Violent Sloshing

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Abstract

Steep standing waves forced by strong vertical motions of a tank are described from experiments and with numerical solutions. Comparisons between the two are better than might be expected.

Standing waves are of importance since they may be responsible for the highest wave crests near reflective coasts or in 'confused' seas. Thus they might impact on the underside of structures such as jetties or oilrigs causing damage. Here we present part of a combined experimental and computational study which is reported in more detail in the preprint, Bredmose *et al.* (2002), available from the publications list at

www.maths.bris.ac.uk/~madhp

The waves reported here are generated by sinusoidal vertical motions of a rectangular tank of dimensions 1480 × 400 × 750 mm^3 (length × width × height), mounted on the Earthquake Shaking Table Facility of the University of Bristol's Civil Engineering Department. Such motions are usually described as Faraday waves and for less violent forcing there is a large literature (reviewed by Miles & Henderson 1990). Breaking Faraday waves are described by Jiang, Perlin & Schultz (1998) who find two types of very steep wave crests that break: sharp crests and crests with flat tops. We use more violent shaking and appear to have less influence of surface tension. The following figures illustrate the motions observed before strong breaking occurs.

Benjamin & Ursell (1954) showed that sinusoidal vertical forcing leads to instability and the growth of standing waves with a period twice that of the forcing period. In order to have an initially deterministic evolution of the flow a small sinusoidal 'seed' wave was generated by horizontal displacement before the vertical forcing was applied. The photographs in the figures are frames taken from a video of the experiment.

Two numerical models were used. For the initial motion the Boussinesq equations extended by Wei *et al*. (1995) and Wei & Kirby (1995) were extended to include the forced motion of the tank, which required special boundary conditions at the walls. Derivation of Boussinesq equations requires an assumption of small wave slopes and waves long compared with the depth. However, as may be seen from the comparison shown in figure 1 this approach gives good results until the wave slope reaches unity. Previous experimental comparisons for these equations have all been for travelling waves.

The second modelling method is for the fully nonlinear irrotational flow using the boundary-integral solver of Dold & Peregrine (1986), see also Dold (1992), extended to include the forcing vertical acceleration. The initial state for this computation was taken from the Boussinesq computation at an early time when the waves had gentle slopes. A comparison with later stages of the same experiment is shown in figure 2. Although there are some slight discrepancies the waves are well described until the final crest shows a very rough surface.

In both sets of computations some smoothing was required to allow the computation to proceed as far as the final pictures show. These flows test the limits of the numerical and mathematical models. Figure 3 is beyond our present limit for another experiment: the photos start where a sharp crest has collapsed to a thin vertical sheet of water, and show the rise of a flat-topped crest. The rise and fall of the crest of the flat topped wave is very close to free-fall for almost one period of the forcing motion. Similar flows have been computed from slightly different initial conditions.

