EXPERIMENTAL STUDY ON CRITICAL RESONANT STATE OF UPSTREAM-ADVANCING WAVES

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INTRODUCTION

The interaction among surface waves, current and uneven bottoms is interesting and meaningful when the steady fluid flow travels over the periodic wavy bottom. In coastal regions, this situation may occur when the tidal or river currents pass through the corrugated topography (particularly the periodic sandbars or periodic artificial submerged structures) in shallow water areas such as river inlets and litoral zones. With this interaction, upstream-advancing waves are generated by steady flow over series fixed sinusoidal beds with specific range of the flow velocity, water depth and bottom steepness. The phenomenon of these waves shows the state of instability and the resonant interaction relationship among surface waves, steady flow and periodic wavy bottom. Furthermore, the critical flow velocity and critical relative water depth which stimulate the maximum wave height of upstream-advancing waves were observed through the modified physical experiment. These precise critical values will provide more accurate evidence to reflect the resonant interactive conditions and the most unstable state.

STATIONARY WAVES

Linear solution of the stationary wave profile by flows over sinusoidal bed extending to both far upstream and downstream was presented firstly by Lamb (1932). The profile of the free surface elevation η is given as the equation (1), in which, k is the wavenumber of sinusoidal bed, b is the wave amplitude of sinusoidal bed, h is the mean water depth (b < h) and U is the steady flow velocity.

$$\eta = \frac{k}{\sqrt{U}} \cdot \frac{\sinh k h}{\sinh k b}$$

The profile expression shows that it will exist a critical speed \(U_c\) as the equation (2) at which the amplitude of the surface elevation becomes unbound or infinite of sides, the relationship between free water surface profile and wavy bottom profile is out of phase if \(U \leq U_c\) and in phase if \(U \geq U_c\). It should be noted that the waves mentioned above are stationary wave profiles which do not propagate upstream or downstream. Mei (1969) made a nonlinear analysis and obtained the steady states for the critical case. It shows that the amplitude of the free surface is finite at the critical velocity and the free surface amplitude can be triple-valued near the critical speed.

INSTABILITY BY RESONANCE

Binnie (1960) observed the self-induced waves by steady flow through an open channel with vertical corrugated sides. In his experiment, continuous trains of waves were formed and upstream-advancing waves with long with eight fixed standard width sinusoidal bottom corrugations which are 24cm wavelength and 8cm wave height.

The experiment was divided into eight groups. In each group, the water depth was fixed and the flow velocity was increased from low values with small increment intervals, then the water depth was adjusted by different groups. It should be noted that the steepness of the sinusoidal wavy bottom is 0.31 (the maximum slope is 1.05 correspondingly).

KEY RESULTS

The free-surface waves were generated and propagating upstream with a small range of current velocities along with the strong oscillation of the water body above the wavy bottom.

I. The distribution of the wave amplitudes with the change of flow velocity

The amplitudes of upstream-advancing waves surge to a maximum value rapidly at a critical flow velocity and decline sharply during the growth of the flow velocity (with negligible current).

The wave gauges also measured small wave components with the same frequency of upstream-advancing waves in the downstream area.

II. The influence of the variation of water depth

• The upstream-advancing waves will not be generated when the ratio of water depth to bottom wavelength is larger than 1/4. The maximum wave height can rise to a peak value and drop down with the increase of the water depth. Besides, the current velocities which excite the maximum upstream-advancing waves in each group shift towards larger magnitudes as the water depth increases.

III. The period and existence of upstream-advancing waves

• The existence of upstream-advancing waves is smaller than the region from Kyotoh (Fig.12).

• The periods of the waves are concentrated between 1.2s~1.5s (Fig.12).

EXPERIMENTAL APPROACH

The experiment has been carried out in a large scale wind-wave-current flume. The flume is 80m long, 1.0m wide and 3.5m deep along with eight fixed standard width sinusoidal bottom corrugations which are 24cm wavelength and 8cm wave height.

The flow was generated by pumps and its velocities were adjusted with an interval of 1 cm/\(\text{s}\). The water depth relative to the bottom wavelength varied from 0.6 to 1.4. Then the water wave profiles were measured by 14 cap flow wave gauges along the length of the flume.

REFERENCES


