The International Journal of Engineering and Science (IJES)
|| Volume || 13 || Issue || 1 || Pages || PP 26-34 || 2024 ||
ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805

Finite element analysis of a small nozzle flow meter

Min-Ming Cui[1,]*, Bo-Jie Xu[2], Bo Wang[2]
1. Dentification of Chongqing Agricultural Machinery Station, Chongqing, 402160, China
2. College of Mechanical Engineering, Quzhou University, Quzhou, 324000, China;

---ABSTRACT---
Nozzle flowmeter is a differential pressure generator for measuring flow rate. It can measure the flow rate of various fluids in pipeline with various differential pressure gauges or differential pressure transmitters. This paper mainly analyzes the stress and strain of different core materials, different load positions and displacement of forgings under the same load. Through the analysis of this paper, we can find the weak link of nozzle flowmeter, and we can easily know how to select material and manufacturing process in the future design.
***Keywords:** Nozzle flowmeter; Finite element; Material; Numerical analysis*

Date of Submission: 01-01-2024 Date of acceptance: 10-01-2024

I. Introduction

Nozzle flowmeter is an absolute flowmeter designed according to the principle of Laval nozzle in fluid dynamics. when the ratio of nozzle outlet pressure to inlet pressure is equal to 0.528, the velocity of air flow in the nozzle reaches supersonic speed and the gas flow through the nozzle reaches the maximum value[1]The nozzle flowmeter is a differential pressure generating device for measuring flow rate. The flow rate of various fluids in the pipeline can be measured with various differential pressure gauges or differential pressure transmitters. Standard nozzle throttling device and differential pressure transmitter matching use, can measure the flow of liquid, steam, gas. The nozzle flowmeter has a long history background and all kinds of test data are complete. Simple structure, no moving parts, long-term stable and reliable use, rich experience in design, manufacture and application. The standardization degree is high, may not need to carry on the real flow calibration. Standard orifice plate has reliable experimental data and perfect international and national standards. There is an inherent huge market in foreign and domestic, users are familiar with, data perfect; follow international standards to calculate and process, flexible and convenient to use; domestic flow measurement is still the most widely used differential pressure flowmeter, according to the relevant data estimated to account for 60-70% of the total amount of flowmeter. It is widely used in many industries such as petroleum, chemical industry, mining and metallurgy, iron and steel, electric power, water conservancy, paper making, pharmaceutical, food and chemical fiber [2]. Based on this, this paper makes further data calculation and analysis of nozzle flowmeter, and analyzes different materials, same load and same load position or different load, same material and same load position or different load position, same material and same load position to make more different situation to better analyze the influence of changing material, load and load position on the performance of standard nozzle core.

1. Building physical models

Open the simulation plug-in in the SolidWorks and establish a new example of static stress for finite element analysis. At the same time, we also set up a new name, modify the unit, set the storage path, and set the number of decimal places. as shown in Figure 1.

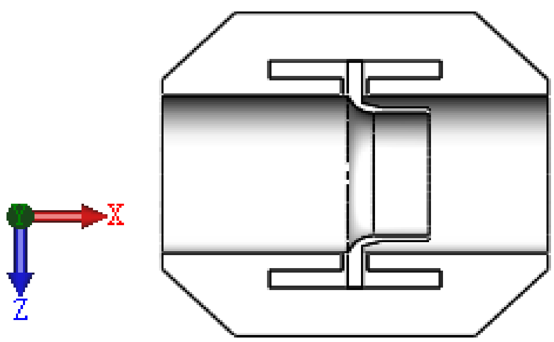


Fig .1 Calculation of Key Components

II. Applied Materials

2.1 Steel material

Standard nozzle forgings are made of stainless steel, and standard nozzle cores are made of stainless steel. Stainless steel has weldability, need raw material welding performance when welding. At the same time, stainless steel also has corrosion resistance, can withstand air, steam, water and other media with weak corrosion properties[3]. The basic parameters are shown in Table 1 below.

Table 1 Basic Properties of Stainless Steel Materials

Material name	Elastic modulus	Poisson's ratio	Mass density
Stainless steel (ferrite)	$2\times10^{11}N/m^2$	0.28	$7800\ kg/m^2$

2.2 Iron material

The material of standard nozzle forgings is stainless steel, and the material of standard nozzle core is gray cast iron.Gray cast iron has good casting performance, good damping, good wear resistance, good cutting performance, low notch sensitivity [4]. The basic parameters are shown in Table 2 below.

Table 2 Basic Properties of Gray Cast Iron Materials

Material name	Elastic modulus	Poisson's ratio	Mass density
Grey cast iron	$6.617\times10^{10}N/m^2$	0.27	$7200\ kg/m^2$

2.3 Aluminium materials

The material of standard nozzle forgings is stainless steel, and the material of standard nozzle core is 1060 aluminum alloy.Aluminum alloy 1060 is the highest aluminum content, up to 99.6% of the composition.1060 Aluminum alloy has a series of advantages, such as lightweight, good mechanical properties, good corrosion resistance, excellent electrical conductivity[5]Because the surface of 1060 aluminum alloy has a dense solid alumina protective film, which can resist acid, weak alkaline medium. The basic parameters are shown in Table 3 below.