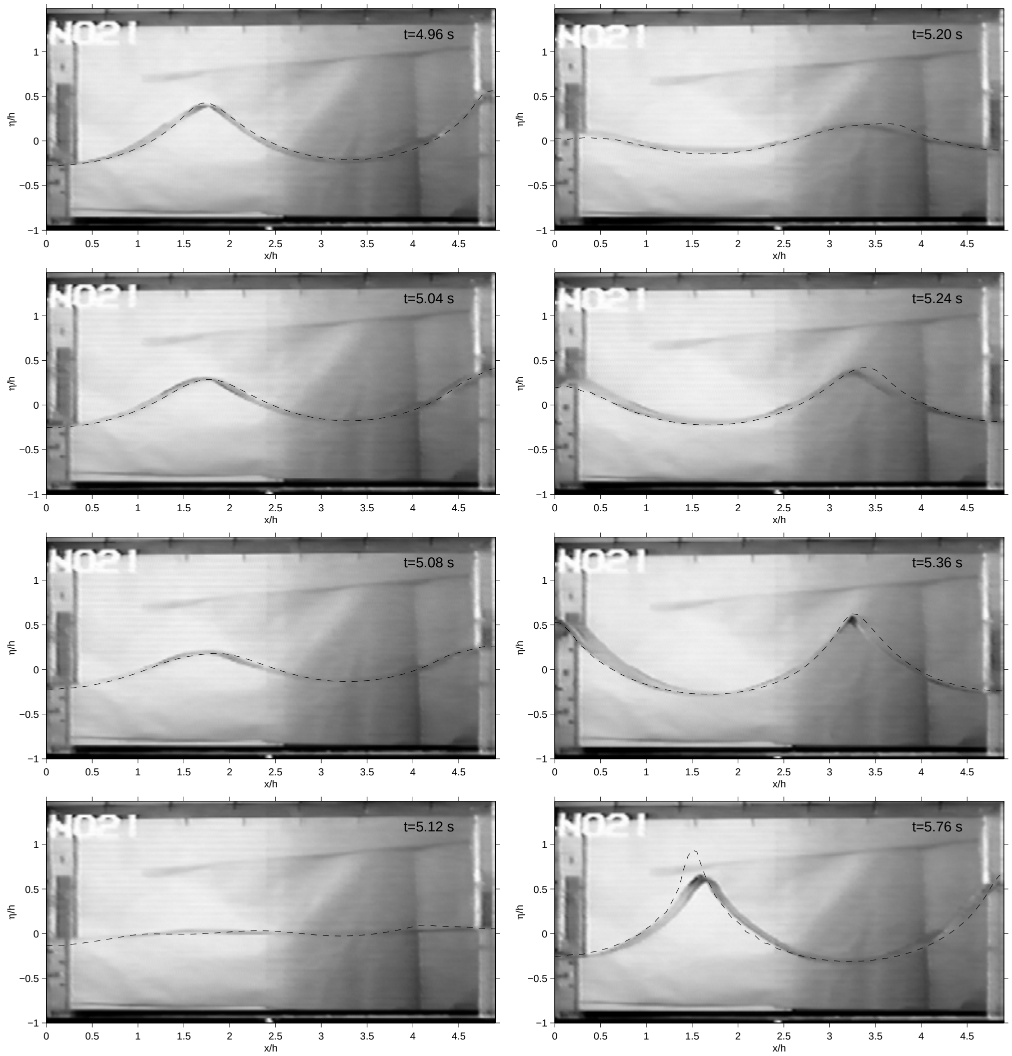

FIGURE 1. Comparison of numerical and experimental results, experiment V4N021 (Boussinesq solver). From top to bottom and from left to right a sequence of snapshots taken by a regular-speed video camera (25 frames per second).Initial water depth 150 mm. Time values are given in the upper right corner of each image.

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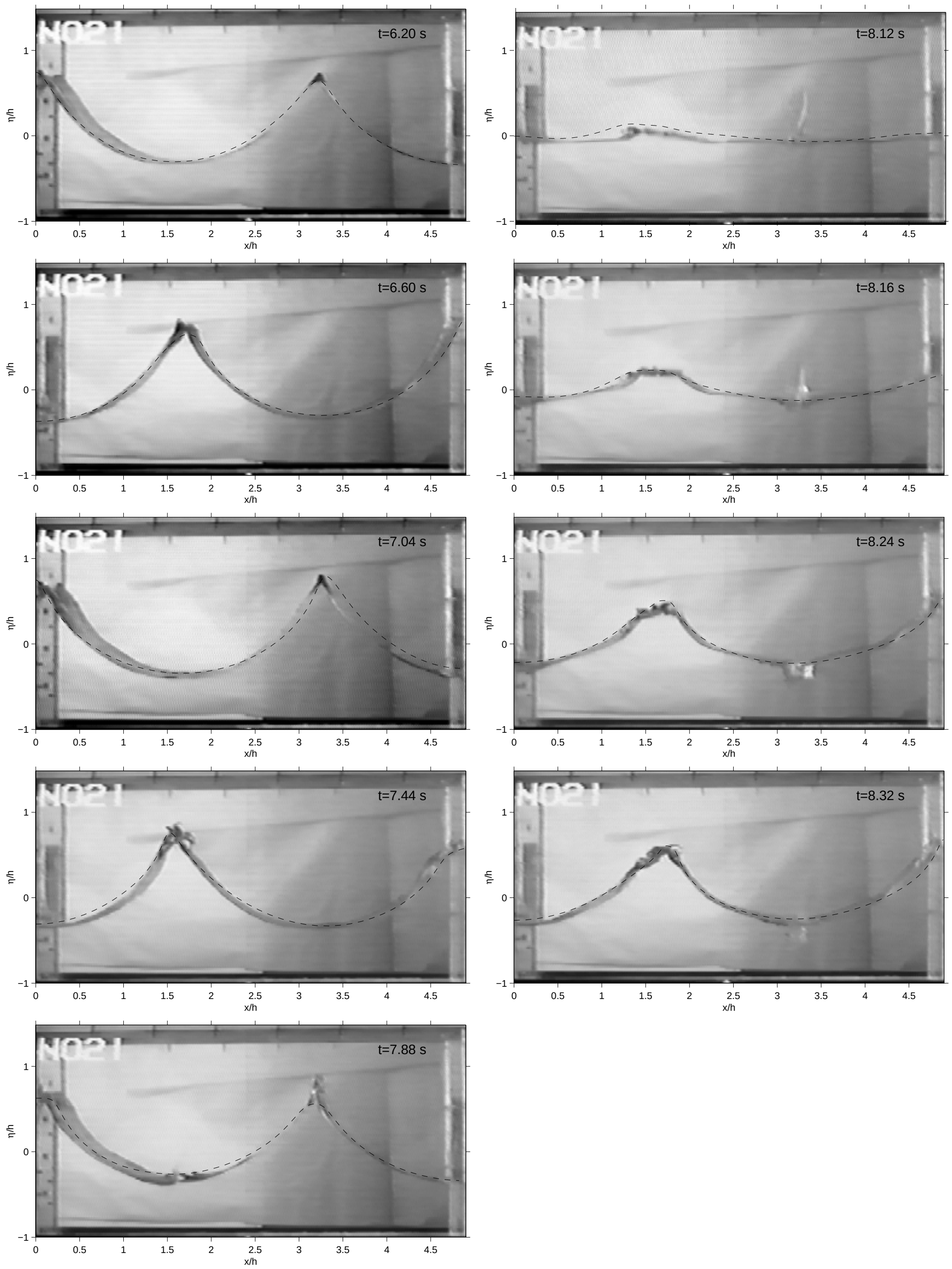

