The CFD Simulation and Experimental Research of the V Type Elbow Flowmeter

Xian-ju Meng, Shao-feng Li, Zhi Li
Hebei Polytechnic University, China
46, Xinhua Road,Tangshan,Hebei province, China,063009
Phone:0315-2592162,FAX:0315-2592164,E-mail:mengxianju@heut.edu.cn

Abstract: This article study the measurement characteristics of the V type elbow meter used CFD approach, the velocity and pressure distributions in the elbow meter were presented. The experiments were carried out in a DN100 pipe,the experimental results show that the flow coefficients of the V type elbow meter is stable,and the relative errors between CFD simulation and experiment are within ±1.0%, the V type elbow meter can satisfy the fluid flow measurement in most industrial applications.

Keywords: Elbow Flowmeter, CFD, Experiment

1. Introduction

Elbow flowmeter has been increasingly widely used in the industrial measurement because of its inherent advantages. V-type elbow flowmeter is one type of the series, which can be directly installed in the straight pipeline, easily meet the request of forward and backword straight pipeline. The characteristic makes its application expanded.

This paper studies the characteristics of V-type flowmeters from three aspects ,namely, theoretic research, CFD analysis and experimental verification ,in order to reveal their intrinsic properties, and provides guidance for the V-type flowmeter in production and industrial applications.

2. Structure of V-type flowmeter

The structure of V-type flowmeter include five parts A, B, C, Bô and Aô, as shown in Figure 1, and the part A,C and Aô share the same radius *R* .The other basic parameters are the diameter D of the pipe,and the length *L* of part B.

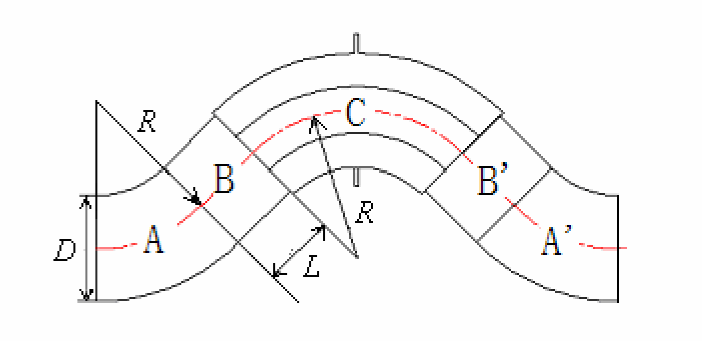


Fig. 1 V-type flowmeter

Diameter of the flowmeter to ensure the different geometric similarity, The ratio of the length of straight pipe to diameter is constant.

3. Flow coefficient

According to the theory in literature[1], flow coefficient of elbow flowmeter can be expression as

$$\alpha\left(\frac{R}{D},\mathrm{Re}\right)=\sqrt{\mathrm{Eu}} \quad (1)$$

Where: Eu is Euler number, Re is Reynolds number

and

$$\mathrm{Eu}=\frac{\rho\bar{v}^2}{\Delta p}, \qquad \mathrm{Re}=\frac{\rho\bar{v}D}{\mu} \quad (2)$$

Where: ρ is fluid density; $\bar{v}$ is average speed; ΔP is pressure difference; μ is the dynamic viscosity.

The average velocity of fluid flowing in elbow flowmeter is expressed as:

$$\bar{v}=\alpha\left(\frac{R}{D},\mathrm{Re}\right)\sqrt{\frac{\Delta p}{\rho}} \quad (3)$$

Where: α is the flow coefficient, R/D is the ratio of radius of part A to the diameter D and α is the function of R/D and Re.

The research on elbow flowmeter often falls into two broad categories.The first research focuses on the way of symplifying the state of fluid flowing throng the elbow and coming to a theoretically approximate expression. But their expressions are often with considerable errors.

Other researchers arrive at expressions based on experimental data by regression. Their formula of flow coefficient are various and hard to guarantee accuracy because of different experimental data and method of regression.

Equation (1) is a general expression of the flow coefficient, but no exact relationship exists in the flow coefficient, R/D and Reynolds number. This paper verified the expression by obtaining numerical solutions to the N-S equations by CFD and analysing the result of experiment.

4. Research on the theory of elbow flowmeter by CFD

4.1 Theoretical solution to flow coefficient by CFD

In solving the N-S equations,some paraments were given as below,in table 1,where R/D and Reynolds number are constant.