Table 3 Basic Properties of 1060 Aluminum Alloy Materials

Material name	Elastic modulus	Poisson's ratio	Mass density
1060 aluminum alloy	$6.9\times10^{10}N/m^2$	0.33	$kg/m\ 2700^2$

III. Geometry fixation

In order to make the standard nozzle core have better static stress analysis, the standard nozzle core should be properly constrained so that there is no movement in the analysis. In this static stress analysis, the fixed geometry under the fixture consultant plug-in in the simulation is used to fix the standard nozzle core to ensure that the standard nozzle core will not move in all directions after the applied load. as shown in Figure 2.

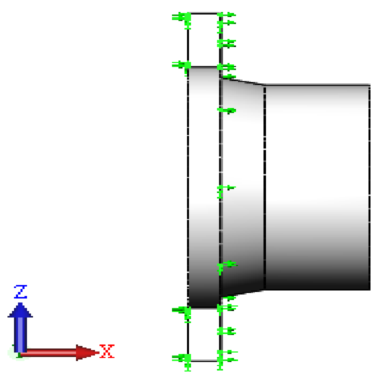


Figure 2 Add Figure of Standard Nozzle Core Fixture

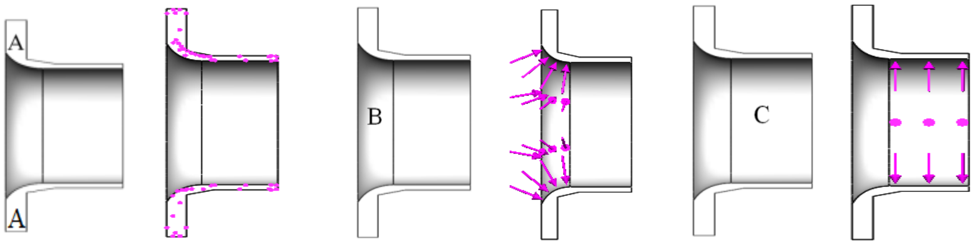
DOI:10.9790/1813-13012634

IV. Load Add

After fixing the step bottom of the standard nozzle core, the load is applied to the standard nozzle core, and the external pressure is applied to the standard nozzle core in real life. However, in this static stress analysis, in addition to changing the material of the standard nozzle core, it is necessary to change the load size and the position of the applied load. make more different cases for subsequent analysis of different materials, same load and same load position or different load, same material and same load position or different load position, same material and same load position to better analyze whether changing material, load and load position will have some effect on the performance of standard nozzle core.

4.1 Load position

For this time, the applied load position will be divided into three cases, applied in different three regions, as shown in (a),(b),(c) of figure 3 below.



(a) (b) (c)

Figure 3 Application of standard nozzle core load

4.2 Load size

The size of the applied load will be divided into two cases , 5000 N 、8000N, different loads in the A 、B 、C three areas will be applied three times. The specific load applied is shown in Table 4 below. The method used in this design is three factors and three levels orthogonal test. In the multi-factor test design, the representative test points are selected by orthogonal test design method to carry out the test. Through the analysis of the orthogonal test results, the situation of the test is fully understood, and the number of tests is greatly reduced. And the best matching scheme with multiple factors can be selected[6]This method can select a few typical test conditions in many tests, and can infer the design method of finding the best process conditions through a few test conditions.The orthogonal factor table is shown in Table 4 below, and the orthogonal test table is shown in Table 5 below.

Table 4 Level of factors (level of factor 3)

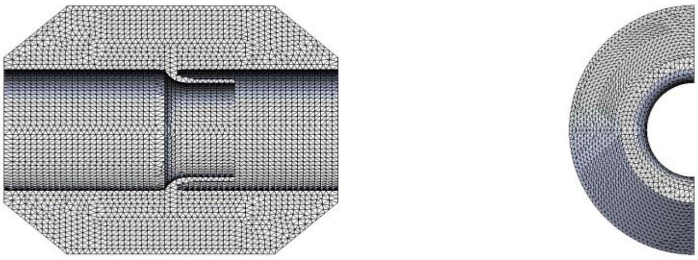
Level	Factors		
	Standard nozzle core material	Load size	Load position
1	Stainless Steel	5000N /8000N	A Area/ B Area
2	Grey cast iron	5000N /8000N	B Area/ C Area
3	1060 aluminum alloy	5000N /8000N	A / B / C areas

