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Numerical Predictions of Flow Characteristics in a 90 Degree Bended Upward Elbow Located at the Downstream Region of a Flow Control Valve (Butterfly Valve)

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1. Introduction

Butterfly valves are widely used in industrial piping components. They are used for flow control in large diameter pipes because of their lightweight, simple structure and the rapidity of manipulation [1,2,3]. Any flow disturbing components such as elbows, orifice plates and tees are recommended to be located in a distance of 8 diameters (L/D≈8) from the downstream of butterfly valves to decrease the effect of flow disturbance [4,5]. However, one would encounter cases where other piping components are installed in a close proximity due to the space restriction. In these cases, the numerical simulation will be useful to evaluate the impact of flow disturbances.

In this study, we have examined one practical case encountered where the elbow is located in a close proximity to the butterfly valve. Due to the close proximity, we are concerned about pipe thinning and we use the numerical evaluation to determine the range of operating regime and options.

2. Methods and Results

In this section, numerical approach and procedures are described. Figure 1 shows that the piping system consists of 50.8cm diameter pipe (I.D=48.6cm), a 90 degree elbow, flanges, an orifice plate and a butterfly valve. The distribution of the flow velocity and shear stress are analyzed to understand the effect of flow disturbance on the piping wall of a 90 degree bended elbow. The present study is conducted using four difference cases. Case 1 is the current arrangement: 60% valve open angle and L/D≈1 for the present operating case. Case 2 is the configuration recommended (L/D≈8) with 60% valve open angle. This will be used as reference data for evaluation. Case 3 is 100% valve open angle and L/D≈1. Case 4 is 60% valve open angle and L/D≈5.

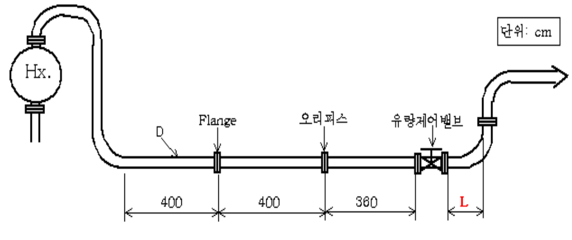


Figure 1. Schematic diagram of the present operating piping system (Case 1)

2.1 Numerical Approach and Procedures

The CFX code, version 10 [6], is employed for the numerical predictions. ANSYS ICEM CFD 10.0 is used for the generation of the computational grid. Figure 2 shows the schematic diagram of the portion of computational grid for the valve and a 90 degree bended elbow section. The grids consist of 430,000 tetrahedral elements. Prism mesh is chosen for the near-wall surface region to resolve the development of the boundary layers better.

The time-averaged flow field is assumed to be at a steady state. Reynolds number based on channel height Re_H is fixed at 1.9×10^6, which corresponds to a spatially averaged channel inlet velocity is 3.72m/s. Working fluid density and viscosity is 1025kg/m^3 and 9.71×10^{-4} kg/m-s, respectively. The RNG (Renormalization Group) k-ε model is chosen as the turbulence model. The RNG model utilizes improved statistic method to cover various length scales. The predictive capabilities and the convergence characteristics of the RNG model are much better than those of the standard k-ε model, specially for a curved flow path such as an elbow.

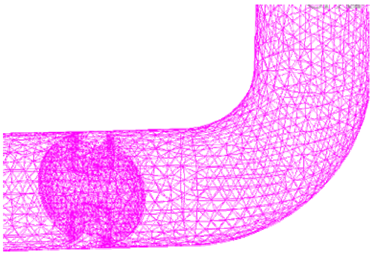
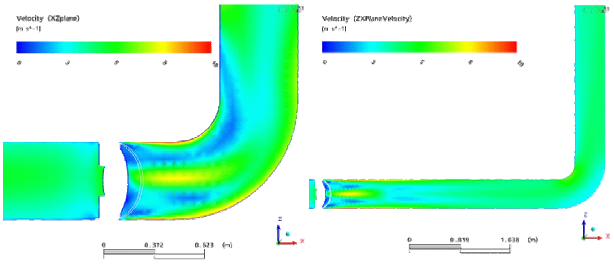


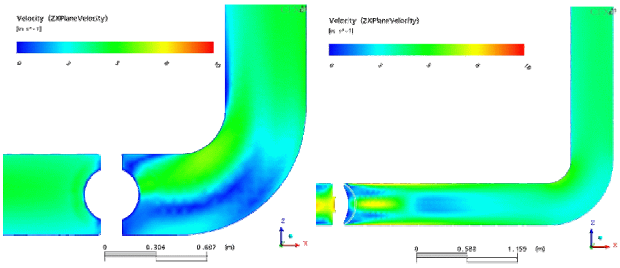
Figure 2. Schematic diagram of the computational grid employed with a valve and a 90 degree bended elbow (Case 1).

