RANDOM WAVES IN THE LABORATORY – WHAT SHOULD BE EXPECTED FOR THE EXTREMES?

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The prediction and reproduction of extreme ocean waves is a difficult task, since they are rare events, and therefore hard to observe in the real ocean. To try to understand all the underlying mechanisms, and the resulting physics, can be confusing, since there may be a number of various conditions leading to the different events actually observed. Ideally, perfect theoretical and physical models should therefore be able to cover a broad range of situations. Such modelling does still not exist, although there are several approaches that include essential linear and nonlinear components and properties. Thus the challenge in present day-to-day applications is to sort out which are the most relevant properties to be modelled, and how to model them. This may vary from application to application, but there are also general patterns. In the present paper, the generation and interpretation of wave extremes in physical model testing is discussed.

There are a number of questions to be handled in connection with laboratory reproduction of extreme wave events. One of them is: What should we expect – or, in other words, what is our reference? This question may be two-fold: 1) What is required from the application?, and 2) what is actually possible, given the laboratory frame? And furthermore, can we learn something about the wave physics itself from the experiment? Some key words in this process are:

- Parameters selected for reproduction
- Input from full scale or theory
- Methodology (Stochastic vs. deterministic approach; Synthesisation etc.)
- Basic physics vs. laboratory effects
- Simplifications

Some practical examples from the experience in an offshore model test basin are presented in the paper. Here a stochastic approach is followed, with synthesisation and physical generation of random storm records (typically of 3-hours duration or more, full scale). Thus, the extremes occur as random events in the scaled wave field, as a result of the random summation of a large number (thousands) of independent input components. Nonlinear effects observed in the records are then mainly interpreted as results from nonlinear couplings in the actual propagation of the laboratory wave field, although one has to be aware of possible laboratory defined effects. Another approach which has been suggested and applied in the literature, is the design and use of single deterministic,

transient wave groups with very specific extreme value properties. The two different approaches may in certain situations be considered as alternatives to each other, but it is perhaps more fruitful to treat them as complementary, since they are based on quite different background philosophies.

The examples shown in this paper include wave elevation time series records from 3-hours storm conditions generated in a large wave basin, at various locations. As ”reference” standards we have chosen to use predictions based on linear as well second-order random wave models. The latter has in recent years been shown to agree quite well with field data, although there are questions regarding the highest (and rarest) extremes. Also in these laboratory examples, a reasonable comparison with the second-order model is seen in most cases, although the model slightly underpredicts the highest extremes in unidirectional storm waves. A better comparison is seen in directional waves.

However, it is also observed that in narrow-banded unidirectional wave trains propagating more than about 10 – 15 wave lengths (which can happen in a very long wave tank, or in very small scale testing), energetic wave groups may sometimes grow and focus in a nonlinear way. This is considered a result of nonlinear dispersion, and particularly high extremes may occur. These are still quite rare events, but the measurements indicate a systematic behaviour. They are clearly repeatable, and are seen to follow Froude’s scaling laws. Links to theoretical predictions in the literature can also be found (”modulational instabilities”). Whether they are possible candidates to explain ”rogue” waves, still has to be clarified, but it seems reasonable that under certain circumstances they could also happen in the open sea. Based on this experience one should be aware that in unidirectional wave generation for model testing applications, random extremes at particularly large distances from the wavemaker can become relatively high, and that this is, in average, probably a conservative effect relative to full scale expectations. But the reality of full scale rare extremes is still not well enough understood.