Table 5 Orthogonal test tables

Serial number	Standard nozzle forgings	Standard nozzle core	Load size	Load position
1	Stainless Steel	Stainless Steel	5000N	A Area
2	Stainless Steel	Stainless Steel	5000N	B Area
3	Stainless Steel	Grey cast iron	5000N	B Area
4	Stainless Steel	1060 aluminum alloy	5000N	B Area
5	Stainless Steel	1060 aluminum alloy	5000N	C Area
6	Stainless Steel	Stainless Steel	8000N	B Area
7	Stainless Steel	Grey cast iron	8000N	B Area
8	Stainless Steel	Grey cast iron	8000N	C Area
9	Stainless Steel	1060 aluminum alloy	8000N	A Area
10	Stainless Steel	1060 aluminum alloy	8000N	B Area

V. Generation of grids

The key parts are divided into limited small units. Mesh parameter selection standard mesh, mesh size 8 mm, tolerance 0.4 mm. The finer the mesh, the more accurate the static stress analysis will be, and the rougher it will be. The grid division of key parts is shown in figure 4.



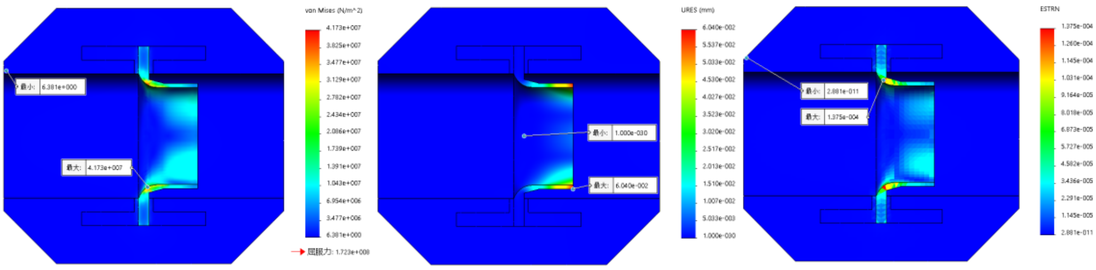
(a) Mesh of Key Components Face-to-face Graph (b) Mesh of Key Components Left View

Figure 4 Mesh of Standard Nozzle Core

VI. Fruit analysis

6.1 Case 1: N 5000 load

(1) Standard nozzle forging material stainless steel, standard nozzle core material stainless steel, load application position A zone select standard nozzle forgings and standard nozzle core material as stainless steel, apply 5000 N load to A zone, run an example, get standard nozzle core stress diagram, displacement diagram and strain diagram as shown in figure 5. The maximum stress of the key parts of the nozzle flowmeter appears in the position R1 the arc of the standard nozzle core is tangent to the plane inlet, that is, the maximum stress is $4.173\times10^{7}\,N/\mathrm{m}^{2}$,the minimum stress occurs in the inlet plane of the standard nozzle forging, that is, the minimum stress is $6.381N/m^{2}$,the yield force is $1.723\times10^{8}\,N$ as shown in figure 5(a) standard nozzle core stress diagram. As shown in figure5(b), the maximum displacement of the key parts of the nozzle flowmeter appears at the end of the standard nozzle core, that is, the maximum displacement is 6.04×10^{-2} mm,the minimum displacement occurs at the positive middle entrance of the standard nozzle core, that is, the minimum displacement is $1.0\times10^{-3}\mathrm{mm}$ .the maximum strain of the key parts of the nozzle flowmeter appears in the position R1 the arc of the standard nozzle core is tangent to the plane inlet, that is, the maximum strain is 1.375×10^{-4} , as shown in figure 5(c) standard nozzle core strain diagram ,the minimum strain appears on the inlet surface of the standard nozzle forgings, the minimum strain is 2.881×10^{-11} .

