

A comparison of RANS turbulence models in the prediction of confined turbulent swirling flows in urban drainage flow controls

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Proposed Theme: Turbulence Modelling

ABSTRACT

Computational fluid dynamics was used to assist the design of an urban drainage flow control. Three Reynolds averaged Navier Stokes (RANS) turbulence models were compared to experimental data in order to verify the modelling approach. The validated CFD modelling procedure was applied to establish data beyond the physical restrictions of the experimental laboratory facilities.

The flow control device geometry consists of a cylindrical body with a tangential inlet and central outlet, similar in geometry to a vortex chamber or swirl tube. This geometry induces a confined turbulent swirling flow to produce a pressure drop across the device, which is beneficial in urban drainage systems as it restricts the flow without imposing any physical constriction or obstruction.

Complexities arise when predicting the behaviour of swirling flows due the transition from a free vortex (irrotational) to forced vortex as the flow approaches the axis of rotation. RANS turbulence models that utilise the Boussinesq hypothesis are often weaker at predicting swirling or rotational effects compared to second-moment closure methods, which capture the rotational components independently.

Jawarneh and Vatistas (2006) have previously investigated various geometric configurations of a vortex chamber at a Reynolds number, based on mean inlet flowrate and chamber diameter, of approximately 10^4 . This study concludes that the Reynolds stress model (RSM) was able to predict the pressure drop across the vortex chamber to within $\pm 10\%$ of the experimental readings. The Reynolds number studied by Jawarneh and Vatistas (2006) is similar in order of magnitude to that of the urban drainage flow control under normal operating conditions.

The previous work by Jawarneh and Vatistas (2006) focused on two-dimensional axisymmetric geometry. This work extends the focus to a real industrial three-dimensional geometry. The experimental pressure loss characteristic was established through installing the flow control device in a pumped recirculating system and monitoring the pressure loss under steady-state conditions for a range of flow rates.

The simulations mimicked the experimental tests, using a transient modelling approach while monitoring the pressure loss across the device until steady state had been achieved (Figure 1). Two eddy viscosity models and a single second moment closure method were investigated to establish preferable modelling parameters. A mesh independence study was performed for the second moment closure method to

ensure the validity of the modelling process. The results obtained for the three-dimensional mesh confirmed the conclusions by Jawarneh and Vatistas (2006) with the RSM results being superior to the eddy-viscosity models with the predictions varying less than 2.5% from the experimental data (Figure 2).

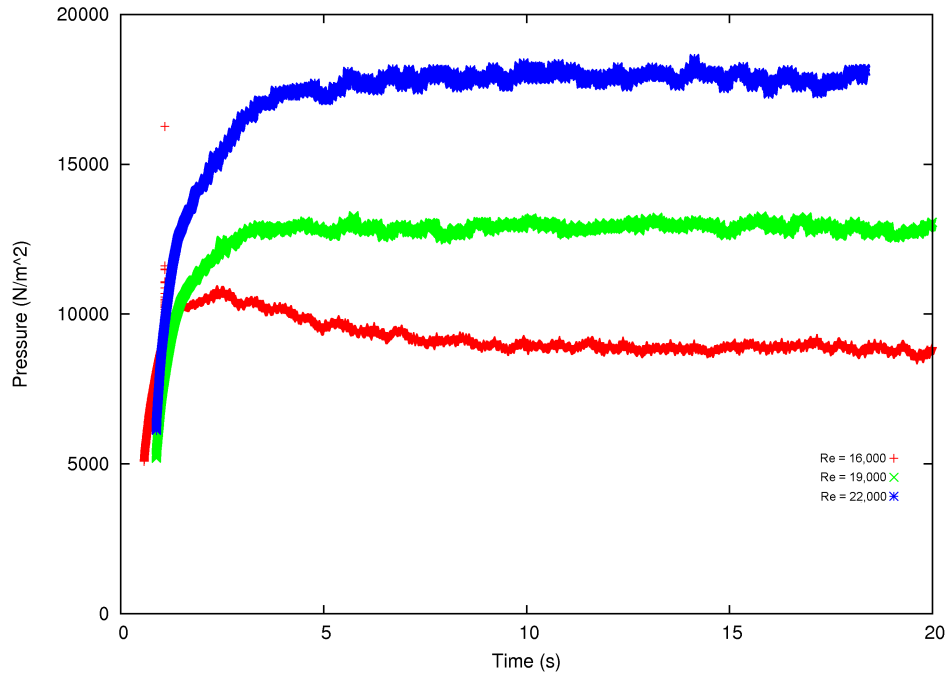


Figure 1: Steady-state monitoring of RSM simulations

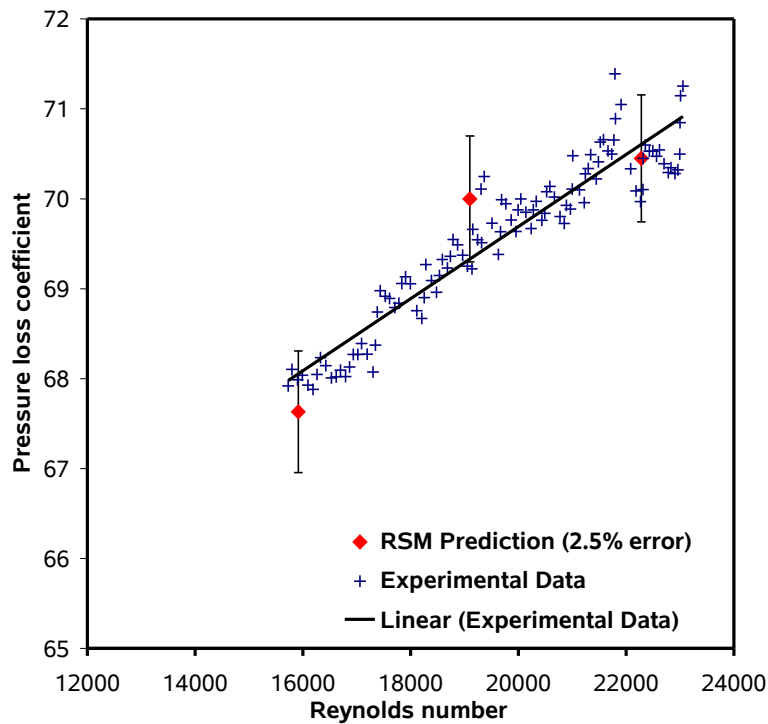


Figure 2: Comparison of pressure drop coefficient for experimental data and CFD predictions

Jawarneh, A. M. and Vatistas, H. G. (2006) Reynolds Stress Model in the prediction of Confined Turbulent Swirling Flows, *ASME Journal of Fluids Engineering*, **128**(6), pp 1377-1382.