Table. 1 Data use in CFD analysis

	D (mm)	L (mm)	R/D	Velocity (m/s)	Dynamic viscosity (Pa*s)	Density (kg/m^3)	Reynolds number
1	118.0	59.0	1.5	3.600	0.001020	1000.0000	771851.68
2	450.0	225.0	1.5	0.944	0.000544	988.4353	771851.68

Fluent was used in CFD analysis,with turbulence model being $k-\varepsilon$, and the method of near-wall treatment is enhanced wall treatment.

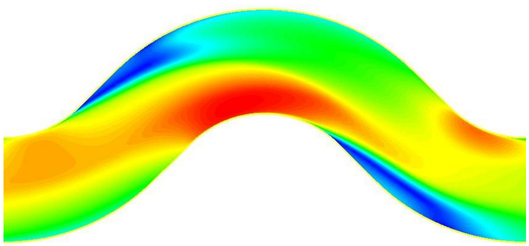


Fig.2 distribution of velocity of case 1

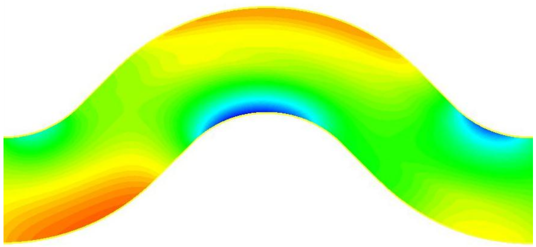


Fig. 3 distribution of pressure of case 1

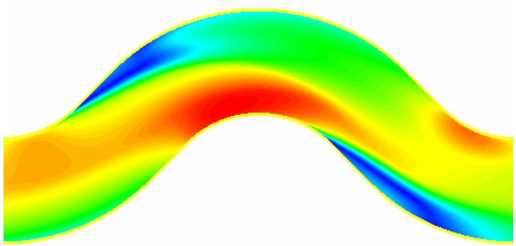


Fig. 4 distribution of velocity of case 2

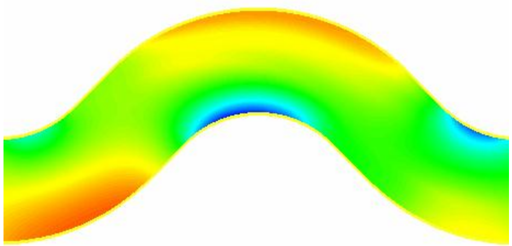
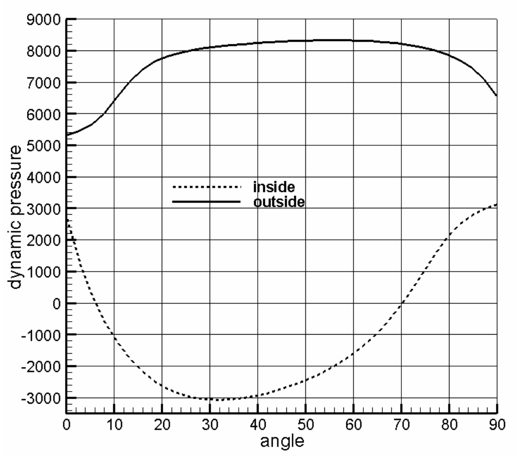


Fig. 5 distribution of pressure of case 2



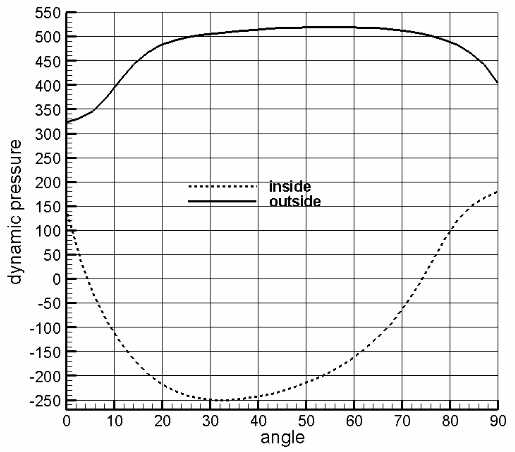
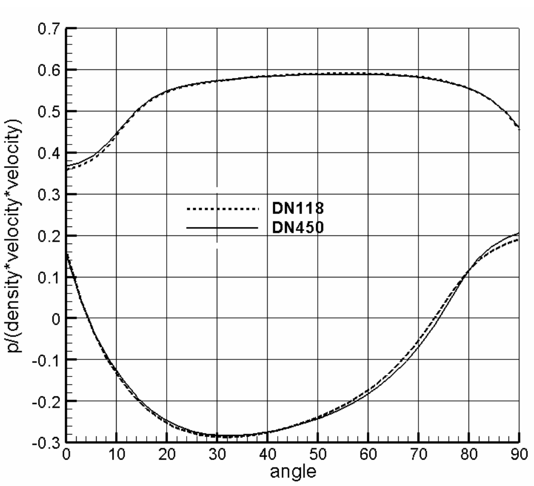


