The Reseach of Correlation Between Flow Coefficent and Diameter Error of Upstream and Downstream Pipe for Elbow Flowmeter

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Abstract: This article study the correlation between flow coefficent and diameter error of upstream and downstream pipe for elbow meter used CFD simulation and experiments, the results of CFD simulation and experiments all show that the flow coefficent is significantly influenced by the diameter error, so the diameter error of upstream and downstream pipe muse be strictly controled when the elbow meter is producted or used ,or modify the flow coefficent, if error of diameter can be measured, to improve the measure accuracy in industrial applications.

Keywords: Elbow Flowmeter, Diameter Deviation, System Error

1. Introduction

In order to ensure the accuracy of measurement, straight pipe connected with the flowmeter, including the length and diameter, is strictly requested in the flow measurement standard. In many project applications,the people concerned about the length of straight pipe, but often ignore the consistency of diameter.In china, internal diameter of industrial pipeline is specified with two numbers: Nominal Pipe Size (external diameter) and wall thickness. So pipeØs internal diameter and flowmeterØs internal diameter are often biased and affect the accuracy of flowmeter.

Based on the Computational Fluid Dynamics and experiment , This article study the correlation between flow coefficent and diameter error of upstream and downstream pipe for elbow meter.

2. Theoretical analysis of straight pipe diameter factor

Elbow flowmeter accuracy depend on the geometry, flow parameters. To be able to analyze the specific impact of each factor, based on the similarity theory, the theoretical model of elbow flowmeter can be derived:

$$\mathrm{v} = \alpha \sqrt{\frac{\Delta P}{\rho}} \qquad (1)$$

Where the flow coefficient α can be expressed as a multivariate function:

$$\alpha = \alpha\left(\mathrm{Re}, \mathrm{Ma}, \frac{R}{D}, \frac{D_1}{D}, \frac{D_2}{D}, \frac{L_1}{D}, \frac{L_2}{D}, \frac{\lambda_1}{D}, \frac{\lambda_2}{D}, \frac{\lambda_3}{D}, \frac{\lambda_4}{D}, \frac{\Delta}{D}\right) \quad (2)$$

Where, Re is Reynolds number, Ma is Mach number, D is diameter of elbow, R/D is bending diameter ratio of elbow, D_1,D_2 is straight pipe internal diameter, L_1,L_2 is length of Straight pipe, $ə_1$,$ə_2$,$ə_3$,$ə_4$ is place of inside and outside wall pressure hole, φ is wall roughness.

Given factors in Expression of flow coefficient α can be computed by CFD.

To analyze the influence of straight pipe diameter, the formulation (2) is expressed

$$\alpha = \alpha\left(D_1, D_2\right) \quad (3)$$

In this paper, the soft of Fluent was used to analyse flow coefficient variation with straight pipe diameter, and pipe diameter range of straight sections is (0.95~1.05)%D.

In the computational model, we use SIMPLE method, QUICK scheme and Reynolds stress turbulence model to solve the flow in elbow. Figure.1 and Figure.2 shows the typical geometric model and mesh generation of elbow with straight pipe, R/D of elbow is 1.5, Reynolds number is 1.2×10^5 . Number of computing grid about 3×10^6, spacing at the wall is set to be less than 2×10^{-4} D in order to obtain y^+å1 base on pipe turbulent flow boundary layer thickness estimates at Reå1.2×10^5

Using above CFD model, we analyzed the status of five straight pipe internal diameters, which is 0.947D, 0.98D, 1.0D, 1.02D, 1.05D. Figure 3 shows calculated pressure distribution of five status with changes in elbow angle. As shown in Figure 4, The curve of flow coefficient are given with change of the straight pipe diameter. When the internal diameter of straight sections increased from 0.947D to 1.05D, flow coefficient decreased from 0.978 to 0.962, the rate of change is 1.63%. The curve also shows that flow coefficient changes more apparent when the straight pipe diameter is smaller than elbow. Note that the pressure taps of corresponding flow coefficients are located at the middle of the elbow, i.e, 45°from inlet, diametrically opposite one another,at the extreme inside and the extreme outside of the bend.

