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Modeling of Velocities in Giant Waves

S. P. Kjeldsen
Norwegian Maritime Academy, Trondheim, Norway

W. M. Drennan
Rosentiel School of Marine and Atmospheric Science, University of Miami, Miami, Florida, USA

M. G. Skafel
National Water Research Institute, CCIW, Burlington, Ontario, Canada

ABSTRACT

The unexpected occurrence of unusually large waves has been documented on numerous occasions. In this study, the nonlinear packet-focusing technique, modified to account for an opposing current, is used to generate steep, plunging waves in a laboratory flume. The kinematics of these waves are measured just upwave of the onset of plunging. These results are compared to those of a superposition model, a modified stretching model and a model based on a Stokes 3rd-order theory developed for the present study. The present model represents the velocity beneath the plunging breakers significantly better than the other two models.

INTRODUCTION

Extremely large waves, though rare, have the potential to cause massive damage to ships — see, for example, Nickerson (1993). These waves, often termed freak and giant waves (twice and 2.5 times the significant wave height, respectively), are being documented more and more, but much remains to be learned about them.

Very little is known about the statistics of freak waves and giant waves and even less of the dynamic conditions under which they occur. Nonlinear interactions among individual waves travelling within a group have been identified as an important mechanism in the formation of giant waves in the ocean (Kjeldsen, 1984). Further, it is now well documented (Kjeldsen and Myrhaug, 1980; Irvine, 1987; Kjeldsen, 1991) that situations in which nonlinear wave groups interact with strong opposing ocean surface currents can lead to the formation of freak waves and giant waves. In this paper, we investigate the kinematics of these large waves on an opposing current in laboratory tests, and propose a new kinematic model which best describes them.

EXPERIMENTS

In order to investigate the kinematics of wave groups travelling on an opposing current, a set of experiments was conducted in the large wave tank at the Canada Centre for Inland Waters. A mean flow (U_M) of 0.040 m/s (±10%, away from the walls and bottom) was used for the experiments in addition to no flow.

The water surface elevation was measured to within ±2 mm using 4 capacitance wave staffs. The velocity was measured with an acoustic Doppler current meter (Sontek ADV-1) mounted horizontally on the carriage (Fig. 1).

The focus of the tests was to measure the kinematics in the wave crest just prior to breaking. Kjeldsen's technique (1982), with modifications to include current, was used to generate the waves. This nonlinear wave generation technique causes a wave group to coalesce at a predetermined location in the tank. Typically, the current meter was less than 1 m upwave of the point in the tank where the front face of the crest became vertical, marking the start of plunging.

LABORATORY RESULTS

Surface Profiles

Examples of water surface profiles just upwave of breaking, normalized by the peak wave number k_o, are shown in Fig. 2a. The plunging waves were very repeatable even in opposing currents. The waves were clearly very steep, with crest-front steepnesses in the 0.25-0.41 range (I.A.H.R./P.I.A.N.C., 1986). In comparison with these laboratory steepnesses, crest-front steepnesses of freak waves measured with wave radar were in the same range on the Norwegian Continental Shelf (Kjeldsen, 1989) and in the North Sea (Sand et al., 1989).

In Fig. 2b, examples of time series of velocity normalized by

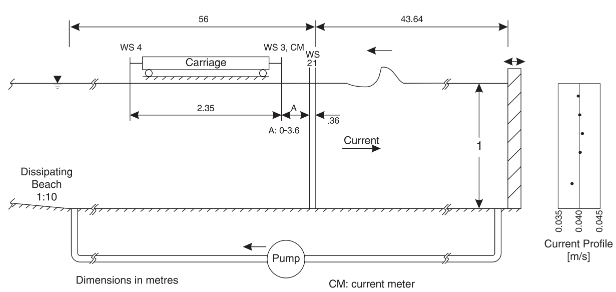

Fig. 1 Sketch of CCIW wind-wave flume showing location of wave staffs and current meter. Tank is 100 m long and 4.5 m wide. Vertical profile of current, 3.6 m downstream of WS2, shown in panel on right.

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