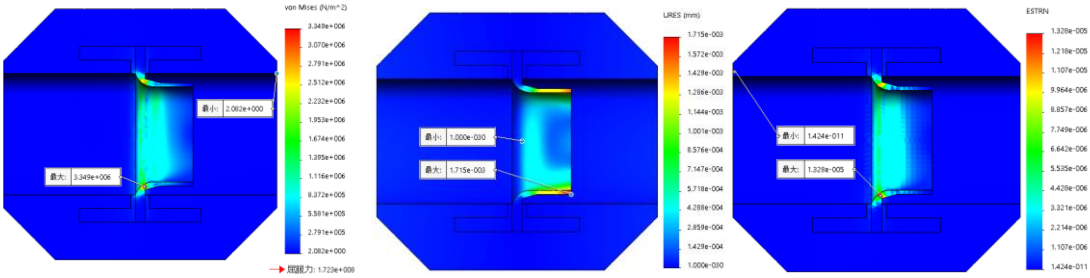


(a) stress map (b) displacement map (c) strain map

Figure 5 Analysis of results

(2) Standard nozzle forging material stainless steel, standard nozzle core material stainless steel, load application position B other conditions remain unchanged, the standard nozzle core material is selected as stainless steel ,5000 N load is applied to the B area, and an example is run to obtain the standard nozzle core stress diagram, displacement diagram and strain diagram as shown in figure 6. The maximum stress of the key parts of the nozzle flowmeter appears in the position R1 the arc of the standard nozzle core is tangent to the plane inlet, that is, the maximum stress is $3.349\times10^{6}\,N/\mathrm{m}^{2}$,the minimum stress occurs in the outlet plane of the standard nozzle forgings, the minimum stress is $2.082N/m^{2}$,the yield force is $1.723\times10^{8}\,N$. as shown in figure 6(a) standard nozzle core stress diagram.As shown in Fig .6(b), the maximum displacement of the key parts of the nozzle flowmeter appears at the end of the standard nozzle core, that is, the maximum displacement is 1.715×10^{-3} mm,the minimum displacement occurs at the center entrance of the standard

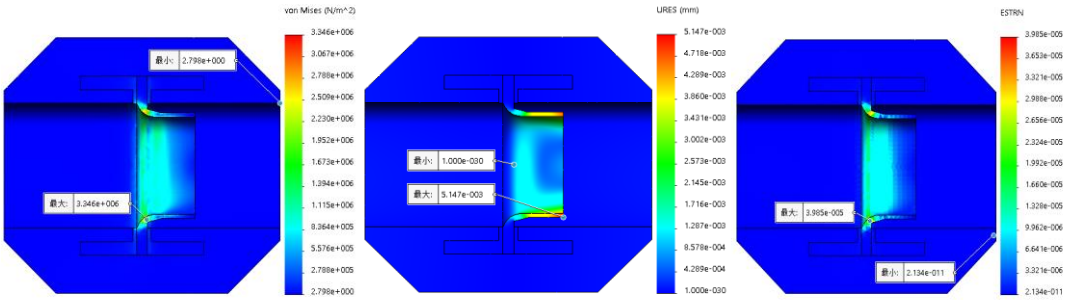
nozzle core. The minimum displacement is $1.0\times10^{-3}\text{mm}$ .The maximum strain of the key parts of the nozzle flowmeter appears in the position R1 the arc of the standard nozzle core is tangent to the plane inlet, that is, the maximum strain is 1.328×10^{-5} ,the minimum strain occurs at the inlet plane of the standard nozzle forging, that is, the minimum strain is 1.424×10^{-11} as shown in figure 6(c) standard nozzle core strain diagram.



(a)stress map (b) displacement map (c) strain map

Figure 6 Analysis of results

(3) Standard nozzle forging material stainless steel, standard nozzle core material gray cast iron, load applied position B other conditions remain unchanged, the material of standard nozzle core is selected as gray cast iron, the load of 5000 N is applied to the B area, and an example is run to obtain the standard nozzle core stress diagram, displacement diagram and strain diagram as shown in figure 7. The maximum stress of the key parts of the nozzle flowmeter appears in the position R1 the arc of the standard nozzle core is tangent to the plane inlet, that is, the maximum stress is $3.346\times10^{6}N/\text{m}^{2}$,the minimum stress occurs in the outlet plane of the standard nozzle forging, that is, the minimum stress is $2.798N/m^{2}$ as shown in figure 7(a) standard nozzle core stress diagram.As shown in Figure 7(b), the maximum displacement of the key parts of the nozzle flowmeter appears at the end of the standard nozzle core, that is, the maximum displacement is 5.147×10^{-3} mm ,the minimum displacement occurs at the center entrance of the standard nozzle core. The minimum displacement is $1.0\times10^{-3}\text{mm}$ .The maximum strain of the key parts of the nozzle flowmeter appears in the position R1 the arc of the standard nozzle core is tangent to the plane inlet, that is, the maximum strain is 3.985×10^{-5} , the minimum strain appears on the outlet surface of the standard nozzle forging, that is, the minimum strain is 2.134×10^{-11} as shown in figure 7(c) standard nozzle core strain diagram.

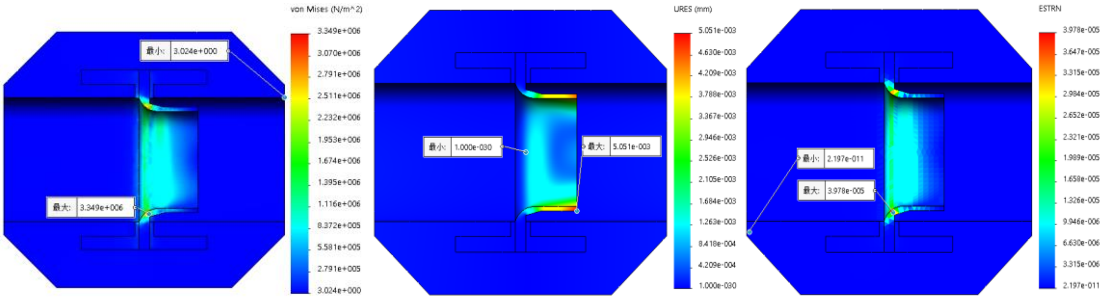


(a)stress map (b) displacement map (c) strain map

Figure 7 Analysis of results

(4)Standard nozzle forging material stainless steel, standard nozzle core material 1060 aluminum alloy, load applied position B other conditions remain unchanged, the standard nozzle core material is selected as 1060 aluminum alloy ,5000 N load is applied to the B area, and the operation example is given to obtain the standard nozzle core stress diagram, displacement diagram and strain diagram as shown in figure 1-8.