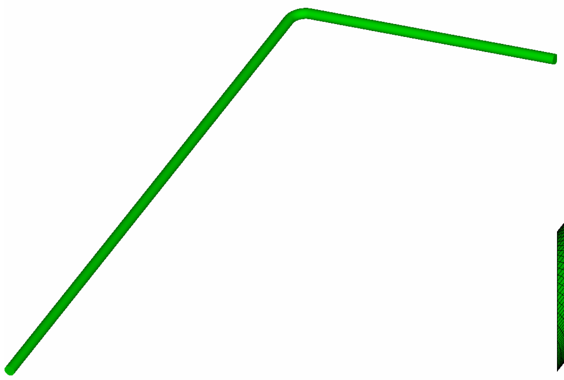


Fig.1 Geometric model

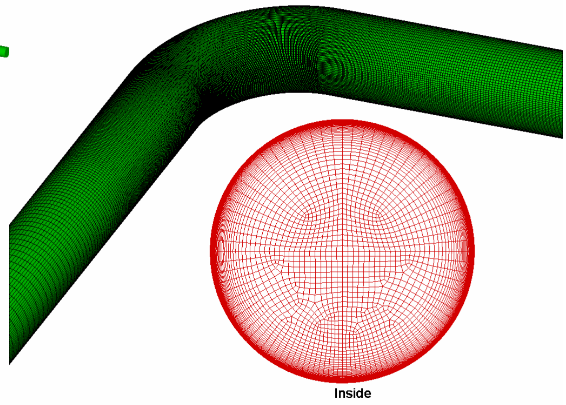


Fig.2　Mesh Generation

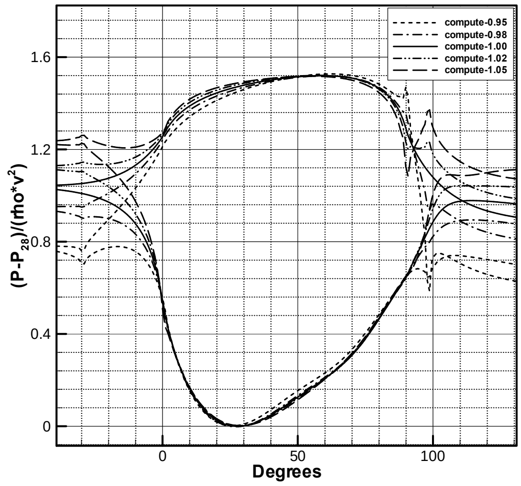


Fig.3 （0.95～1.05 ）%D theoretical pressure distribution

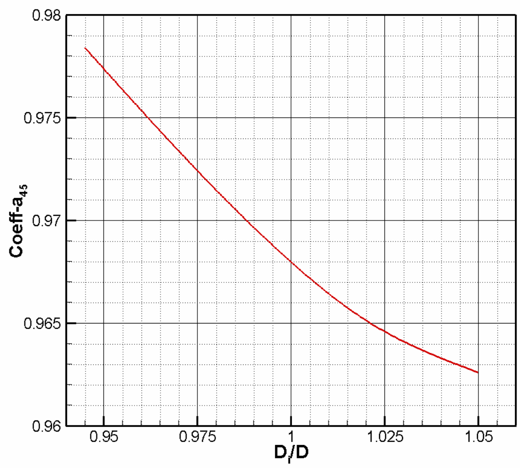
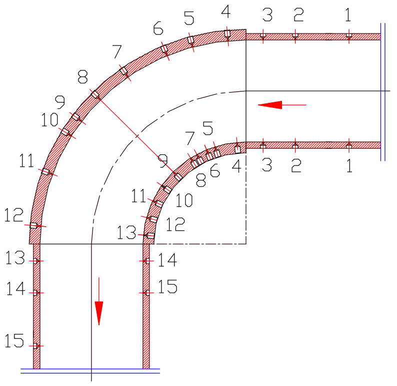


Fig.4 flow coefficient curve with straight pipe diameter

3 Experimental research for straight pipe diameter factor

In the experiment, We set a number of positions to take pressure on the generatrix of elbow. Figure.5 shows photo and schematic diagram of flowmeter in which give taken pressure positions.

