Experimental and Simulation Research of Channel Flowmeter Based on Gas and Water

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Abstract: The measurement performance of the channel flowmeter is studied by means of numerical simulation and experimental verification. The variation trend of the outflow coefficient and differential pressure value of the channel flow rate with the flow velocity under the gas-liquid two media is obtained, and the measurement error under the gas-water and liquid-phase conditions is analyzed. The results of numerical simulation are compared and analyzed. Research shows that there is a stable region of outflow coefficient in both gas phase and water phase experiment conditions. As the Reynolds number increases, the outflow coefficient tends to be a constant and does not change. In the stable outflow coefficient region, the difference of the upper limit value of Reynolds number is smaller than the difference of the lower limit value of Reynolds number. In the stable region of the outflow coefficient, the difference of the average outflow coefficients of the gas and liquid phases is not significant. In addition, the gas phase test shows that the critical back pressure ratio has a great influence on the outflow coefficient outside the stable outflow coefficient region, and the effect is not significant in the stable outflow coefficient region.

1. Introduction

Differential pressure flowmeter is a type of flowmeter widely used in industrial production, and has important applications in petroleum, petrochemical and natural gas fields. The differential pressure flowmeter represented by the orifice plate has a long history of application in the industrial field. Field.The throttling part of the orifice flowmeter itself has certain limitations, so that the outflow coefficient of the orifice flowmeter cannot keep the stability of the outflow coefficient during the use process, which is a very serious shortcoming for the differential pressure flowmeter and will seriously affect it. The promotion and use of the orifice plate flowmeter in the use site have high conditions for the installation of straight pipe sections, and cannot be well adapted to the installation and use site of complex working conditions. The turndown ratio of classic differential pressure flow meters such as venturis and nozzles is only about 5:1, and requires the provision of straight pipe sections of minimum length upstream and downstream to ensure suitable flow conditions[1-2].Therefore, the optimization design work for the throttling device of the differential pressure flowmeter has not stopped for a long time[3]. In the past period of time, several new types of differential pressure flowmeters have been successfully developed, among which wedge and V-cone flowmeters are widely used. Reynolds number is not sensitive and so on. According to the relevant public literature, the V-cone flowmeter has a measurement accuracy of ±0.5% and a repeatability of 0.1% when the turndown ratio is 30:1[4,6].Research shows that although the special V-cone throttling device of the V-cone flowmeter has a certain rectification effect, the low-pressure pressure taking area is still in the traditional separation area, so the inevitable existence of pulsating flow in the low-pressure area is essentially impossible to avoid flow separation.[7]Therefore, the optimization and improvement of the throttling device of the differential pressure flowmeter has not stopped for a long time. In recent years, the appearance of the channel flowmeter has made a breakthrough in this research. Compared with the previous throttling device, the channel The throttling device of the type flowmeter is designed in the shape of a droplet[5-6]. After the fluid enters the measuring tube, it will not be rapidly contracted to the center of the pipeline. After a straight pipe section between the throttling element and the measuring tube, a uniform annular flow channel is formed with the inner wall of the measuring tube[7-8].The pressure drop along the central axis of the pipeline has a very good linearity, which can provide a relatively stable static pressure, so the new throttling device can adjust the flow well, basically effectively avoid the occurrence of flow separation, and improve the Measurement accuracy and repeat ability.

Based on the requirements of confidentiality and patentability, there are few published documents about channel flowmeters. After consulting a large number of documents, it is found that there is no unified international and domestic standard for channel flowmeters. Therefore, the key factors such as the outflow coefficient are The impact of performance parameters on their petrology perform WVHFFTance requires in-depth scientific research.sed the inner cone flowmeter of DN150mm and three equivalent ratios to experimentally study the performance change of the flowmeter in the presence of vortices. Not significantly.Professor Xu Ying of Tianjin University and others used numerical simulation software to predict the gas outflow coefficient of the inner cone flowmeter based on the RNG-K-ε

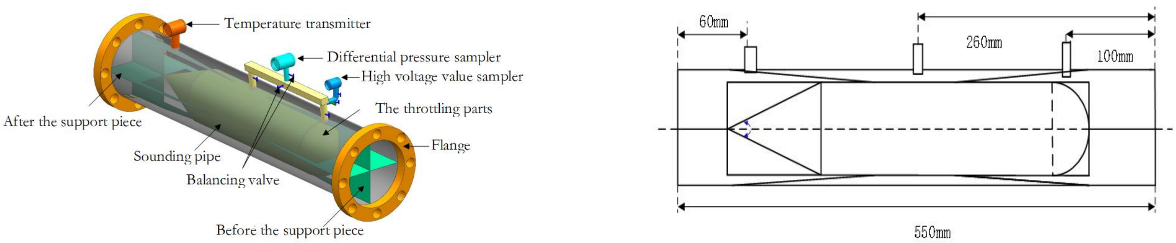
model[3-4]. The study showed that the front cone angle of the inner cone flowmeter has a great influence on the gas outflow coefficient. The prediction accuracy between simulation and simulation is between 2% and 7%. In addition, Xu Ying, Chen Wuxiao and others also studied the flow field simulation and outflow coefficient prediction of the double-supported inner cone flowmeter by using the *SST k-ω* and *K-ε* models[3].

