ITTC Quality System Manual

Recommended Procedures and Guidelines

Procedure

Analysis Procedure for Model Tests in Regular Waves

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Analysis Procedure for Model Tests in Regular Waves

1. PURPOSE OF PROCEDURE

To ensure the best possible quality and consistent analysis of model test results in regular waves.

2. ANALYSIS PROCEDURE FOR MODEL TESTS IN REGULAR WAVES

It is recommended to perform the regular wave analysis according to the following procedure.

It should be noted that depending on the wave parameters, the regular waves generated in the basin are not expected to be purely sinusoidal, unless the wave steepness is very small. Wave nonlinearities may appear associated to steep waves such crest-through asymmetries and the presence of multi-harmonics. It is then recommended to follow Procedure 7.5-02-07-03.13 Analysis of Model Tests in Irregular Waves.

Spurious free waves from the wavemaker can contaminated the testing area in the basin. These effects should be carefully verified and controlled to guarantee high-quality wave generation (Aknin and Spinneken, 2017).

2.1 Visual inspection

During the model tests, it is recommended to examine the time histories of all the signals as well as the responses to be analysed. If a signal contains an exceptionally high noise level, it may require special treatment. Otherwise, the analysis should be done as described in the subsequent sections.

2.2 Choice of interval to be analyzed

The time interval to be analysed should be chosen carefully. It should start after the transients and it should end before the reflected waves reach the model. In case of long start-up transients, one may have to accept wave reflections to maintain a minimum number of wave cycles. The final choice may be a compromise.

Unwanted reflected waves are produced by the interaction of incoming waves with tank walls and wave absorbers, at non-zero incidence. Radiated or diffracted waves from the model may also be reflected by tank walls, wavemakers and wave absorbers. Such phenomena must be minimized, especially for zero-speed tests.

The choice of interval can be manually done during a visual inspection process. This process may be assisted by estimating the arrival time of the reflected wave from the absorbing beach based on the wave group celerity, i.e., the wave energy velocity.

2.3 Number of cycles to be analyzed

For the determination of transfer functions a few wave cycles are, in principle, sufficient. Generally, the numerical accuracy is improved by increasing the number of cycles. It may be necessary to find the optimum compromise among the quality of the waves, the length of the recording, and the available time in a facility.

In practice, a number of cycles between 10 and 20 is recommended for the determination of transfer functions. The lowest value depends on the wave conditions and the basin. For responses with a long natural period and important non-linear effects, such as slowly drifting motions of moored structures, a much larger number of cycles will normally be required.

2.4 Determination of Fundamental Period

The fundamental period should be obtained from the time histories and should be used for the analysis of all the responses.

There are several methods available for the determination of fundamental period (Cohen Tenoudji, 2016):

a) to perform a spectral analysis of the time histories and derive the peak frequency,
b) to choose the start and end points in the time history, and divide the time duration between start and end points by the number of cycles. Most laboratories use this method for preliminary analysis. The resolution of this method depends again on the record length and can be seriously affected by the presence of noise unless special precautions are taken, e.g., neglecting too short and/or small cycles.
c) Alternatively, a non-linear least squares fitting of a multi-harmonic theoretical signal can be carried out by minimizing the error:

$$\varepsilon^2(\omega, \mu, A_j, \varphi_j) = \frac{1}{N}\sum_{i=1}^{N}\left[x_i - \mu - \sum_{j=1}^{M} A_j \cos(j\omega t_i + \varphi_j)\right]^2$$

where ε is the error, μ is the mean value of the signal, A_j and φ_j are the amplitude and the phase angle of the *j*-th component of the signal, ω is the fundamental frequency of the signal, x_i, respectively, *M* is the total number of components, *N* is the number of time instants, and t_i is the *i*-th time instant.

This function is non-linear only in terms of ω for which, normally, a good initial estimate is known (i.e., the expected fundamental frequency). This method is robust and still accurate even for short records (for example, 3 cycles) and records with large amount of noise. Furthermore, the fitting function accepts several components with different phases and does not need an integer number of cycles to obtain the mean value and component amplitudes. Note that other non-linear fitting methods are available and may be used.

2.5 Filtering and Trend elimination

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. A simplified version of the high-pass filtering is 'trend elimination', which subtracts not only the mean value, but also a ramp function, determined by the mean slope of the response signal in the time interval to be analysed.

2.6 Fourier analysis

After the considerations above have been considered, the amplitude of the input signal, and the amplitude and phase angle of the responses should be determined by a standard Fourier analysis.

If the input signal is not measured at the same point of the response signal, the signal or the phases can be corrected by applying the linear dispersion relationship for the given flat bottom water depth. Note that in very shallow water (water depth less than 1/10 of the wave length) the incident waves and responses may not be sinusoidal. Note that in certain conditions, the incident waves and responses may not be sinusoidal. Nonlinear effects will add higher harmonics to wave components. Those nonlinear effects may be due to high wave steepness (bound higher order components), wavemaker stroke (free higher order components), or shallow water effects (water depth less than 1/10 of the wave length).

3. PARAMETERS

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

4. UNCERTAINTY ANALYSIS

Many parameters cause uncertainties in regular wave 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. PRESENTATION OF RESULTS

The following items should be included in the analysis results:

- Time histories of raw input and response signals
- Chosen intervals with specified start and end points
- Fitting and filtering parameters and methods
- Filtered and fitted time histories
- Results in terms of amplitude and phase at each harmonic component, for example, first-order to third-order results
- Uncertainty analysis results

6. REFERENCES

Aknin, D., Spinneken, J., 2017, "A laboratory investigation concerning the superharmonic free wave suppression in shallow and intermediate water conditions", Coastal Engineering, 120, pp., 112-132.

Cohen Tenoudji, F, 2016. Analog and Digital Signal Analysis: from Basics to applications, Modern Acoustics and Signal Processing, Springer, 618p, DOI 10.1007/978-3-319-42382-1

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.