Editorial

Selected Papers from the Future Paths and Needs in Wave Modelling Workshop

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As an outcome of the International Workshop “Future needs and challenges in wave modelling”, held by SINTEF in Trondheim, Norway, 21–22 October 2019, this Special Issue includes 10 full Journal scientific papers [1–10] and two Technical notes [11,12], which have been prepared based on a selection of the Workshop presentations. All publications were peer-reviewed according to Journal standards by international experts. Originally 27 Workshop presentations were given, including four keynotes, attended by altogether 58 participants.

The aim of the Workshop, and thereby also of this Special Issue, was to present recent research and development within the field of ocean waves modelling, and on the basis of this, to clarify current and future needs. The broader background for this can be depicted by the increased human activities related to the oceans for energy, food, transportation, and other purposes, as well as the expected climate changes for which we have to be prepared. This requires an increased focus on new and improved research tools and infrastructure in the field.

The present contents include results and discussions of theoretical, experimental, and numerical tools. It is obviously an ambitious task to cover this wide area, which comprises a variety of quite different challenges. We believe that the final 12 publications reflect quite well the diversity in this field. Most of the works deal with needs in the modelling of local wave fields (phase-resolving methods), while large-scale wind-driven wave spectra over large ocean areas are also addressed.

Brief overview of the topics. In the following we shall highlight some main topics emphasized by the authors.

Ocean Wave Spectra; Wave Directionality

Cavaleri et al. [1] present a critical analysis of the state-of-the-art approach within 3D ocean wave spectrum modelling, which forms the input to all ocean engineering and naval architecture applications in the local modelling relevant to structures. It is argued that many major developments were made 25 years ago and earlier, and there is now a need to step forward. Predicted maximum Hs-values from today’s models sometimes underestimate real field measurements. Spectra alone are strictly not enough, and the spectral resolution should be improved to uncover more details. Suggestions are made for possible future alternative approaches.

Ponce de León and Osborne [2] address the multidirectionality occurring at low and high wave frequencies as a result of 4-wave nonlinear interactions, observed from simulations based on their numerical model. Mas-Soler et al. [3] present promising results on estimating directional spectra from laboratory vessel motion measurements (thereby being independent of dedicated wave sensors), using an improved Bayesian wave inference procedure.
Interaction Wind/Waves and Current/Waves

A better representation of the dynamic two-way interaction between the wind and propagating wave fields is needed according to [1]; the two fields should preferably be considered as one integrated domain. This also includes the wave breaking phenomenon. Accomplishing this aim is clearly a more complex task than today’s models but is highlighted as a long-term goal.

Also, currents influence the waves and waves influence the currents. Bratland [11] describes the increased wavelength and celerity in third-order wave theory by defining a wave-driven shear current, arising in addition to the well-known second-order Stokes drift. Comparisons to Computational Fluid Dynamics (CFD) are shown, and floater responses derived from such computed time-varying current forces seem to compare reasonably well with model test results. Furthermore, the challenges in properly defining a current field are addressed in [1].

Nonlinear Modulations, 4-Wave Interaction, and Breathers

A state-of-the-art technology in efficient nonlinear 3D wave propagation modelling over large areas (for which, e.g., CFD would be computationally impossible) needs to capture 4-wave interactions (quadruplets) [1,2,4]. Osborne [4] gives a thorough mathematical description with related examples of illustrative results of one related particular analysis method and physical phenomena, namely nonlinear Fourier analysis and breathers. These mentioned types of models predict modulational instabilities, i.e., nonlinear wave grouping formation, leading to spatial development of 3D spectral changes and possibly extreme waves. Gudmestad [12] recommends further investigation of these effects for a better understanding of extreme waves for engineering design.

Nonlinear Extreme and Steep Waves; Kinematics; Area Effects

In model testing for design load estimation in given sea states, it is important to represent relevant wave events, critical for such design loads, and numerical models must properly take into account nonlinear effects such as the above mentioned nonlinear wave-wave interaction [1,4]. Ideally, for efficient testing one should only include critical events that are important for the design loads [5,6,12]. Extreme crests are clearly non-Gaussian, and a set of point observation data in 17 m depth show extremes well above both second and third-order models [1]. For a proper understanding of extreme waves and crests, the latter reference also highlights the need to look for extremes over an area as well as over time, in which case “freak” wave observations may not be that freak anymore. This effect is also highlighted in the numerical study by Bitner-Gregersen et al. [7].

