

Energy Dissipation Processes of Free Jump and Submerged Jump

Sung-Uk Choi and Seongwook Choi

The flows over an embankment-type weir show various flow types depending on the tailwater level, namely, free jump, submerged jump, and washed-out jump. Among the three flow types, free jump and submerged jump are important in practical engineering due to their energy dissipation capability. The free jump refers to both optimum jump and swept-out jump. The optimum jump, occurring when the toe of the jump is located immediately downstream of the weir, shows the highest efficiency in dissipating the mean kinetic energy. The submerged jump, which creates an extended roller region with strong re-circulating flows, is dangerous due to extremely calm water surface. Air entrainment of the submerged jump is much less than that of the free jump because the body of the jump is not directly exposed to air. The submerged jump is known to induce much smaller pressure fluctuations on the bed than the free jump does. The energy loss by the submerged jump is a function of inflow Froude number and submergence factor. In general, the energy loss by the submerged jump is less than that by the free jump. The energy loss by the free jump can easily be estimated by so called Belanger equation. However, it is not easy to estimate the energy loss by the submerged jump.

This study presents a numerical study to compare energy dissipation processes of both free jump and submerged jumps. Hydraulic jumps of flows over an embankment-type weir are considered. For the numerical simulations, 2D Unsteady Reynolds-Averaged Navier-Stokes (URANS) equations are solved with the k - ω SST turbulence model. The volume of fluid method is used to track the free surface and to compute the water-air multiphase flow. For a fixed unit discharge, a free jump and three submerged jumps with several submergence factors are reproduced by varying the tailwater depth. Model validation is carried out by comparing computed vertical structures with measured data obtained in the literature.

Using the computed results, longitudinal changes in energy loss for both free jump and submerged jumps are presented. The mean flow and turbulence statistics are provided, including the streamwise mean velocity, turbulence intensity, Reynolds stress, mean pressure at the bed, and bed shear stress. The simulated results are used to investigate the decay of the mean flow and turbulence statistics in the longitudinal direction. Results indicate that the energy loss by the free jump is greater than

that by the submerged jumps and the energy loss by the submerged jumps increases with decreasing submergence factor. For both free jump and submerged jumps, the energy dissipation is nearly completed within the roller region, but the decaying processes of the mean flow and turbulence statistics are not.

keywords: free jump, submerged jump, turbulence statistics, embankment-type weir, k-w SST turbulence model, energy dissipation