ITTC Quality System Manual

Recommended Procedures and Guidelines

Procedure

Analysis Procedure of Model Tests in Irregular Waves

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
7.5-02-07-03.14	Analysis Procedure of Model Tests in Irregular Waves

Edited /Updated	Approved
Ocean Engineering Committee of the 28th ITTC	28th ITTC 2017
Date 07/2017	Date 09/2017

Table of Contents

Analysis Procedure of Model Tests in Irregular Waves

1. PURPOSE OF PROCEDURE

The purpose of this analysis procedure is to ensure the best possible quality and consistent analysis of model test results in irregular waves. Usually model tests in irregular waves are performed to obtain the spectral and statistical characteristics of the responses.

2. ANALYSIS PROCEDURE FOR IRREGULAR WAVE TESTS

2.1 Choice of duration to be analysed

The raw time series for analysis should be chosen by excluding the transient signals at the beginning and at the end of tests. The start and end points should be specified and documented. Note that the duration of measurement should be sufficiently larger than the one for analysis to assist an accurate definition of the initial and end transient periods.

2.2 Filtering and trend elimination

Any high-frequency noise, for example, electrical and mechanical noises, should be filtered from the response time series before the statistical or spectral analysis.

In case of low-frequency trends, high-pass filtering prior to the spectral analysis should reduce the corresponding errors in the analysis of the responses.

The filtering process should not change the phases of response signals.

2.3 Fourier analysis

The same considerations provided in the Section 2.6 of Procedure 7.5-02-03.2 Analysis Procedure for Model Tests in Regular Waves can be adopted.

The measured spectrum is commonly smoothed to reduce undesired fluctuations. This can be achieved by using the weighted averaging method either in the frequency domain or in the time domain.

If the time series contain samples in terms of continuous and singular frequency components, the multi-tapered method can be used for the Fourier analysis (Thomson, 1982).

2.4 Non-Fourier based analysis

The statistical analysis of measured signals, for example, zero-crossing analysis (ITTC, 2014), can also be carried out to obtain statistical distributions and parameters such as significant values, and maximum / minimum values.

Wavelet and Hilbert transforms can be applied to time varying phenomena such as wave grouping (Hudspeth and Medina, 1988).

2.5 Data presentation

The following items should be included in the analysis results:

- Time histories of raw input and response signals
- Chosen analysed intervals with specified start and end points
- Fitting and filtering parameters and methods

- Filtered time histories
- Wave and response spectra and their parameters
- Results in terms of RAOs, significant values, RMS, mean values, minimum and maximum values, parameters for extreme value distributions, skewness, and kurtosis
- Uncertainty analysis results

3. PARAMETERS

In order to obtain reliable results from irregular wave analysis, the irregular wave tests should be conducted by considering recommended parameters in Procedure 7.5-02-07-03.1 Floating Offshore Platform Experiments.

In addition, the parameters below should be carefully taken into account.

3.1 Wave spectrum

The obtained wave spectrum based on the time series of measured irregular waves should be compared with the targeted one (ITTC, 2002).

3.2 Directional waves

Directional wave analysis is preferably performed using the measurements by an array of 5 wave probes. As shown in Figure 1, their locations on a circle of diameter *R* depend on the main wave direction (*x*) and the spectrum peak frequency corresponding to a wave length λ. It is necessary to keep the ratio, R/λ, in the range of 0.1 to 0.5, with a recommended value of 0.2 (Benoit, 1993).

Several methods, such as Maximum Likelihood Method (MLM) and Maximum Entropy Method (MEM) (ITTC, 2002), are available for the directional wave analysis. The Bayesian Directional Method (BDM) (Hashimoto and Konbune, 1988) is recommended to ensure robustness and accuracy, despite its computational cost.

