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Digital structure design of a small nozzle flowmeter

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---***ABSTRACT***---

Nozzle flowmeter is a differential pressure generating device for measuring flow. It can measure the flow of various fluids in the pipeline with various differential pressure gauges or differential pressure transmitters. Because of its small pressure loss, it can save energy and is more durable. It is suitable for high temperature and high pressure fluid. It is widely used in the steam flow measurement of electric power, chemical industry and other industries. In this study, through the numerical calculation and analysis of nozzle flowmeter parameters and the determination of appropriate model, the working performance of nozzle flowmeter is preliminarily estimated and the digital structure design is carried out. The results of this study will provide a good basis for further study of nozzle flowmeter.

Key word： *Nozzle flowmeter, Structure design, Parameter calculation*

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I. INTRODUCTION

There are two kinds of nozzle flowmeter: Standard Nozzle and long diameter nozzle. It has the advantages of simple structure, convenient installation, high temperature and high pressure resistance, impact resistance, corrosion resistance, stable performance and long service life. It is widely used in many industries, such as petroleum, chemical industry, mining and metallurgy, steel, electric power, water conservancy, papermaking, pharmacy, food and chemical fiber. The working principle of nozzle flowmeter[1~3] is based on the throttling principle of fluid mechanics. When they flow through the nozzle in the pipe, the velocity of flow will form a local contraction in the nozzle, which will accelerate the flow rate and reduce the static pressure. Therefore, the pressure drop or differential pressure will be generated before and after the nozzle. The greater the flow rate of medium flow, the greater the pressure difference before and after the nozzle So the fluid flow can be measured by measuring the pressure difference. In this paper, a design scheme of nozzle flowmeter is proposed. SolidWorks[4~6] modeling technology is used to build digital model of nozzle flowmeter, and the parameters determined by calculation and model selection are used to obtain the overall three-dimensional modeling.

II. PARTS DESIGN

2.1 Design parameters

The main basic parameters of this model refer to the standard nozzle flowmeter (ISA1932 nozzle)：

（1）Nominal diameter（DN）：refers to the standardized diameter series of standard nozzle core, in mm. The scope of application is 50mm≤DN≤500mm.

（2）Nominal pressure（PN）：It refers to the value related to the pressure resistance of standard nozzle core components. Generally, the priority number of R10 series is adopted, and the unit is MPa. The scope of application is PN≤32MPa.

（3）Aperture ratio（β）：the scope of application is 0.30≤β≤0.8.

（4）Reynolds number（ReD）：a dimensionless number used to represent fluid flow . When 0.30≤β≤0.44 , 70000≤ReD≤107. When 0.44≤β≤0.8 , 20000≤ReD≤107.

（5）Total nozzle length：when 0.30≤β≤2/3 , Nozzle length = 0.6041d.

When 2/3≤β≤0.8， Nozzle length $=\left(0.4014+\sqrt{\frac{0.75}{\beta}-\frac{0.25}{\beta^2}-0.5225}\right)d$.

The external structure is shown in Figure 1.

