Generation of Long Waves in Laboratory

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Abstract: A consistent theory is presented for generating arbitrary, finite-amplitude, long waves at any location in a two-dimensional, constant-depth wave tank using a vertical paddle-type wavemaker. The theory consists of solving an inverse evolution problem of the Korteweg–de Vries equation; given specific initial data the boundary motion that produces that data is determined. The theory also suggests the appropriate method for calculating the force on the wavemaker. Application of this theory allows for the laboratory generation of very detailed single waveforms at arbitrary lengths away from the wave-maker; this formalism obliterates the limitations of the existing shallow-water wavemaker algorithms which can only reproduce wave motions either of periodic or of constant form. A series of laboratory experiments is described where relatively arbitrary single waves are specified as initial data, the theory calculates the correct boundary motion, the waves are generated and then compared with the initial data as appropriate. The experiments also demonstrate the limitations of this theory, which, even though capable of generating the leading wave emerging after a long wave breaks, it cannot model the details of the tail of the breaking wave.

Introduction

The generation of long waves is a classic problem in applied mathematics and it has been studied extensively in account of its fundamental applications in many fields. In coastal engineering it arises in the study of tsunamis, storm surges, and other long free-surface waves.

The process of long-wave generation is now well understood. Scott-Russel (1844) described a number of generation methods many of which are still in use. However, most long waves are generated by moving partitions. Various aspects of this process have been studied by Havelock (1929), Kennard (1949), Biessel and Suquet (1951), Gilbert et al. (1971), and Chwang (1981), who determined the free-surface motion for forced small-amplitude gravity waves using linear theory. The theory developed by them is now referred to as the wave-maker theory; it describes wave generation using a vertical moving partition, the wave plate, and it has been verified in the laboratory in the classic study of Ursell et al. (1959). It is only applicable when the plate motions are small; the boundary conditions are applied at the initial plate position rather than at its instantaneous position. Chwang (1983) presented a perturbation solution to the third order, only valid for very small times after the initiation of motion.

The initial value problem of forced finite-amplitude waves has received considerable attention after the work of Gardner et al. (1967) that led to the development of the transform of Ablowitz, Kaup, Newell and Segur, also known as the AKNS transform (Ablowitz et al. 1974). In the context of water-wave theory, it has been discussed in detail by Peregrine (1966, 1967), Madsen et al. (1970), Segur (1973), and Hammack and Segur (1974).

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