Diameter of elbow flowmeter is 95.787mm, and two sizes of straight pipe to be used, one is the same as D, the other is reduced 5.3%D. To ensure the same Reynolds number for the experiment and theoretical calculations, the experimental average velocity is 1.6 m / s.



NUM	Inside	Outside
1	up 96mm	up 96mm
2	up 46mm	up 46mm
3	up 16mm	up 16mm
4	5.0°	5.0°
5	17.5°	15.0°
6	22.5°	22.5°
7	28.5°	35.0°
8	32.5°	45.0°
9	45.0°	53.0°
10	55.0°	58.0°
11	65°	70.0°
12	75.0°	85.0°
13	85.0°	down16mm
14	down16mm	down46mm
15	down46mm	down96mm

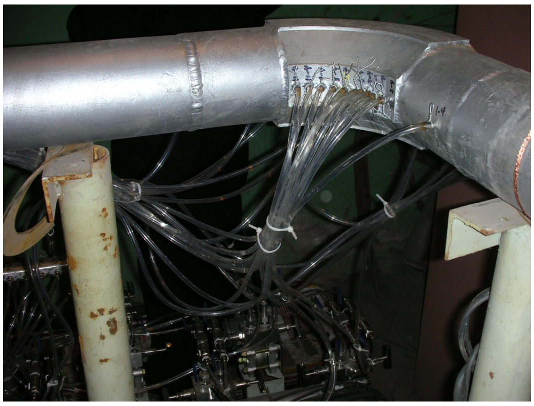


Fig.5 schematic diagram and photo of experimental flowmeter

Chart 6 shows measured pressure distribution and the theoretical pressure distribution which is corresponding to two diameters of straight pipe. Comparition the results, theoretical curves fit very well with the experimental data. When the internal diameter of straight pipe is reduced 5.3%D, the local wall pressure reduced above 20% than normal diameter. This change leads to the different pressure distribution of elbow, and makes the inside of minimum pressure point to move forward and the outside of maximum pressure point to move backward.

In the experiment, the flow coefficient of 45° decreased percent 2.4 when internal diameter of straight increase from 0.947D to 1.0D, so the internal diameter of straight pipe is an important factor to affect the measure precision in elbow flowmeter.

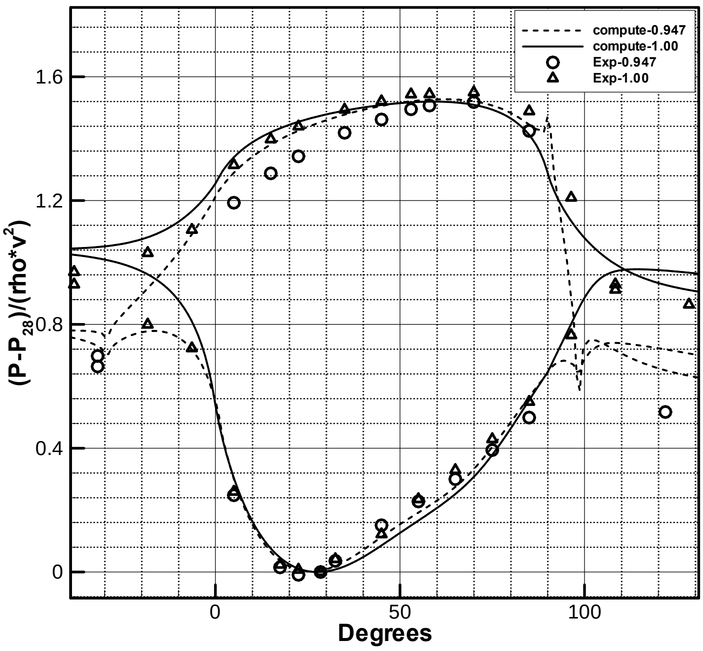


Fig. 6 CFD analysis and experimental pressure distribution

4. Conclusion

The theoretical and experimental data show that the change of pipe diameter of straight significant impact the measure precision for elbow flowmeter.

Taken the pressure difference from 45° position, flow coefficient increases with the straight pipe diameter decreases. If we know the deviation, the measure error of elbow flowmeter can be corrected by using this rule.

References

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