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Wave Group Evolution, Wave Deformation, and Breaking: Simulations Using *LONGTANK*, a Numerical Wave Tank

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ABSTRACT

Non-linear, planar wave trains have been simulated numerically using an efficient computational method. This method utilizes matrix diagonalization, based on multi-subdomains. The waves are created by a wavemaker at one end and followed to downtank distances, x/λ of $O(10^2)$. High resolution of wave shapes has been obtained.

This numerical tank, LONGTANK , has been used to study non-linear sideband growth, strong group evolution, wave deformation, energy redistribution in the deformed waves, and jet formation (breaking). Comparisons of steepness at breaking and distance to breaking, as they depend on wave steepness, have been made, with excellent agreement. Similar agreement is shown between simulated and photographed wave shapes in the final stages of breaking. A criterion for the onset of breaking is suggested by the simulations.

NOMENCLATURE

- ω : Angular frequency
- D : Water depth
- k : Wave number in linear theory ($\omega^2 = gk \tanh(kD)$)
- λ : Wave length ($2\pi/k$)
- a : Wave amplitude (half of vertical distance from wave crest to preceding trough)
- C_p : Phase velocity of initial wave
- C_g : Group velocity of initial wave
- $/_o$: Denotes initial wave

INTRODUCTION

In connection with energetic waves in the ocean, there is now great interest in planar wave groups, and wave deformation and breaking within such groups (Tulin and Li, 1992). The nonlinear processes at work, leading to breakdown, are largely not susceptible to analysis. For the understanding of these processes, numerical simulation is therefore required.

The progress of real waves under unstable conditions leads to strong spatial variations. The downtank distance (x/λ) over which these nonlinear processes occur increases with decreasing initial wave steepness (a_ok_o), roughly as $(a_ok_o)^{-2}$. Experiments show (Su and Green, 1985) that distances, (x/λ), of order 10^2 are required. This is roughly 1 order of magnitude larger than numerical tank lengths achieved to date (Dommermuth et al, 1988; Grilli et al, 1989; Cointe, 1990). In these prior investigations, the waves were created by a wavemaker at one end and absorbed at a beach on the other. In Cointe, for example, approximately 400 nodes, over 10-15 wavelengths, were distributed on the free surface; the quadratic increase in computing time with tank length prevents longer computations.

Here we have developed a two-dimensional numerical wave tank, called *LONGTANK*, Fig. 1; featuring multisubdomains, Fig. 2a; tank lengths (x/λ) up to 120 have been achieved, utilizing

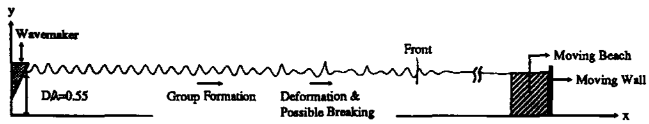

Fig. 1 Wave train generated by wavemaker in numerical wave tank — *LONGTANK* (schematic)

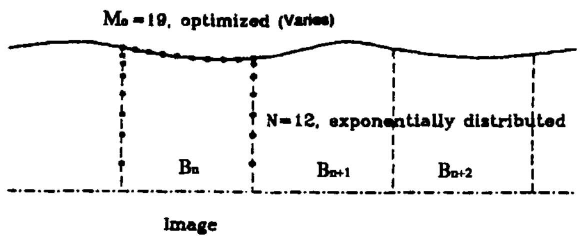

Fig. 2a Multisubdomain division (n = 1, ... , K-2; schematic)

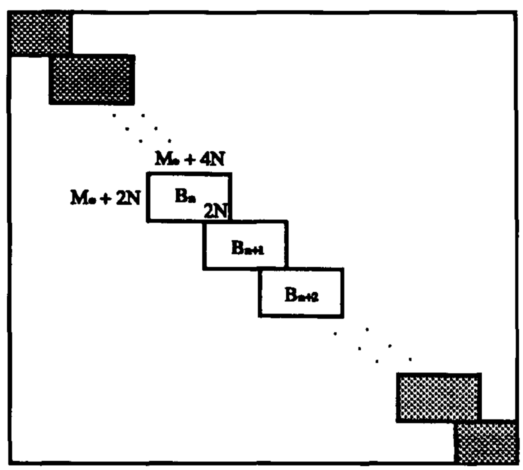

Fig. 2b Matrix block diagonalization resulting from multisubdomain division (schematic)

5000 nodes on the free surface. The waves are generated by a wavemaker at one end; a moving beach is placed beyond the front of the complete wave group, which is generated in time, and this beach damps the smaller fast waves beyond the front.

LONGTANK, which operates on an IBM 9000, has been used to calculate the progress of unstable, deep-water wave systems (a

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KEY WORDS: Wave group evolution, wave deformation, wave breaking, numerical simulation, multisubdomains, *LONGTANK*.