A Numerical Investigation of Three Dimensional Extreme Water Waves

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This thesis presents a new numerical model that is capable of providing the first fully nonlinear computations of extreme ocean waves arising within directionally spread seas. The calculations are fully three-dimensional and allow both the water surface elevation and the underlying water particle kinematics to be predicted. The proposed formulation builds upon the unidirectional model proposed by Craig and Sulem (1993), developing a new approximation of the Dirichlet-Neumann operator for the propagation of the water surface. Using a similar approach, a new and efficient numerical method is developed for predicting the internal flow field from the properties of the wave surface.

To validate the numerical procedure, comparisons are made between the model available experimental data, which confirms that the model can reproduce all the characteristics of an evolving wave-field. On this basis, the model is applied to the description of extreme ocean waves, derived from the statistical New-Wave theory applied to a JONSWAP spectrum. The results from the simulation of extreme waves show the significant effects that both directionality and water depth have on the evolution of large events. This is followed by a detailed analysis of the wave energy, in particular the study concentrates on the changes in the directionality within the wave groups and the movement of free-waves energy outside the initial spectral range.

The thesis concludes with an examination of two areas of direct engineering relevance: Firstly there is growing interest in the physics underpinning the formation of wave groups that disperse slowly, including the formation of ‘freak’ waves. Secondly, the model is used to calculate the forces, including the nonlinear inertia terms, acting on a vertical surface-piercing cylinder. The contrast between these results and common design practice highlights the importance of using a fully nonlinear, directional model in design.