As a new type of non-standardized differential pressure flowmeter, the channel flowmeter has few published literatures on its measurement performance, and its outflow coefficient pressure loss needs to be further studied.

In this paper, water and air are taken as the measurement objects, and the measurement characteristics of channel flowmeters are studied, and the variation law of the outflow coefficient under different Reynolds number ranges is emphatically investigated. For the change of outflow coefficient at low Reynolds number, an accurate and reliable numerical analysis model was established, and the measurement error of channel flowmeter in gas and liquid medium was studied and analyzed by the research method of real flow and simulation.

2. Experiment and Simulation of Channel Flowmeter

2.1 Structure and parameters



a b

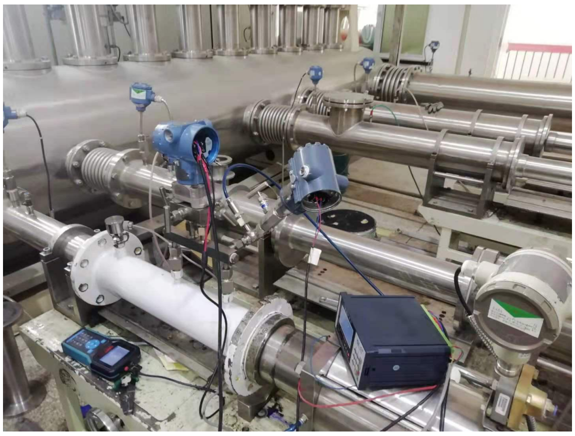
Figure1：Structure of channel flowmeter

The flowmeter is composed of a measuring tube, a differential pressure transmitter, a temperature transmitter, a differential pressure throttle, and a support rod. The throttling piece installed coaxially in the measuring tube and the corresponding temperature and pressure ports. High pressure (positive pressure) is the pressure tap in the pipe wall before the upstream fluid contracts. The static pressure *P1* measured at *P1*, the low pressure (negative pressure) is the pressure *P2* at the end face of the throttling piece facing the downstream, the pressure hole opened at the central axis, *ΔP* is the differential pressure value, and the ellipse of the throttling piece is the flow direction , the rear of the throttling piece forms an acute angle. a is a three-dimensional diagram of the flowmeter, and b is a two-dimensional plane of the flowmeter.

2.2 Experiment and device

The experimental system for gas and liquid media adopts the critical Venturi nozzle method gas flow standard device and the static mass method flow standard device respectively. The medium is clean air and water. In the real flow experiment, the upstream flow ensures that the minimum straight pipe section meets the front section. 10 times the diameter of the pipe under test and 5 times the diameter of the pipe under test at the rear end. When the fluid passes through the straight pipe section and reaches the high pressure pressure position, the flow is relatively balanced. In order to fully develop the flow, the influence of the inlet benefit on it can be ignored.

Critical venturi nozzle method gas flow standard: (1-15000) m^3/h, U=0.25%, k=2; kPa, medium is air, density is 1.287 kg/m3; static mass method water flow standard device: (0.1 -2200) t/h, U=0.05%, k=2. The laboratory temperature is (23.2-23.6)℃,and the atmospheric pressure is (94.13-94.30) kp. Each point is measured 6 times and the average value is taken as the indication value of this point. After the flow is stable for 60s, the indication value of this point is recorded.



gas experiment

liquid experiment

Figure2.Field experiment

In this study, the compressibility coefficient of liquid medium is taken as 1, and the gas medium is calculated by adopting the latest international standard:

In 2003, a new differential pressure flowmeter fluid expansion coefficient calculation model was issued：

$$\varepsilon = 1 -（0.351 + 0.256\beta^4 + 0.93\beta^8）\left[1-\left(\frac{P_2}{P_1}\right)^{\frac{1}{\kappa}}\right]$$

κ is the isentropic index of the medium;

3. Conclusion and Analysis

Table1：Re& outflow coefficient （Liquid medium）

average velocity (m/s)	*Re*	C_d	experimental standard deviation %	C_d	deviation rate%
0. 159	1. 66E+04	0. 8778	0. 50	0. 9151	4. 249
0. 442	4. 61E+04	0. 8397	0. 51	0. 8763	4. 359
0. 558	5. 82E+04	0. 8515	0. 48	0. 8765	2. 936
0. 771	8. 05E+04	0. 8851	0. 31	0. 9212	4. 079
1. 041	1. 09E+05	0. 8731	0. 35	0. 9113	4. 375
1. 427	1. 49E+05	0. 8733	0. 45	0. 9061	3. 756
1. 819	1. 90E+05	0. 8605	0. 48	0. 8902	3. 451
2. 213	2. 31E+05	0. 8703	0. 32	0. 8968	3. 045
2. 484	2. 59E+05	0. 8760	0. 42	0. 9045	3. 253
2. 950	3. 08E+05	0. 8883	0. 48	0. 9162	3. 141
3. 299	3. 44E+05	0. 8792	0. 50	0. 9112	3. 640
3. 585	3. 74E+05	0. 8851	0. 45	0. 9145	3. 322