2.2 Results

Figure 3a through 3d show the numerically predicted velocity distributions. For the Case 1, flow velocity through the valve is 7-8m/s near the wall and the central part of a 90 degree elbow (Fig. 3a). For the Case 2, the flow velocity is 5-6m/s for the corresponding locations (Fig. 3b). The reason for the higher velocity for the Case 1 is that the bigger counter-rotating vortex flow occurs through the valve and the effect of the vortex flow is felt near the intrados and extrados regions of the 90 degree bended elbow. For the Case 3, the velocity distribution through the valve is relatively steady



(a) case 1 (b) case 2(reference)



(c) case 3 (d) case 4

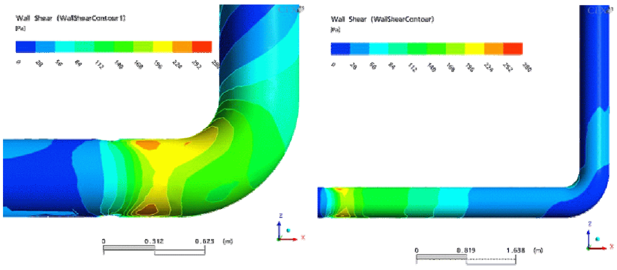
Figure 3. Distributions of a velocity contour for (a) 60% valve open, (b) L/D≈8, (c) 100% valve open, and (d) L/D≈5.

because the flow restriction is very small (Fig. 3c). The vortex is observed at the extrados region. However, the velocity is very low and almost stagnant in that region. Thus, the effect of the vortex would be small and would not threat the piping integrity. For the Case 4, the flow through the valve shows small vortex sheddings (Fig. 3d). The flow becomes stable passing through the relatively long straight pipe section. Therefore, the velocity distributions at the elbow for Case 2, Case 3, and 4 are similar.

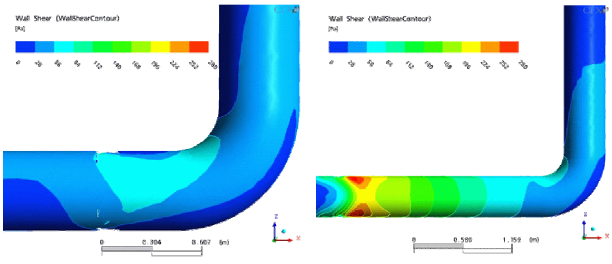
Figure 4a through 4d show the distribution of shear stress. For Case 1, the shear stress is high, 180-200Pa. and the effect of the shear stress is observed from the front part of elbow to the elbow curvature (Fig 4a). Specially, the shear stress is high near the intrados area. The flow through the valve experiences a high disturbance and the flow direction has changed approaching the elbow. For Case 2 (reference case), the shear stress is about 80 Pa at the elbow (Fig 4b). The shear stress gradually increases in a straight piping downstream of the valve and then increases sharply at the upward wall of the 90 degree bended elbow. For Case 3 and Case 4, the magnitude and distribution of the shear stress are similar to that of Case 2 (Fig. 4c-4d).

3. Conclusion

The effect of a butterfly valve open angle and the distance between a butterfly valve and a 90 degree bended elbow is examined using CFX code.



(a) case 1 (b) case 2(reference)



(c) case 3 (d) case 4

Figure 4. Distributions of a shear stress contour for (a) 60% valve open, (b) L/D≈8, (c) 100% valve open, and (d) L/D≈5.

Case 1 shows that the flow disturbance at the elbow is substantial and the pipe thinning would be a concern. Case 3, the case with 100% valve open, shows the disturbance is similar to the reference case (Case 2). Hence, with the current piping configuration, operating with the fully open valve while regulating flow using a valve upstream could be a solution. Case 4, the case with L/D≈5, shows that the flow disturbance is similar to the reference case. Hence, the modification of piping configuration to ensure L/D≈5 would be a long-term solution for the example we investigated.

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