Short-Crested Waves in the Laboratory and Related Phenomena

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Steep, short-crested waves, as well as a large variety of three-dimensional propagating wave patterns have been created in our laboratory in two separate facilities, utilizing a plunging half-cone wavemaker. Monochromatic waves, over a range of wave frequencies and amplitudes through breaking and including soliton wave groups near resonance, have been observed and studied in a small wave flume (3' x 3' x 70'), utilizing wave wires and photography. More recently, stochastic short-crested wave spectra simulating the Pierson-Moskowitz spectra have been produced in a large wave tank (14'W x 8'D x 175'L). Appropriate theoretical analyses have been conducted.

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In the case of monochromatic driving, the shaped wavemaker produces waves which propagate according to the well-known dispersion relation:

$$k_n^2 = [(\omega/g)^2 - (2\pi n/l)^2]^{1/2}$$

where k_n is the n^{th} mode, down-tank wavenumber; and l is the tank width. The wave corresponding to $n = 0$ is a planar wave. Larger integer values of n correspond to cosine wave patterns across the channel; these are symmetric with regard to the centerline for n, integer, and asymmetric for n, half integer. For each frequency, ω, there exists a value of n sufficiently large that $2\pi n^*/l > \omega^2/g$, so that k_n is imaginary, and the modes decay down-tank. Therefore, only a finite number of modes for $n < n^*$ will result in propagating waves; in general, the higher the wave frequency, the greater the number of propagating modes. At frequencies corresponding to the zeros of k_n (cut-off frequencies), free waves exist in a purely transverse (sloshing) mode; these are resonance frequencies near which very large amplitudes may be expected at the wavemaker.

Even in the case of two-mode propagation, the waves produced are interesting: diamond-shaped patterns propagate in such a way that the amplitude of individual wave crests oscillate with distance down-tank. As a result, intermittent breaking can be caused to occur at specific locations away from the wavemaker. The amplitude patterns have been measured with wave wires (for both 2 and 3 mode propagation) and compared with theoretical predictions (based on a linearized slender-body theory of wave generation at the wavemaker). These predictions included the effect of viscous damping due to the tank walls (Ursell). Good agreement was found away from resonance and in the absence of wave breaking (which heightens the down-tank dissipation).

In the neighborhood of the first cut-off frequency, strong non-linear effects were observed. Symmetric-standing sloshing waves generated at the wavemaker spontaneously form a moving hump (soliton), which propagates very slowly down-tank. The hump then builds up again in time at the wavemaker and the process is repeated. Systematic data taken near cut-off shows that soliton propagation occurs only for a sufficiently large stroke (amplitude on-set), and that both the amplitude and propagation speed of the soliton then increase linearly with wavemaker stroke. The amplitude on-set is not predicted by existing non-linear (third order) theory. A curiosity observed in the experiments is that the planar mode is suppressed at the first cut-off frequency.

When operated between the first and second cut-off, the conical wavemaker was used to produce steep and breaking waves. The inception of breaking was found to occur over a range of wave steepness, from a minimum (consistent with other experiments, and decreasing with short-crestedness) to a maximum (close to the

Stokes limiting steepness). Breaking was observed to occur, providing: (i) the wave steepness exceeds a threshold (minimum) value; and, simultaneously, (ii) the propagating wave crest reaches a maximum and begins to decline. This latter condition would normally be difficult to observe in nature, but was observed in these tests because of the special nature of the propagating wave patterns created by the shaped wavemaker. These observations suggest a new criteria for the inception of breaking.

The shaped wavemaker has been used to generate stochastic seas in a large wave tank (14'W x 8'D x 175'L) and a scaled Pierson-Moskowitz directional spectra has been produced. Data and video are presented.