Free-Surface Flows over an Obstacle Problem Revisited

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Abstract: Two-dimensional steady flow of a fluid over a bottom obstacle is considered. The fluid is assumed to be inviscid and incompressible; and the flow is irrotational. Both gravity and surface tension are included in the dynamic boundary condition. Far upstream flow is assumed to be uniform. Fully nonlinear problem is formulated for positive (bump) and negative (dip) obstacles by using a boundary integral equation technique. The resulting integrodifferential equations are solved iteratively by using Newton's method. For a positive obstacle, Forbes and Schwartz (1982), Vanden-Broeck (1987) and Forbes (1988) investigated this problem numerically without the effect of surface tension for subcritical, supercritical, and critical flows, respectively. In case of subcritical flow, there exist two types of solutions for which the first type is characterized by a train of nonlinear waves behind the obstacle and the other is a drag-free solution corresponding to the geometry of the obstacle. When the Froude number F decreases to its critical value F_c, the amplitude of the nonlinear waves of the first solution decreases and ultimately vanishes, which is the so-called drag-free solution. This solution exists where $F < F_c$. When surface tension is included, there is an additional parameter in the problem known as the Bond number B. Forbes (1983) calculated numerical solutions of subcritical and supercritical flows. In this paper, new solutions are presented for supercritical and critical flows. Numerical results show that there is an influence of Bond number non-uniformity on the numerical solutions. In addition, for a negative obstacle, new solution of the critical flow is proposed. Discussion on a comparison between fully nonlinear and weakly nonlinear solutions is also presented.

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