Surface Waves on Veritcally Sheared Currents

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This dissertation presents a study of the interaction between finite-amplitude, surface water waves and co-linear currents. In contrast to previous studies, the present interest lies solely in depth-varying currents possessing large near-surface vorticity within depth-decaying vorticity distribution.

A new perturbation analysis is presented which provides a first approximation to the wave-current interaction. The model is shown to provide a good description of laboratory data provided by Swan, Cummins & James (2000) and of results from a numerical formulation. These comparisons confirm that the near-surface vorticity leads to an important modification of the dispersion relation. The results also suggest that the vorticity leads to an important modification of the dispersion relation. The results also suggest that the vorticity distribution may lead to a significant change in the water-surface profile, with an associated increase in both the maximum water-particle accelerations and the maximum horizontal water-particle velocities. Comparisons with constant-vorticity solutions also suggest that it is important to model the entire vertical distribution of the current.

The study also addresses the initial interaction between regular waves and current, where results of a new laboratory investigation are presented. A further series of experiments concerning random waves has also been conducted and provides new data describing the changes in the variance spectra of water-surface displacement and of horizontal water-particle velocity. Comparisons between both data sets and a new solution based upon conservation of total energy flux confirm that the vertical structure of the vorticity is again critically important in defining the nature of the wave-current interaction. N both cases the wave-induced changes in the current are shown to be significant.

Finally, a new numerical formulation has been developed to predict the evolution of two-dimensional, transient wave events on currents possessing an arbitrary distribution of vorticity. The model is applied to the description of extreme wave groups generated on a stable current and to the description of amplitude modulations within a regular wave train resulting from stream-wise current variations. Both these applications represent the first calculations of their kind.