The understanding of wave-structure interaction for proper load modelling in extreme conditions is a subject of continuing research. Not only the extreme crest heights, but also the extreme local steepness or slope of individual energetic wave events matter for the impact on structures. This is addressed in Stansberg [5] where correlations between local front steepness estimates and resulting wave-in-deck impact loads from a model test are demonstrated. The maximum orbital velocity in such waves, closely related with the local slope, is another critical parameter addressed in van Essen et al. [6]. Historically, obtaining good estimates for near-crest steep wave kinematics has been a challenge and therefore clearly on the “wish list”; the present work shows informative comparisons between spatial field diagrams from CFD and Particle Image Velocimetry (PIV) experiments.

Statistical Scatter due to Finite Records in Time and Space

Given the random nature of ocean waves, estimates of finite-wave record characteristics such as significant wave heights, maximum crests etc. are random variables, with statistical variability uncertainties defined by the record duration and/or spatial area (i.e. the amount of information available). This is important for engineering design, for which probabilistic methods are applied. A thorough numerical study on the variability in linear and nonlinear (second-order and third-order) wave records is carried out in [7]. Time-
domain as well as spatial finite sampling are addressed. Clear and quantified variability effects are demonstrated which should be considered within engineering applications; the effects are strongest for the third-order model. A related random scatter is seen in the wave/load correlation study in [5]; the variability is even stronger there because of the very strong nonlinear wave-structure slamming physics.

**Advances in Model Testing Techniques**

Spurious waves. Wave generation by paddles or flaps will also lead to unwanted laboratory-defined “spurious” wave components, which has been a topic for development in the wave basin community for some decades. In Lykke Andersen et al. [8], the effects from spurious waves on active absorption, in the case of generation of oblique waves from a segmented wavemaker, is numerically investigated. With the expected future increased focus on multidirectional wave generation, such and similar effects will need more attention.

Integration with CFD and other numerical models. The outcome from model testing is greatly enhanced when combined or integrated with numerical models (CFD or other). Several examples on this are demonstrated in [6]. One point of note is the increased reliability that can be achieved for both physical and numerical results. Furthermore, the combination gives a better physical insight, particularly for physical effects that are hard to measure in the laboratory. Spatial flow effects are one such example, while there is a variety of other applications. These types of combined studies are expected to become even more important in the future.

Non-stationary wave record generation. In testing with random waves, it is common to assume and simulate waves that are stationary over, e.g., 1 or 3 h (full scale). However, there are cases where this is not a reasonable choice. Kerpen et al. [9] have developed a procedure where they divide the time axis into segments with different water levels and different wave steepnesses. The results turned out to be important especially when varying the steepness. The study opens with a discussion on model testing methodology and criteria.

Efficient testing including screening of critical events. Proper estimation of design load and response from random wave tests (or numerical simulations) quite often requires an extremely large amount of model test (and/or numerical) data for robust extreme value statistics, such as in slamming for example. A need to establish improved procedures for identifying and running tests with critical wave events only is addressed in [5,6,12]. A possible choice for a critical wave parameter for screening is investigated in [5], where correlations against wave-in-deck model test impact data are recognized despite the type of random scatter that is typical for such data.

**Nonlinear Waves in Shallow Water**

The understanding of ocean waves approaching a shore, interacting with an area with varying bathymetry in finite and shallow water depths, is expected to become more and more important with increased human activities along coastlines. Eldrup and Lykke Andersen [10] present a numerical study of nonlinear regular waves on a submerged shoal in finite and shallow water. Their focus is the wave shoaling and de-shoaling before and after the shoal, and the effects from wave nonlinearities. The separation into “free” and “bound” waves is studied, and their results are compared to previous results in the literature.

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