FIGURE 2. Comparison of experimental results and numerical results of an irrotational flow solver, experiment V4N021, continuing from figure 1.

BREDMOSE, H., BROCCHINI, M., PEREGRINE, D.H. & THAIS, L. 2002 Experimental investigation and numerical modelling of steep forced water waves. *Preprint* 30pp.

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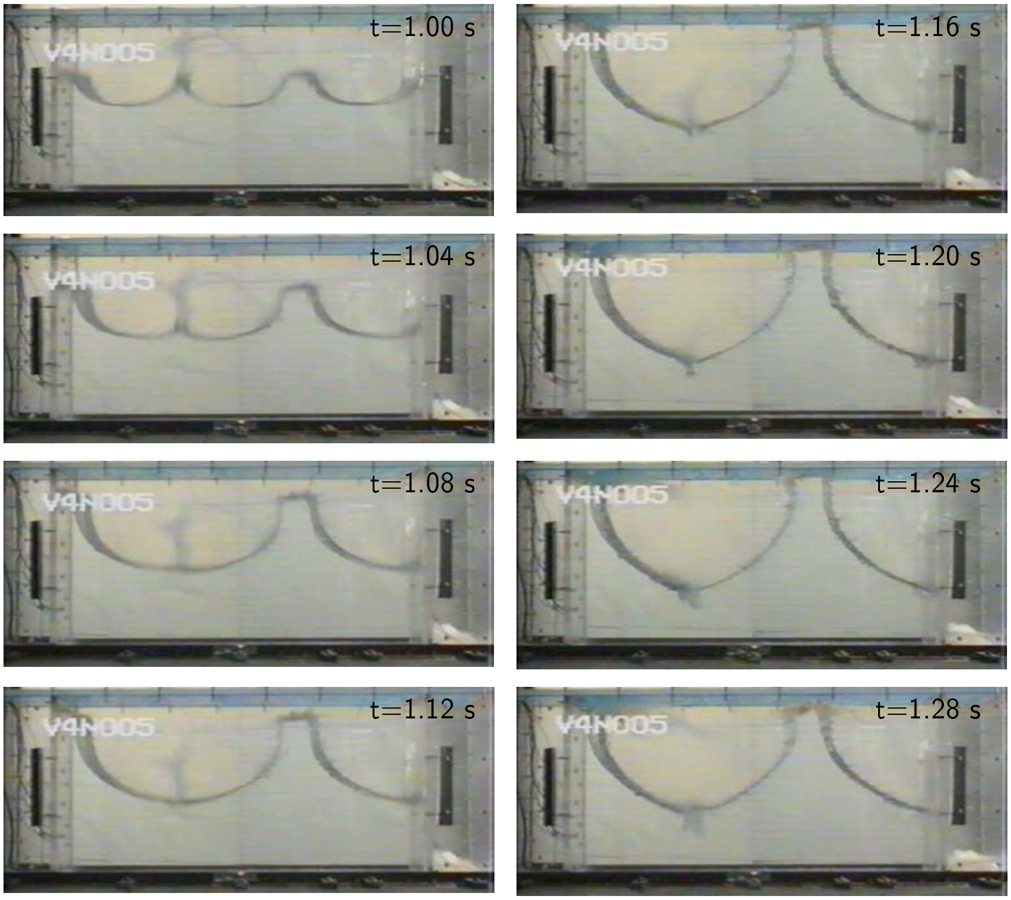

FIGURE 3. Vertical shaking. From top to bottom and from left to right sequence of snapshots taken by a regular-speed video camera (25 frames per second). Initial water depth 400 mm. Experiment V4N005.

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Discussion Sheet

Abstract Title :	Violent Sloshing		
(Or) Proceedings Paper No. :	04	***Page :***	013
First Author :	Bredmose, H.		
Discusser :	Kazu-hiro Mori		

Questions / Comments :

Didn't you observe any 3-dimensionality in your 2-D sloshing experiment? How wide is your experimental tank?

Author's Reply :
(If Available)

The tank was 400mm wide. Three-dimensional effects were observed. However, before splashing occurred they were only at the scale of the meniscus.

Questions from the floor included; Alexander Korobkin & Fritz Ursell.