Fig. 6 pressure curve of part C of case 1

Fig. 7 pressure curve of part C of case 2



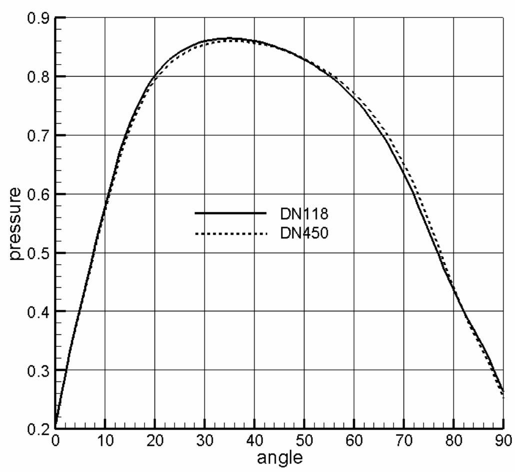


Fig. 8 dimensionless pressure curve of part C of case 1

Fig. 9 dimensionless pressure curve of part C of case 2

4.2 Numerical Solution to flow coefficient

Under the condition of constant R/D in the V-type elbow flowmeter,pressure differences can be obtained with different Reynolds number by solving the N-S equation(calculated paraments shown in Table 1). The curve of pressure different with Reynolds number abort the position that the hole of obtaining pressure is disposed, shown as below.