Table2：Re& outflow coefficient （Gas medium）

average velocity (m/s)	back pressure ratio	*Re*	nozzle temperature ℃	C_d	experimental standard deviation %	C_d	deviation rate%
1. 785	0. 72	1. 15E+04	26. 06	0. 56	0. 89	0. 60	7. 33
3. 550	0. 71	2. 28E+04	26. 04	0. 74	0. 78	0. 79	6. 57
7. 113	0. 74	4. 57E+04	25. 96	0. 90	0. 85	0. 94	5. 06
10. 828	0. 71	6. 82E+04	26. 00	0. 90	0. 85	0. 95	5. 90
14. 296	0. 70	8. 86E+04	26. 03	0. 88	0. 65	0. 92	4. 17
28. 379	0. 73	1. 80E+05	26. 03	0. 88	0. 62	0. 93	5. 43
35. 067	0. 77	2. 22E+05	26. 03	0. 89	0. 71	0. 93	4. 42
41. 932	0. 77	2. 66E+05	26. 03	0. 89	0. 70	0. 93	4. 83
51. 380	0. 74	3. 25E+05	26. 03	0. 90	0. 72	0. 94	4. 36
60. 085	0. 75	3. 82E+05	26. 03	0. 90	0. 75	0. 93	3. 64

The outflow coefficient is a very important characteristic parameter of the channel flowmeter. Its calculation model is the ratio of the actual flow rate to the theoretical flow rate, which is mainly affected by the flowmeter structure, the material of the incoming fluid, and the Reynolds number Re and other parameters.

Table 1 and Table 2, it can be seen that there is a stable outflow coefficient region in both the gas phase and the liquid phase, that is, the outflow coefficient does not change with the change of Reynolds number within a certain range of Reynolds number.

In the whole test range, the difference of outflow coefficient between liquid and gas phase is not significant, and in the stable region of outflow coefficient, the difference in the lower limit of Reynolds number is not significant, but the difference in upper limit of Reynolds number is more significant. The range of Reynolds number in the outflow coefficient stable region is quite different. In addition, in the gas phase test, the back pressure ratio has a great influence on the outflow coefficient outside the stable outflow coefficient area, and the back pressure ratio in the stable area has almost no effect on the outflow coefficient.

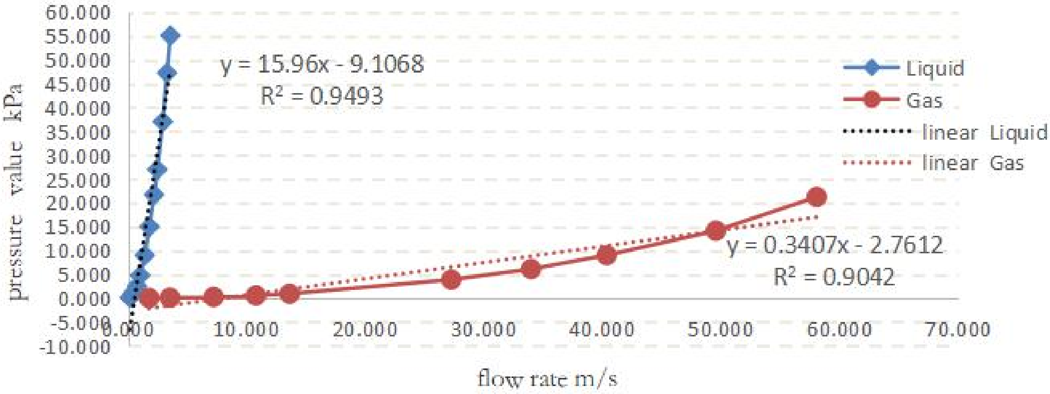


Figure2.Field experiment

In this paper, under the experimental conditions of gas phase and liquid phase, the standard deviation of the outflow coefficient in the stable zone is not large, and the variation trend of the differential pressure value with the flow rate is basically a linear relationship of R^2=0.9493 for the liquid medium and R^2=0.9042 for the gas phase medium, indicating that the two kinds of The fluid has excellent stability in the stable zone, and the difference in the lower limit of the Reynolds number Re in the stable zone is not significant. It also shows that the Reynolds number Re and the outflow coefficient Cd are mainly determined by the structural parameters of the flowmeter and are affected by the physical parameters of the incoming fluid. Not significantly.

4.Conclusion

The channel type has significant stability in the outflow coefficient in the stable zone, which is determined by the special structure of the channel type flowmeter. The fluid is not forced to shrink to the vicinity of the central axis of the pipeline, and the throttling part is not a barrier, so that the fluid suddenly changes the flow direction. It will pass through a straight pipe section between the throttling member and the measuring pipe, and form a uniform annular flow channel with the inner wall of the measuring pipe.There is no significant difference in the outflow coefficient under the condition of gas phase or liquid phase, indicating that the flowmeter has excellent metering performance.

5.References

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