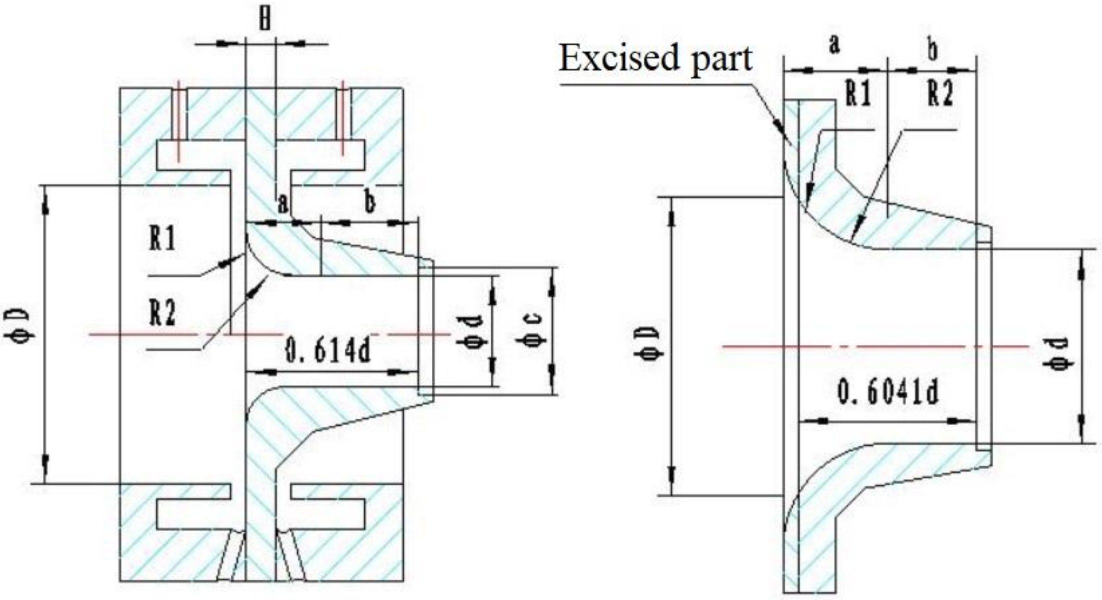


Figure 1 External structure

The flow calculation formula is as follows (1) and (2).

$$q_m=\frac{C\varepsilon_1}{\sqrt{1-\beta^4}}\times\frac{\pi}{4}d^2\sqrt{2\rho_1\Delta p} \tag{1}$$

$$q_v=\frac{C\varepsilon_2}{\sqrt{1-\beta^4}}\times\frac{\pi}{4}d^2\sqrt{\frac{2\Delta p}{\rho_1}} \tag{2}$$

The relationship between volume flow rate and mass flow rate is shown in the following equation (3) .

$$\frac{q_v}{V}=\frac{q_m}{\rho} \tag{3}$$

2.2 Part design

（1）Design of standard nozzle forging

The standard nozzle forging is mainly composed of high-pressure and low-pressure pressure taps, as shown in Figure 2.

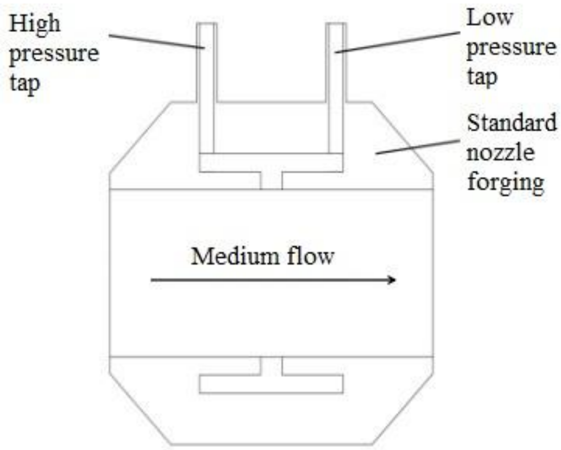


Figure 2 Structure of standard nozzle forging

According to the nominal diameter of the standard nozzle forging, the length of the standard spray forging can be obtained, as shown in Table 1 below.

Table 1 Reference values of DN and L for standard nozzle forgings

DN	L	β
DN50-DN150	200mm	According to different pipe size and pressure level requirements.
DN200-DN250	220mm	
DN300-DN350	240mm	
DN400-DN450	260mm	
DN500	300mm	

（2）Standard nozzle core design

The geometry of the nozzle is complex, and the accuracy of its size processing directly affects the measurement accuracy of the whole set of differential pressure flowmeter. The working principle of standard nozzle core is throttling principle of fluid mechanics. When the liquid in the pipe flows to the standard nozzle core, the flow rate will contract locally at the standard nozzle core, resulting in faster flow rate and lower static pressure, resulting in pressure difference between the front and the back of the standard nozzle core. When the flow rate of liquid is larger, the pressure difference of standard nozzle core is larger. The external structure of standard nozzle core is shown in Figure 3.

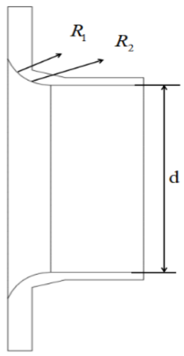


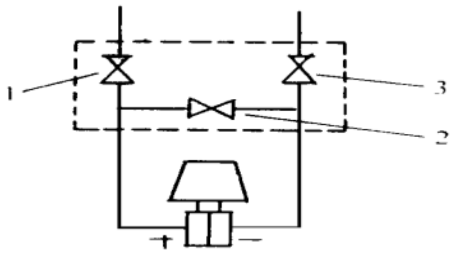
Figure 3 Outline structure of standard nozzle core