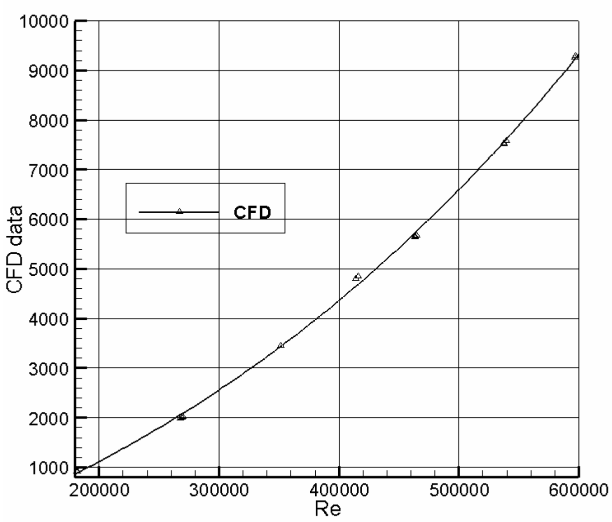


Fig. 10 The curve of pressure different with Reynolds number

5. Experimental research

5.1 Experimental device and data collection

Experimental device is shown below

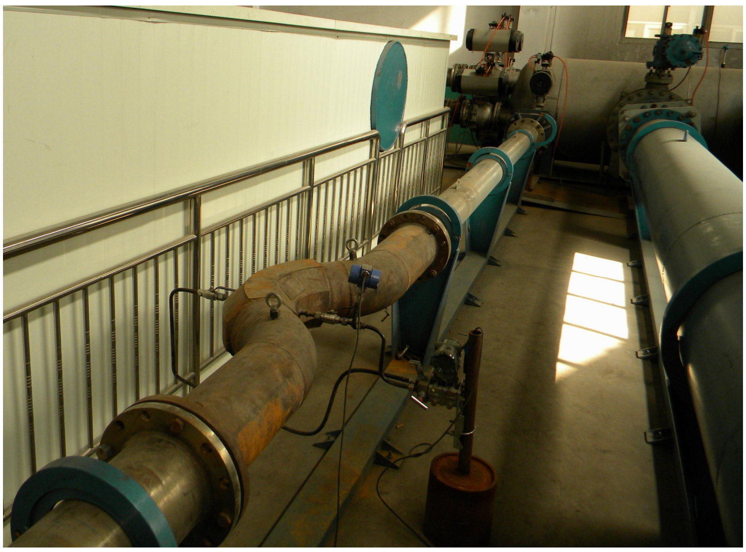


Fig. 11 V-type flowmeter experiment

Table. 2 Experimental data

Reynolds number	Calculation of differential pressure Pa	Experimental Pressure Pa	Pressure error (%)	Calculated flow coefficient	Experimental flow coefficient	Flow coefficient error (%)
181048.99	913.6046	924.8615	1.2171	0.887805	0.882385	-0.6142
181465.04	914.9477	914.9783	0.0034	0.887892	0.887878	-0.0017
181774.29	919.8005	918.7463	-0.1147	0.887892	0.888402	0.0573
267591.02	1987.405	2002.5208	0.7548	0.888042	0.884684	-0.3796
268840.35	2006.220	2013.6534	0.3691	0.888044	0.886404	-0.1851
269954.09	2027.349	2031.4956	0.2041	0.888051	0.887144	-0.1022
351401.81	3446.580	3427.2146	-0.5650	0.887208	0.889711	0.2813
351443.74	3452.650	3439.2014	-0.3910	0.887197	0.888930	0.1949
351463.26	3457.360	3440.1153	-0.5013	0.887199	0.889420	0.2497
414009.30	4800.290	4748.8055	-1.0842	0.888479	0.893282	0.5377
416314.40	4842.820	4828.7506	-0.2914	0.888501	0.889794	0.1454
416011.03	4843.950	4794.0361	-1.0412	0.888473	0.893086	0.5166
463204.76	5632.810	5578.6613	-0.9706	0.887556	0.891853	0.4818
463668.44	5653.880	5567.9921	-1.5425	0.887559	0.894378	0.7625
464664.76	5671.830	5596.0322	-1.3545	0.887562	0.893553	0.6704
537372.38	7514.020	7479.0951	-0.4670	0.893148	0.895231	0.2327
537701.87	7526.60	7518.1535	-0.1123	0.893140	0.893642	0.0561
539704.19	7574.510	7557.9638	-0.2189	0.893168	0.894145	0.1093
596185.28	9254.700	9169.1812	-0.9327	0.893280	0.897436	0.4631
596478.39	9263.770	9191.0489	-0.7912	0.893275	0.896802	0.3933
597195.29	9286.150	9239.0986	-0.5093	0.893271	0.895542	0.2537

The Average value of flow coefficient from CFD analysis is 0.889369,and mean square error is 0.00252. The Average value of flow coefficient obtained dy experiment is 0.881129,and mean square error is 0.00409. The error of CFD analysis and experimental results is 0.1975%, sharing a good consistency.

5.2 CFD analysis compared with experiment

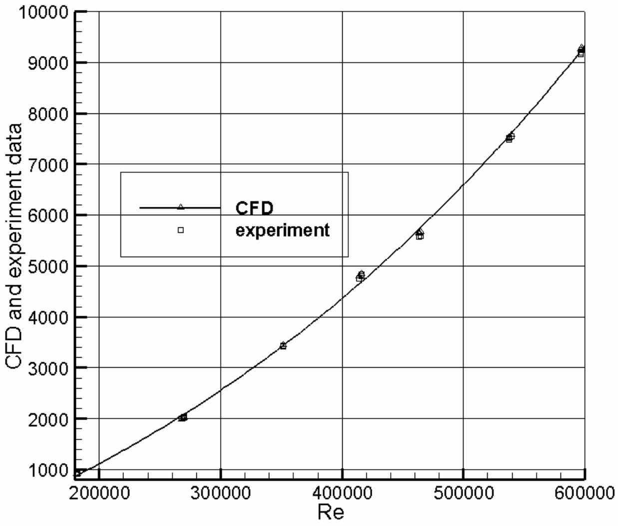


Fig. 12 CFD analysis and experimental differential pressure

6. Conclusion

This paper verified the theory of V-type elbow flowmeter by CFD analysis and experimental results from literature[1],the findings showed that from theory, CFD analysis and experiment have a good agreement when Reynolds number was in Within 200000 to 600000. The results of this paper give the guidance for the V-type flowmeter production and application.

References

[1] Li Zhi, Xian-Ju Meng, the vortex flow theory of elbow flowmeters based on numerical solution of the N-S equations, Hebei University of Technology, 2008 (1).