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THREE-DIMENSIONAL NUMERICAL SIMULATION OF AERATED FLOWS DOWNSTREAM SUDDEN FALL AERATOR EXPANSION-IN A TUNNEL *

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Abstract: Air entrainment is known to be one of efficient and inexpensive methods to prevent cavitation damages in hydropower projects. The shape of sudden expansion-fall is used as a common device for mitigating cavitation erosions. The complex flow patterns with cavitation are numerically simulated by using the realizable $k-\varepsilon$ turbulence model and the air-water mixture model. The calculated results are compared well with the experimental results as well as those obtained with the $k-\varepsilon$ turbulence model with the Volume Of Fluid (VOF) Model. The calculated results agree well with the experimental data for the aeration cavity and wall pressure. Moreover, the air concentration near sidewall is simulated by a mixture model. It is found that the mixture turbulence model is superior to the VOF turbulence model.

Key words: sudden expansion-fall aerator, RNG $k-\varepsilon$ turbulence model, realizable $k-\varepsilon$ turbulence model, Volume Of Fluid (VOF) method, air-water Mixture turbulence model, numerical simulation

Introduction

Air entrainment is known to be one of efficient and inexpensive methods to prevent cavitation damages in hydropower projects[1-3]. Sudden expansion and fall aerator as an air entrainment device is used widely in flood tunnels with high speed flows. The air entrainment of an aerator are closely related to its design parameters, with the cavity length L below the aerator as one of the most important parameters. The cavity length L is affected by various factors, including structural and hydraulic parameters[4-8], which can be estimated by projectile method, dimensional analysis and numerical simulations. As far as the flows of a physical model is concerned, the flow patterns of impact regions on the sidewall is complex, and it is very difficult to measure hydraulic parameters in physical model tests[9,10].

In the calculation of air-water two phase flows, the Volume Of Fluid (VOF) model and the Mixture model are usually used to track the free water surface, such as in simulating the water surface profile of a spillway, and the flows in stilling basin, shaft and many other discharge structures. Studies by Karim and Mali[11], Xu et al.[12], Wang et al.[13], Wu and Ai[14], Chen et al.[15] show that the $k-\varepsilon$ two-equation turbulence model is an useful tool in simulating this kind of complex water flows. Therefore, it is adequate to apply turbulent mathematical models to study the hydraulic behavior, such as the cavity morphology and pressure distribution on the wall[16-20]. Chen et al.[17] simulated the flows in a stepped spillway by using the VOF model combined with the standard $k-\varepsilon$ turbulence model. Cheng et al.[18,19] used the VOF model and the Mixture model, respectively, combined with the RNG $k-\varepsilon$ turbulence model to simulate the air entrainment of flows in a stepped spillway. Qian et al. [20] adopted the Mixture model combined by the realizable $k-\varepsilon$ turbulence model to simulate the air entrainment of flows and found that the realizable $k-\varepsilon$ turbulence model is better than

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