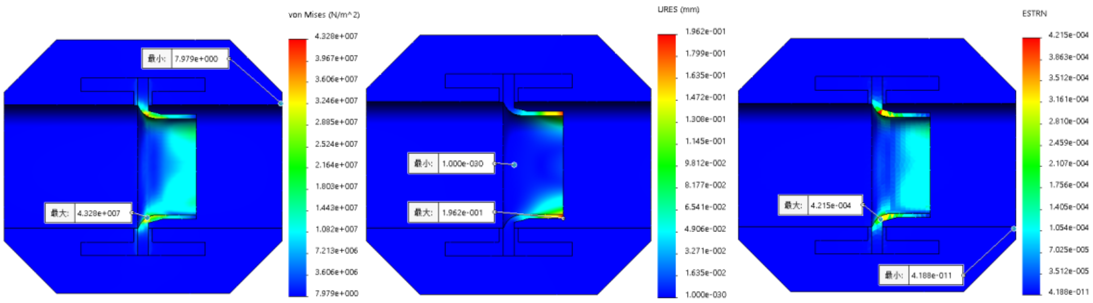
The maximum stress of the key parts of the nozzle flowmeter appears in the position R1 the arc of the standard nozzle core is tangent to the plane inlet, that is, the maximum stress is $3.349\times10^{6}N/\text{m}^{2}$, the minimum stress occurs in the outlet plane of the standard nozzle forging, that is, the minimum stress is $3.024N/m^{2}$ as shown in figure 8(a) standard nozzle core stress diagram.As shown in Fig .8(b), the maximum displacement of the key parts of the nozzle Flowmeter appears at the end of the standard nozzle core, that is, the maximum displacement is 5.051×10^{-3} mm,the minimum displacement occurs at the center entrance of the standard nozzle core. The minimum displacement is $1.0\times10^{-3}\text{mm}$ .The maximum strain of the key parts of the nozzle flowmeter appears in the position R1 the arc of the standard nozzle core is tangent to the plane inlet, that is, the maximum strain is 3.978×10^{-5} , the minimum strain occurs at the inlet plane of the standard nozzle forging, that is, the minimum strain is 2.197×10^{-11} as shown in figure 8(c) standard nozzle core strain diagram.



(a)stress map (b) displacement map (c) strain map

Figure 8 Analysis of Results

(5)standard nozzle forging material stainless steel, standard nozzle core material 1060 aluminum alloy, load applied position C area keep nozzle forging material unchanged, select standard nozzle core material is 1060 aluminum alloy, apply 5000 N load to C area, run example, get standard nozzle core stress diagram, displacement diagram and strain diagram as shown in figure 9. The maximum stress of the key parts of the nozzle flowmeter appears in the position R1 the arc of the standard nozzle core is tangent to the plane inlet, that is, the maximum stress is $4.328\times10^{7}\,N/\text{m}^{2}$, the minimum stress occurs on the outlet surface of the standard nozzle forging, that is, the minimum stress is $7.979N/m^{2}$ as shown in figure 9(a) standard nozzle core stress diagram.As shown in Fig .9(b), the maximum displacement of the key parts of the nozzle flowmeter appears at the end of the standard nozzle core, that is, the maximum displacement is 1.962×10^{-1} mm,the minimum displacement occurs at the center entrance of the standard nozzle core. The minimum displacement is 4.214×10^{-4} ,the minimum strain appears on the outlet surface of the standard nozzle forging, that is, the minimum strain is 5.761×10^{-11}.



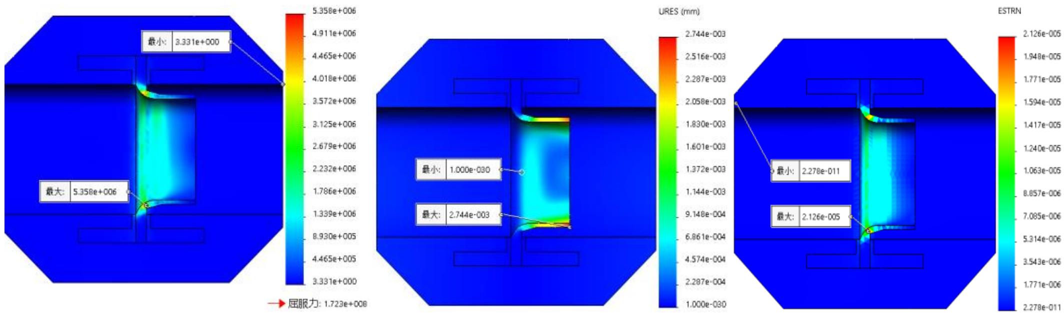
(a)stress map (b) displacement map (c) strain map

