurring Events.

4.1 Definition

Each rarely occurring event has an associated probability of occurrence. This probability is different and determined differently depending on the phenomenon causing the event. Still a response level can be formulated in terms of an exposure time and probability of exceedence. Often the platform is designed such that the probability of exceedence is at a given risk level. This risk level determines the severity of the environment in which to test.

4.2 Environment

The testing environment, wind, waves, and current, need to be able to produce the phenomenon in question, e.g., wave slap. Important non-linearities and interactions need to be included.

Also because the events are rarely occurring, more data may need to be collected to record the event. Longer collection times ensure a statistically valid data set. The use of a deterministic "largest wave" time history should be investigated carefully as it may miss possible resonant behaviour.

5. VALIDATION

5.1 Uncertainty Analysis

ITTC Procedure 7.5-02-07-02.1, Seakeeping Experiments, has an extensive uncertainty analysis section. The principles there can be applied to any response, not just heave and pitch as in the example. Reference 4 presents an uncertainty methodology that is useful.

5.2 Test - Calculation

None.

5.3 Test - Full-scale

None.

5.4 Benchmark Tests

1-1) Estimation of Ship Behaviour at Sea from Limited Observation (11th 1966 pp.426-428)

2) Spry, S.C., Empey, D.M., and Webster, W.C., "Design and Characterization of a Small-Scale Azimuthing Thruster for MOB Module", (Proc. 3rd Intl. Workshop on Very Large Floating Structures – Vol II Sep 22-24, 1999)

3) Smith, T.C., Sikora, J., and Atwell, J. "Mobile Offshore Base Model Test Design Philosophy" (Proc. 3rd Intl. Workshop on Very Large Floating Structures – Vol. II Sep 22-24, 1999)

4) Richardson, W.M. "Uncertainty Analysis for the Mobile Offshore Base Model Test" (Proc. 3rd Intl. Workshop on Very Large Floating Structures – Vol. II Sep 22-24, 1999)

5) Rodd, J.L., Devine, E.A., and Bruchman, D.D., "Physical Model Design for a MOB Hydro-elastic Test" (Proc. 3rd Intl. Workshop on Very Large Floating Structures – Vol. II Sep 22-24, 1999)

6) Stahl, R. G., "Ship Model Size Selection, Facilities, and Notes on Experimental Techniques", (CRDKNSWC/HD-1448-01 May 1995)

7) Buchner, B., "Numerical Simulation and Model Test Requirements for Deep Water Developments", (Deep and Ultra Deep Water Offshore Technology Conference, Univ. of Newcastle, March 1999)