According to the requirements of GB / T2624.3-2006, 《Measurement of full pipe fluid flow using differential pressure devices installed in circular cross-section pipes - Part 3: nozzles and Venturi nozzles》,when $d < \frac{2D}{3}$ and $\beta < 0.5$, $R_1 = 0.2d \pm 0.02d$. The arc referred to by R1 is tangent to the plane entrance. The arc center of R1 is 0.2d away from the plane entrance and 0.75d from the axis of standard nozzle core. The arc referred to by R1 and R2 are tangent to the throat, $R_2 = \frac{d}{3} \pm 0.033d$. R2 refers to the distance between the arc center and the axis of the standard nozzle core is $\frac{d}{2} + \frac{d}{3} = \frac{5}{6}d$, The distance from the plane entrance $a_n = \left(\frac{12 + \sqrt{39}}{60}\right)d - 0.3041d$.

（3）Other parts design

Other main parts of standard nozzle flowmeter include three valve group, valve, etc.

Three valve group is composed of three valves communicating with each other, and is one of the important accessories of differential pressure transmitter. The three valve group can be divided into balance valve, high pressure valve and low pressure valve according to its function. As shown in Figure 4. The starting sequence of three valve group is to open balance valve 2 first, then high pressure valve 1 or low pressure valve 3. It must be ensured that at least one of high pressure valve 1 and low pressure valve 3 is closed, then close balance valve 2, and finally close low pressure valve 3 or high pressure valve 1. The shutdown sequence of three valve group is to close high pressure valve 1 or low pressure valve 3 first, and then open balance valve 2.



1-High pressure valve   2-Balance valve   3-Low pressure valve

Figure 4 Three valve assembly

According to the reference data, the valve body model of three valve group can be selected, as shown in Table 2 below.

Table 2 Model selection of three valve group valve body

Valve group category	Three valve group
Thread	1/2NPT
Texture of material	SUS 304 or 1Cr18Ni9Ti
Joint	Nothing
Temperature	≤ 260℃
Pressure	Nominal pressure：16MPa

Valve is a mechanical device to control the flow, flow direction and pressure of fluid medium. It is also a basic component in the pipeline system. It is produced along with the production of fluid pipeline. It is a medium transmission and control equipment with a large number of uses.

According to the reference data, the valve body model can be selected, as shown in Table 3 below.

Table 3 Valve body model selection

Valve category	Globe valve
Nominal pressure	PN1.0-16.0MPa
Nominal diameter	DN10~500
Connection mode	Threaded connection
Applicable temperature	-196℃~700℃
Driving mode	Manual

III. 3D DIGITAL MODELING

（1）Modeling of standard nozzle forging

Open SolidWorks, take the top view datum plane as the sketch drawing plane, after drawing sketch 1, rotate the boss to get a hollowed out standard nozzle forging prototype. Then use the upper view reference plane as the sketch drawing plane, draw a rectangle larger than sketch 1 for stretching and cutting to obtain half of the standard nozzle forging rudiment. And then the upper viewing reference plane is used as the sketch drawing plane in the Draw a symmetrical axis between them, and draw two identical figures on both ends of the symmetry axis to carry out 10 mm stretch cutting. Draw a half ring on the datum plane and carry out tensile cutting to obtain high-pressure and low-pressure pressure pressure tapping pipes, that is, to obtain half standard nozzle forgings. To assemble two one-and-a-half standard nozzle forgings, namely, standard nozzle forgings. As shown in Figure 5, the semi sectional three-dimensional drawing of the standard nozzle forging.

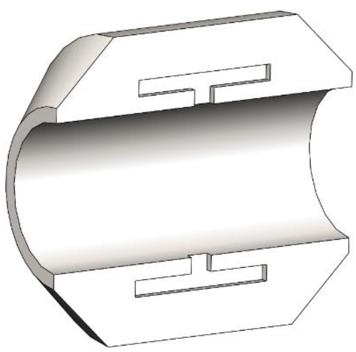


Figure 5 Semi sectional 3D drawing of standard nozzle forging

（2）Modeling of standard nozzle core

Open SolidWorks, use the front view datum plane as the sketch drawing plane, draw sketch 1 and stretch to get the solid cylinder. Then use the right view datum plane as the sketch drawing plane, draw a box larger than sketch 1 for stretching and cutting to obtain half of the standard nozzle core. Then, take the right view datum plane as the sketch drawing plane, draw sketch 3, and then rotate and cut. And The right view datum plane is the sketch drawing plane. After the sketch 4 is drawn, the rotary cutting is carried out. Finally, two datum planes parallel to the upper viewing datum plane are made, and the sketch is drawn in the datum plane, and the convex body is stretched. After this operation, half of the standard nozzle core is drawn. As shown in Figure 6, a three-dimensional half section of the standard nozzle core is shown.

