Numerical and physical experiments of wave focusing in short-crested seas

Félicien Bonnefoy, Pierre Roux de Reilhac, David Le Touzé and Pierre Ferrant
Laboratoire de Mécanique des Fluides, Ecole Centrale de Nantes, France
pierre.ferrant@ec-nantes.fr

Introduction

The evolution of extreme waves due to the focusing of several wave components is studied both in laboratory experiments and simulation. Our main concern here is to deterministically reproduce in a wave basin a large wave event that could have been measured in the open ocean or in our case generated preliminary in the wave basin. Whereas the classical use of linear backward propagation and transfer function of the wavemaker leads to good results in small amplitude waves, this approach obviously fails at larger amplitudes and hence needs further improvement.

The estimation of the nonlinear phase velocity is the key point for accurate reproduction of deterministic wave trains, see e.g. the iterative technique of Clauss et al. (2). In two dimensions, the direct iterative corrections of the wavemaker motion frequency components (1) have furnished a first attempt to improve the reproduction both for experiments and numerical simulations using a fast and accurate fully nonlinear spectral model. This original model reproduces the complete 3D wave basin with perfectly reflecting sidewalls, damping at one end to simulate the physical beach and generation process by imposing an inlet flux condition on the opposite boundary of the domain. A novel approach is considered here where the nonlinear phase speed is evaluated from the generation of the wave packets with the determined input (crest focusing $\eta$) and the $\pi$ radians out of phase input (trough focusing $\eta_\pi$). Correction of the wavemaker motion with this adjusted phase velocity shows considerable improvement of the reproduced wave field. In three dimensions, arrays of probes are generally too coarse to produce reliable results from a spatial Fourier Transform so an alternative approach is investigated to deduce the wavemaker motion.

In two dimensions

The difference between the wave packet generated from the linear or second order decomposition input and the target event is believed to be due mainly to the nonlinear increase of phase velocity by four wave resonant interactions as predicted in (4). The linearised surface elevation $\eta_{\text{odd}} = (\eta - \eta_\pi)/2$ (e.g. (3)) is interpreted here as the superposition of components with the linear input amplitudes and phases but modified phase velocity (or wavenumbers). This linearised wave elevation turns out to be useful for evaluating this nonlinear phase velocity. Figure 1 presents

![Wave elevation graphs](image)

Figure 1: Wave elevation: target (--), initial input(--) and corrected input (•••) (left: linear input, right: second order input)
the simulated surface elevation at the focusing location for the reproduced wave packets, from both the initial input and the nonlinear phase velocity corrected input. Comparison with the target elevation shows the better agreement obtained with the nonlinear correction.

**In three dimensions**

A first step towards directional deterministic reproduction is achieved. The target wave field is a directional wave packet, measured in a wave basin with five probes, set in a truncated pentagon shape commonly used for laboratory irregular directional wave analysis. This target is seen as the linear superimposition of directional waves, with a single direction per frequency. The Fourier Transforms of the five recorded surface elevations form the RHS of a set of nonlinear equations

\[ a \ e^{-ik(x_p \cos \theta + y_p \sin \theta)+\phi} = TF(\eta_p) \text{ for } p = 1 \text{ to } 5 \]

where the unknowns are the amplitude \(a\), the direction \(\theta\) and phase \(\phi\). This system is solved with a nonlinear least squares method where initial guess for the three unknowns is provided respectively by the mean of the probe Fourier modulus, a gaussian random angle with estimated mean direction and spreading and a random phase. Local minima are expected so several solutions are computed with different initial guess and the solution is selected for the reproduction as the one that minimises the time integral squared errors between target surface height and linearly reconstructed elevation on the five probes. We finally obtain a set of directional components that is linearly propagated backwards to the wavemaker to calculate its motion. In case the requested direction of the wave is too high regarding the dimensions of the basin, the wavelength and the capabilities of the serpent-type wavemaker the Dalrymple method is used to control the motion and avoid spurious reflection on the sidewalls. Figure 2 shows a view of the target and reproduced wave fields at \(t = 33s\) before the focusing event. Most of the frequency and directional contents of the wave packet are correctly estimated by the described method.

Figure 2: View of the target wave field (left) and the reproduced one (right)

**References**