Figure 9 Analysis of results

6.2 Case 2: Load N 8000

(1) Standard nozzle forging material stainless steel, standard nozzle core material stainless steel, load applied position B other conditions remain unchanged, the material of standard nozzle core is selected as stainless steel, the load of 8000 N is applied to the B area, and an example is run to obtain the standard nozzle core stress diagram, displacement diagram and strain diagram as shown in figure 10.The maximum stress of the key parts of the nozzle flowmeter appears in the position R1 the arc of the standard nozzle core is tangent to the plane inlet, that is, the maximum stress is $5.358\times10^{6}\,N/\text{m}^{2}$, the minimum stress occurs in the outlet plane of the standard nozzle forging, that is, the minimum stress is $3.331N/m^{2}$, the yield force is $1.723\times10^{8}N$ as shown in figure 10(a) standard nozzle core stress diagram.As shown in Figure10(b), the maximum displacement

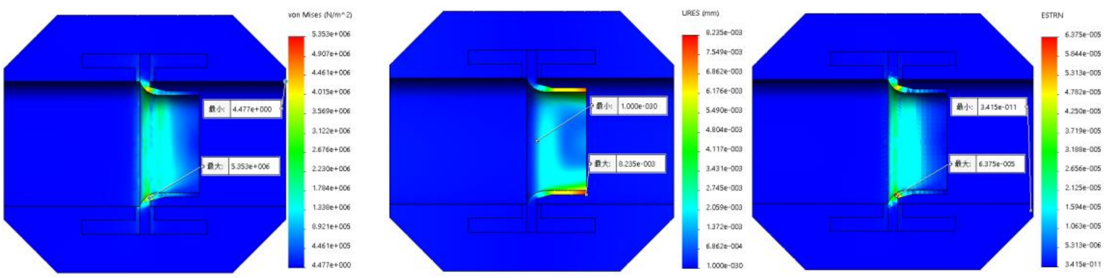
of the key parts of the nozzle Flowmeter appears at the end of the standard nozzle core, that is, the maximum displacement is 2.744×10^{-3} mm,the minimum displacement occurs at the center entrance of the standard nozzle core. The minimum displacement is $1.0\times10^{-3}\mathrm{mm}$ .The maximum strain of the key parts of the nozzle flowmeter appears in the position R1 the arc of the standard nozzle core is tangent to the plane inlet, that is, the maximum strain is 2.126×10^{-5} ,the minimum strain occurs at the inlet plane of the standard nozzle forging, that is, the minimum strain is 2.278×10^{-11} as shown in figure 10(c) standard nozzle core strain diagram.



(a)stress map (b) displacement map (c) strain map

Figure 10 Analysis of results

(2) Standard nozzle forging material stainless steel, standard nozzle core material gray cast iron, load applied position B area to keep nozzle forging material unchanged, select standard nozzle core material as gray cast iron, apply 8000 N load to B area, run example, get standard nozzle core stress diagram, displacement diagram and strain diagram as shown in figure 11. The maximum stress of the key parts of the nozzle flowmeter appears in the position R1 the arc of the standard nozzle core is tangent to the plane inlet, that is, the maximum stress is $5.353\times10^{6}N/\mathrm{m}^{2}$, the minimum stress occurs in the outlet plane of the standard nozzle forging, that is, the minimum stress is $4.477N/m^{2}$ as shown in figure 11(a) standard nozzle core stress diagram.As shown in figure11(b) standard nozzle core displacement diagram, the maximum displacement of nozzle flowmeter appears at the end of the standard nozzle core, that is, the maximum displacement is 8.235×10^{-3} mm,the minimum displacement occurs at the middle entrance of the standard nozzle core. The minimum displacement is $1.0\times10^{-3}\mathrm{mm}$ .The maximum strain of the key parts of the nozzle flowmeter appears in the position R1 the arc of the standard nozzle core is tangent to the plane, that is, the maximum strain is 6.375×10^{-5} , the minimum strain appears on the outlet surface of the standard nozzle forging, that is, the minimum strain is 3.415×10^{-11} as shown in figure 11(c) standard nozzle core strain diagram.