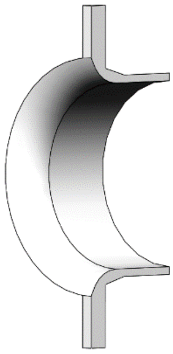


Figure 6 Three dimensional drawing of standard nozzle

（3）Modeling of valves

Open SolidWorks, use the front view datum plane as the sketch drawing plane, draw sketch 1 and stretch to get solid cylinder 1. Then fillet one side of the cylinder. Then draw sketch 2 to stretch to get solid cylinder 2. Then use one side of solid cylinder 2 as sketch drawing plane to draw sketch 3 Line stretch to get solid cylinder 3. Then take one side of solid cylinder 3 as sketch drawing plane, draw sketch 4 to stretch to get solid cylinder 4. Then take one side of solid cylinder 4 as sketch drawing plane, draw sketch 5 to stretch to get solid cylinder 5. Then take the top view datum plane as sketch drawing plane, draw sketch 6 to stretch both sides symmetrically. And then make a datum Finally, a straight line is drawn from cylinder 1 to scan the ring to get the valve. As shown in Figure 7, the valve is shown in three dimensions.

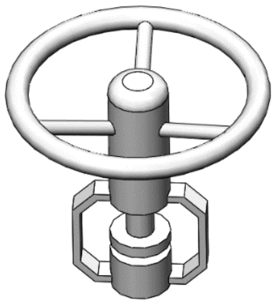


Figure 7 Three views of valve

（4）Modeling of three valve group

Open SolidWorks, use the front view datum plane as the sketch drawing plane, draw sketch 1 and stretch to get solid rectangle. Then use the front side of the rectangle as the datum plane, draw sketch 2 for stretch cutting. Then use the side of the rectangle as the datum plane to draw sketch 3 for stretch cutting. Finally, assemble the part with the valve to get the three valve group. As shown in Figure 8, the three-dimensional diagram of the three valve group is shown.

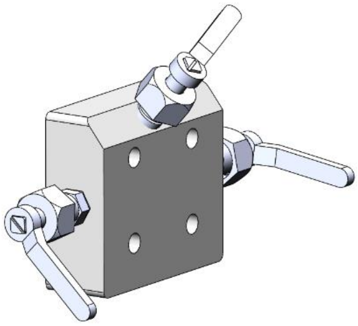


Figure 8 Three views of three valve group

（5）Assembly ligand diagram

The standard nozzle forging, standard nozzle core, valve, three valve group and standard parts are assembled by SolidWorks, and the isometric drawing of the final assembly ligand is shown in Figure 9, the front view is shown in Figure 10, and the left view is shown in Figure 11.

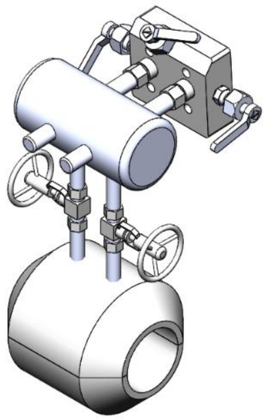


Figure 9 Isometric drawing

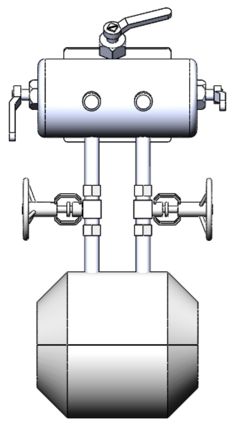


Figure 10 Front view

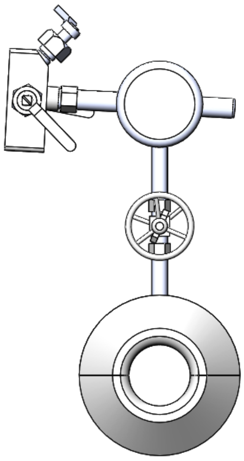


Figure 11 Left view

IV. CONCLUSION

According to the design parameter requirements of nozzle flowmeter, the reasonable parameters of nozzle flowmeter are determined by numerical calculation. In addition, according to the use of the nozzle flowmeter, the appropriate parts are selected, and the three-dimensional modeling and assembly of each part of the nozzle flowmeter are carried out by using SolidWorks, which provides a better basis for further research on the nozzle flowmeter.

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