SIMULATION OF TURBULENCE FLOWS ON CONCAVE SURFACES OF SPILLWAYS INCLUDING THE EFFECTS OF STREAMLINE CURVATURE

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With the rapidly changing advances in computational modeling for solving the governing equations of fluid flow, engineers now face the decision of which method(s) to use in evaluating existing and proposed spillway designs. The choice of a physical model or computational model can be a daunting task. This is especially true if an engineer is unfamiliar with the capabilities and limitations of state-of-the-art computational modeling if the effects of extrapolating are not fully understood and thereby one method cannot be justified over the other.

To assist the engineer in the decision about which methodology to pursue, in this study we firstly analyze the properties of turbulence flows with effects of streamline curvature; and then propose a kind of mathematical model being used to simulate these turbulence flows.

Due to the closure problem of the governing equations for turbulence flows, numerous turbulence models for predictions of turbulent flows have been proposed. The eddy-viscosity type of turbulence closure modeling has demonstrated a variety of good numerical predictions both qualitatively and quantitatively. Among them, the K-ε model is the most widely employed isotropic two-equation model. It has been extensively applied to different turbulent flow problems. However, the standard K-ε model appears to be insufficient in predicting the complex turbulence shear layers, such as flows subjected to curvature and rotation. The main reason is that the streamline curvature produces unexpectedly large changes in boundary layer properties and that the eddy-viscosity for standard K-ε model is isotropic. So several researchers have discussed the sensitivity of turbulence flow characteristics to even small amounts of mean streamline curvature. For example, in the study by Kreith (1995) and in subsequent investigations by Thomann(1968) and Mayle et al (1979) , it has been shown that the best flux through the concave wall of a curved channel can be up to 33% larger, and through the convex wall 15%smaller, relative to that through the walls of a straight channel. Therefore, many researchers have proposed numerous models in the last two decades to account for the effects of streamline curvature, such as Launder, B.E., Pridden , C.H. and Sharma, B.I.(1997), Pourahmadi, F. and Humphrey. .A.C.(1983) and Wei Wen-li and Li Jian-zhong(1999,2000).

In order to combine the simplicity (i.e., easily adopted into other programs or models), generality (suitable for different geometries), physical rationale, and efficiency (less computing time), the present study applies the curvature correction method by Launder et al. and Sharma (1997) in the two-equation $K-\varepsilon$ turbulence model under orthogonal curvilinear coordinates. Thus, a mathematical model for prediction of turbulence flow with effects of streamline curvature under orthogonal curvilinear coordinates has been established, with which the characteristics of the turbulence flow field on the ogee spillway has been numerical simulated. In the numerical simulation, the flow control equations in orthogonal curvilinear coordinate system are discretized by the finite volume method; the physical parameters (pressure P, U, V, K, ε, γ_t, etc.) are arranged on a staggered grid; the discretized equations are solved by SIMPLEC method; and the complex free surface is dealt with VOF method. The computed results show that the velocity fields, pressure field, shear stress distribution and kinetic energy of turbulent flow on the ogee spillway are in agreement with experimental data. This confirms that the model can be used for numerical simulation the turbulence flow on ogee spillway. The research results will be widely used in the prediction of complex turbulence flows in hydraulic engineering.

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