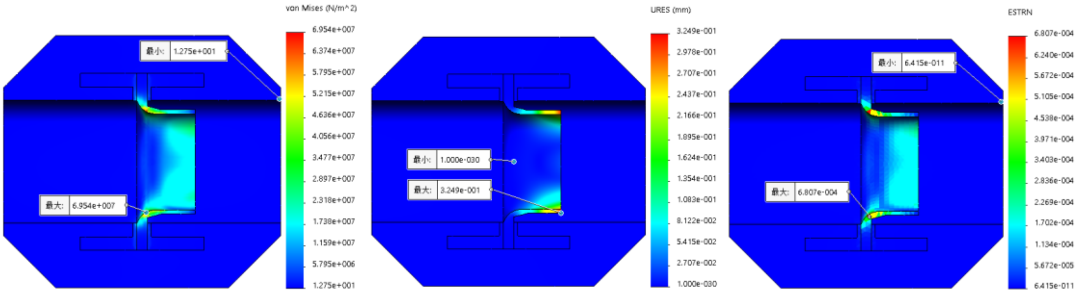


(a)stress map (b) displacement map (c) strain map

Figure 11 Analysis of results

(3) Standard nozzle forging material stainless steel, standard nozzle core material gray cast iron, load applied position C other conditions remain unchanged, the material of standard nozzle core is selected as gray cast iron, the load of 8000 N is applied to the C area, and an example is run to obtain the standard nozzle core stress diagram, displacement diagram and strain diagram as shown in figure 12. The maximum stress of the key parts

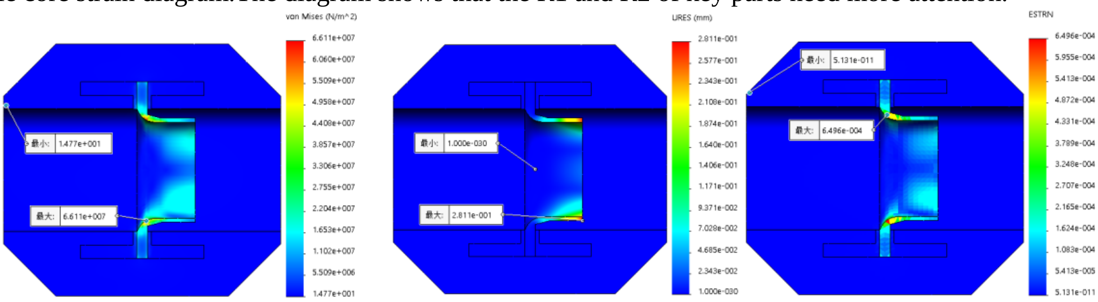
of the nozzle flowmeter appears in the position R1 the arc of the standard nozzle core is tangent to the plane inlet, that is, the maximum stress is $6.954\times10^{7}\,N/\mathrm{m}^{2}$, the minimum stress occurs in the outlet plane of the standard nozzle forging, that is, the minimum stress is $12.75N/m^{2}$, as shown in figure 12(a) standard nozzle core stress diagram.The diagram shows that the R1 and R2 of key parts need more attention. As shown in figure 12(b), the maximum displacement of the key parts of the nozzle flowmeter appears at the end of the standard nozzle core, that is, the maximum displacement is 3.249×10^{-1} mm, the minimum displacement occurs at the middle entrance of the standard nozzle core and the minimum displacement is $1.0\times10^{-3}\mathrm{mm}$.The maximum strain of the key parts of the nozzle flowmeter appears in the position R1 the arc of the standard nozzle core is tangent to the plane, that is, the maximum strain is 6.807×10^{-4}, the minimum strain appears on the outlet surface of the standard nozzle forging, that is, the minimum strain is 6.415×10^{-11}as shown in figure 12(c) standard nozzle core strain diagram.



(a)stress map (b) displacement map (c) strain map

Figure 12 Analysis of results

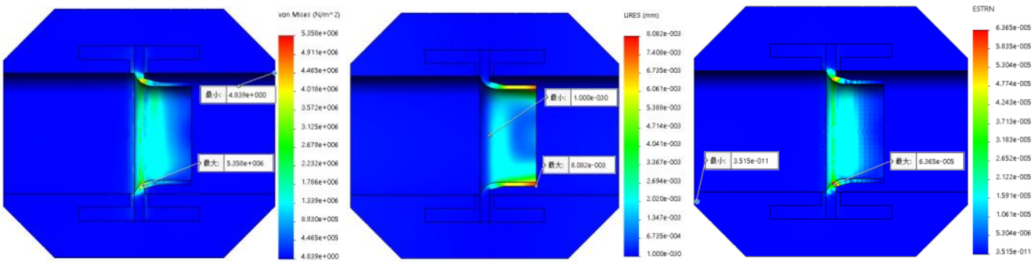
(4)Standard nozzle forging material stainless steel, standard nozzle core material 1060 aluminum alloy, load applied position A area to keep nozzle forging material unchanged, select standard nozzle core material 1060 aluminum alloy, apply 8000 N load to A area, run example, get standard nozzle core stress diagram, displacement diagram and strain diagram as shown in figure 13. The maximum stress of the key parts of the nozzle flowmeter appears in the position R1 the arc of the standard nozzle core is tangent to the plane inlet, that is, the maximum stress is $6.611\times10^{7}\,N/\mathrm{m}^{2}$, the minimum stress occurs in the inlet plane of the standard nozzle forging, that is, the minimum stress is $14.77N/m^{2}$ as shown in figure 13(a) standard nozzle core stress diagram.According to the diagram, the entrance of the standard nozzle core, that is, the small area of the B area, is not stressed.As shown in figure 13(b), the maximum displacement of the key parts of the nozzle Flowmeter appears at the end of the standard nozzle core, that is, the maximum displacement is 2.811×10^{-1}mm,the minimum displacement occurs at the center entrance of the standard nozzle core. The minimum displacement is $1.0\times10^{-3}\mathrm{mm}$.From the diagram, we can see that the end of the key parts need more attention.The maximum strain of the key parts of the nozzle flowmeter appears in the position R1 the arc of the standard nozzle core is tangent to the plane, that is, the maximum strain is 6.496×10^{-4}, the minimum strain appears on the inlet surface of the standard nozzle forgings, the minimum strain is 5.131×10^{-11} as shown in figure 13(c) standard nozzle core strain diagram.The diagram shows that the R1 and R2 of key parts need more attention.



