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EXTENDED ABSTRACT

Investigation of Hydraulic Jump Turbulence Parameters in Divergent Rectangular Sections using Fluent Model

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Introduction

A Stilling basin with divergent section has better performance and lower constructional costs than the classic basin. It can easily adapt itself to the upstream and downstream conditions in terms of depths and cross sections (Omid et al., 2007). Khalifa and McCorquodale (1979) studied radial hydraulic jumps in a gradually expanding channel of rectangular cross section and developed a theoretical equation assuming a second degree polynomial for the surface profile. Omid et al. (2007) studied the hydraulic jump formed in a gradually expanding stilling basin of trapezoidal cross section. They also investigated the hydraulic jumps for three different basin side slopes. Their experimental results indicated that the divergence of the basin for a given side slope causes reductions in the sequent depth and jump length, and an increase of the energy loss in jump relative to those observed in rectangular cross sections. Sahebi (2013) simulated a divergent hydraulic jump in rectangular basins using standard and RNG turbulence models. The outputs of the numerical model showed that the standard turbulence model evaluated the free surface of flow, jump length and maximum velocity in defined sections better than RNG turbulence model. In this study, for seven Froude numbers in the range of 3.2-9.1, three models of the divergent basins were numerically simulated at three dimensional conditions with various geometries of divergence angle and wall type. The k-ε RNG and RSM models were used for turbulence analysis and volume of fluid (VOF) model was used for simulating of free surface profile in the Fluent model. Also, vertical distributions of turbulence intensity, Reynolds stresses and turbulent kinetic energy were investigated using the RSM model in various sections of the hydraulic jumps.

Methodology

Experimental model

Experimental data of Sadeghi (2013) were used in this research. In the mentioned research, characteristics of hydraulic jump formed in three models of divergent basins with various geometries of divergence angle and wall type were investigated. Geometrical parameters of the models are listed in Table 1. Also, hydraulic characteristics of the experiments are listed in Table 2, where Q, H and Fr_1 are referred as the discharge, flow head and Froude number for incoming flow, respectively.

Table 1- Geometrical parameters of the experimental model (Sadeghi, 2013)

Model	*Type of basin wall*	*Wall basin length (m)*	*Upstream channel width (m)*	*Downstream channel width (m)*	*Divergence angle (degree)*
1	*Straight*	1.5	0.4	0.8	7.7
2	*Straight*	0.6	0.4	0.8	19.5
3	*Curved*	0.6	0.4	0.8	19.5

Table 2- Hydraulic characteristics of the experiments (Sadeghi, 2013)

Q (lit/s)	*H (m)*	Fr_1
17.5	0.68	3.2
26.3	0.79	4.5
30.1	0.87	5.1
34.2	0.95	6.2
39.2	1.06	7.4
43.4	1.12	8.3
47.1	1.18	9.1

Numerical model

In this research, Fluent model was employed for numerical simulation. Fluent is one of the most popular and suitable models of CFD that provides a wide array of advanced physical models for fluid flow and heat transfer applications including multiphase flow. It can exchange the dominant differential equations to algebraic equations by using the finite volume method and solve them in 2D and 3D dimensions (Nikpour et al., 2014). In order to make the numerical model independent from the number of meshes, the lowest required number of meshes that has the least computational error should be determined. Considering a constant boundary conditions, four different grids were applied to the numerical model. Comparing the mean relative error of the above mentioned, the most appropriate number of meshes was obtained equal to 773840, 616080 and 680080 for the models 1, 2 and 3, respectively.

Results and Discussion

The validation results of the numerical model indicated that the accuracy of the turbulence models in simulating of free surface profile was similar and the average relative errors of calculation were 7.4% and 5.7%, respectively. But the RSM model performed better than the k-ε RNG model in simulating of velocity profiles, so that the values were 16.2% and 7.7%, respectively. The agreement rate between the measured and computational values varied in different points of the hydraulic jump, so that the model’s errors mostly observed in the third initial of the jump. On the other hand, the velocity profiles showed as the distance increased from the bed, the agreement between numerical and measured values decreased. Indeed, by moving away from the bed, simulation accuracy of the turbulence models reduced due to changes of the turbulence intensity as well as air and water mixture. Also, for the same divergence ratio, by increasing of the divergence angle, the computational error increased, and for the same angles and divergence ratios, the curvature of the wall reduced the partial value of the numerical model error. Moreover, the numerical model showed the vortices and bistable flow occurred by diverging walls as well as experimental results. Therefore, considering the importance of bi-stable flow occurring in the divergent sections, the numerical simulation can be used to study the rolling length due to the occurrence of the phenomenon and its development to the downstream.

Conclusion

Based on the overall results obtained from this study, it was concluded that since the run time for the simulation of hydraulic jump using the RSM model was approximately 2 times of the k-ε RNG model, therefore, when simply considering the jump free-surface profile simulation, the RSM model is not recommended due to its high computational cost. But for analyzing the turbulence and gaining velocity values, the RSM model has a higher accuracy, therefore, based on the results of this study, the percentage of computational error decreased by more than 50% compared to the k-ε RNG model.

References

1- Khalifa, A.M. and Mccorquodale, J.A., 1979. Radial hydraulic jump. *Journal of the Hydraulics Division*, *105*(9), pp.1065-1078.

2- Nikpour, M.R., Nazemi, A.H., Dalir, A.H., Shoja, F. and Varjavand, P., 2014. Experimental and numerical simulation of water hammer. *Arabian Journal for Science and Engineering*, *39*(4), pp.2669-2675.

3- Omid, M.H., Esmaeeli Varaki, M. and Narayanan, R., 2007. Gradually expanding hydraulic jump in a trapezoidal channel. *Journal of Hydraulic Research*, *45*(4), pp.512-518.

4- Sadeghi, H., 2013. *Effect of wall shape on hydraulic jump in open- channels transitions*. MSc. thesis, Department of Civil Engineering, Faculty of Technology and Engineering, Islamic Azad University, Branch of Maragheh, Maragheh, Iran. (In Persian).

5- Sahebi, F., 2013. *Comparison of k-ε turbulence models in simulation of hydraulic jump in divergent rectangular sections using Fluent software*. MSc. thesis, Department of Water Engineering, Faculty of Agriculture, University of Tabriz, Tabriz, Iran. (In Persian).