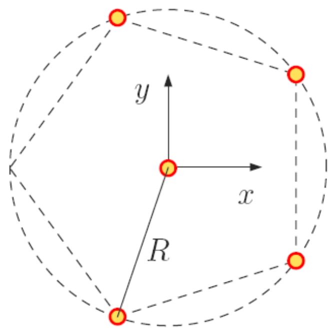

Figure 1. Locations of the five wave probes

3.3 Nonlinear effects and extremes

Nonlinear effects in irregular wave analysis can be taken into account in terms of extreme values, which are then used for extrapolation. The histograms derived from measured time series are fitted with a known probability distribution, such as Rayleigh distribution and Weibull distribution. The extreme values can then be estimated using the corresponding probability of exceedance.

3.4 Wave grouping

Wave grouping occurs in experiments when wave heights are not present in a uniform way (in time) but in groups of high waves or low waves. It can be quantified by the wave groupiness factor (Mase, 1989). Even though generated from the same wave spectrum, two time signals of wave elevation with different wave groupiness factors may lead to substantially different nonlinear effects and/or drift effects. The wave grouping analysis should therefore be performed and documented for the wave time series. An example of wave grouping analysis is provided in the Coastal Engineering Manual (2008).

3.5 Finite depth

If the water depth of the basin varies along the direction of propagation of the waves, the characteristics of the waves will be changed. For example, if the depth diminishes, the phase speed and the wave length will decrease, while the wave height and the wave steepness will increase (wave period remains constant). This wave transformation effect is known as shoaling.

Provided that the water depth of the basin varies slowly relatively to the wave lengths, i.e., the basin depth changes slowly over the longest wave length considered, the formulae to estimate the changes in wave characteristics presented in DNV (2014) can be used.

3.6 Waves in current

The spectrum of irregular waves in current should be checked against the targeted one.

3.7 Deviation from ideal condition

Any deviations from targeted conditions should be identified and documented. For example, the low- and high-frequency wave spectrum tails may be not included in the actual wave spectrum due to the limitation of a wavemaker. Wave breaking at the wavemaker can also dissipate parts of incident energy leading lower significant wave height.

Recommended spectrum modification and methods to calculate confidence intervals and tolerance intervals related to generated waves can be found in Kent and Lee, (2016).

3.8 Frequency of Encounter

Models may be towed in a towing tank to simulate the current conditions and/or towing conditions. In this case, the response spectra obtained using the measured time series are corresponding to frequencies of encounter in terms of speed and heading rather than the wave frequencies. Except for the following seas, the final results can then be presented in terms of frequency of encounter for a better understanding of the model behaviour.

4. UNCERTAINTY ANALYSIS

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

Details on the sources of uncertainties can be found in the work of Qiu et al. (2014).

5. REFERENCES

Benoit M, 1993, “Extensive Comparison of Directional Wave Analysis Methods from Gauge Array Data”. Proceedings of International Symposium on Ocean Wave Measurement and Analysis, Volume 1, pp. 301–328, New Orleans, USA,

DNV, 2014. “Environmental Conditions and Environmental Loads”, DNV-RP-C205.

Hashimoto N and Konbune K, 1988. “Directional Spectrum Estimation from a Bayesian Approach”. Proceedings of 21st Conference on Coastal Engineering, Torremolinos, Spain.

Hudspeth, R. T. and Medina, J. R., 1988. “Wave Group Analysis by the Hilbert Transform”, Proceedings of 21st Conference on Coastal Engineering, Torremolinos, Spain.

ITTC, 2002. "Specialist Committee on Waves Final Report and Recommendations to the 23rd ITTC".

ITTC, 2014. "Symbols and Terminology List".

Kent, C., Lee,S.S., 2016."Wave-breaking modification and spectral statistics of wave Spectra". 31st Symposium on Naval Hydrodynamics, Monterey, USA.

Mase, H., 1989. "Groupiness Factor and Wave Height Distribution", Journal of Waterway, Port, Coastal and Oceanic Engineering, Vol. 115, No.1.

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.

Thomson, D. J., 1982. "Spectrum Estimation and Harmonic Analysis", Proceedings of IEEE, Vol. 70, pp. 1055-1096.

US Army Corps of Engineers, 2008. "Coastal Engineering Manual", Part II: Coastal Hydrodynamic – Section II-1-3.c.(8).