(a)stress map (b) displacement map (c) strain map

Figure 13 Analysis of results

(5)Standard nozzle forging material stainless steel, standard nozzle core material 1060 aluminum alloy, load applied position B area to keep nozzle forging material unchanged, select standard nozzle core material as gray cast iron, apply 8000 N load to B area, run example, get standard nozzle core stress diagram, displacement diagram and strain diagram as shown in figure 14. The maximum stress of the key parts of the nozzle flowmeter appears in the position R1 the arc of the standard nozzle core is tangent to the plane inlet, that is, the maximum stress is $5.358\times10^{6} N/\mathrm{m}^{2}$, the minimum stress occurs in the outlet plane of the standard nozzle forging, that is, the minimum stress is $4.839 N/m^{2}$ as shown in figure 14(a) standard nozzle core stress diagram.According to figure 14(a), except for some changes in the stress at the entrance of the standard nozzle core, the other stresses are almost constant. As shown in figure 14(b), the maximum displacement of the key parts of the nozzle flowmeter appears at the end of the standard nozzle core, that is, the maximum displacement is 8.082×10^{-3} mm,the minimum displacement occurs at the middle entrance of the standard nozzle core. The minimum displacement is $1.0\times10^{-3}\mathrm{mm}$. According to figure 14(b), except for some changes in the displacement at the outlet of the standard nozzle core, the other displacements are almost constant. The maximum strain of the key parts of the nozzle flowmeter appears in the position R1 the arc of the standard nozzle core tangent to the plane inlet, that is, the maximum strain is 6.365×10^{-5}, the minimum strain appears on the inlet surface of the standard nozzle forgings, the minimum strain is 3.515×10^{-11} as shown in figure 14(c) standard nozzle core strain diagram.



(a)stress map (b) displacement map (c) strain map

Figure 14 Analysis of results

VII. Conclusion

This paper first builds the model of the key part of the nozzle flowmeter and uses the simulation plug-in in the SolidWorks to establish a new example of static stress and carry out finite element analysis. According to the analysis, the position of maximum stress and strain at different loading positions of different nozzle core materials, same load and same forging position are all at the position of tangent R1 of standard nozzle core arc and plane entrance, the position of minimum stress is in the exit plane of standard nozzle forgings, the position of maximum displacement is at the end of standard nozzle core, and the position of minimum displacement is at the middle entrance of standard nozzle core. Through the analysis of this paper, we can find the weak part of nozzle flowmeter, and solve the problem of avoiding risk more reasonably and effectively in the production of casting.

Acknowledgements

The work was supported by the national college students' science and technology innovation project (No. 202211488028).

Reference documentation

[1]. Zhong Yunhui, Luo Gensong, Huang Zhimin, iso-nozzle flowmeter and vacuum dropper flowmeter [J]. and Vacuum ,2012,49(002):29-32.

[2]. Analysis on Natural Gas Flow Measurement with Standard Nozzle flowmeter by Zhang Fuyuan, Gao Jun [J]. Wang Jingan China Metrology ,2016(1):96-100.

[3]. Li Xingkai. Analysis of Chemical Composition of Stainless Steel [J].by ICP-AES Method Arts and Science Navigation (mid-day),2012000(005):65-66.. Processing Technology [M].

[4]. Huang Tianyou, Du Dong, Fang Gang Tsinghua University Press ,2004.

[5]. Jurgen HIRSCH.Recent development in aluminium for automotive applications[J]. Transactions of Nonferrous Metals Society of China,2014,24(007)：1995-2002.

[6]. Liu Ruijiang, Zhang Yewang, Wen Chongwei [J].] on Orthogonal Experimental Design and Analytical Methods Experimental Technology and Management ,2010,27(9):52-55.