

Optimization Design of Three Eccentric Metal Seal Butterfly Valve based on Finite Element Analysis

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Abstract

ANSYS software has strong finite element analysis ability, which can accurately simulate the structure, flow field and temperature field, and has been widely used in valve industry. In this paper, three eccentric metal butterfly valve is taken as the research object, and the strength of butterfly plate and valve rod is simulated and checked at 1.5 times of design pressure. According to the simulation results, the structure optimization scheme is proposed; and the flow field of butterfly plate under different opening degrees is simulated to study the influence of butterfly plate structure on flow field.

Keywords

Structure Analysis; Flow Field Analysis; Three Eccentric Butterfly Valve.

1. Introduction

The structure of the valve is more complex, and functional software is needed in the design process. ANSYS is the most convenient and effective software for valve design. Through ANSYS, the actual working condition of the valve can be simulated and analyzed, so as to optimize the valve structure design according to the analysis results.

Traditional valve design is generally carried out according to the way of "design manual + experience", that is to find the design manual according to the working conditions to determine the key parameters and design experience to determine part of the parameters. When using this method to design new products, due to the lack of previous experience, the determination of some key parameters may be biased. If the results of relevant tests do not meet the requirements, redesign is required, and even safety problems may occur during the test. Therefore, for this kind of traditional design method, on the one hand, it requires designers to have rich design experience, on the other hand, it often causes excessive product safety margin and increases production cost.

At present, valve design and simulation with 3D software has become a trend, many valve enterprises have begun to use parametric digital design means for product development and design, greatly improving the quality of valve products and production efficiency. On the basis of parametric design, the simulation is carried out on the structure, flow field, temperature field, and the optimization design is carried out according to the simulation results. In this paper, SolidWorks software is used to establish the three-dimensional model of triple eccentric butterfly valve, and ANSYS software is used to analyze the structure and flow field of the butterfly valve.

2. General structure and working condition of triple eccentric butterfly valve

The working medium of the triple eccentric butterfly valve studied in this paper is sea water, the nominal size is dn2700mm, the design pressure is 0.5MPa, and the connection mode is flange connection. In order to improve the pressure bearing capacity of the butterfly plate, the butterfly plate is designed as a turtle back arched structure with large curvature, and the back

of the butterfly plate adopts the stiffener structure. The three-dimensional model of the butterfly valve studied is shown in Figure 1, and the three-dimensional model of the butterfly plate is shown in Figure 2. In order to improve the corrosion resistance of butterfly valve in seawater medium, the material parameters of each structure of butterfly valve are shown in Table 1.

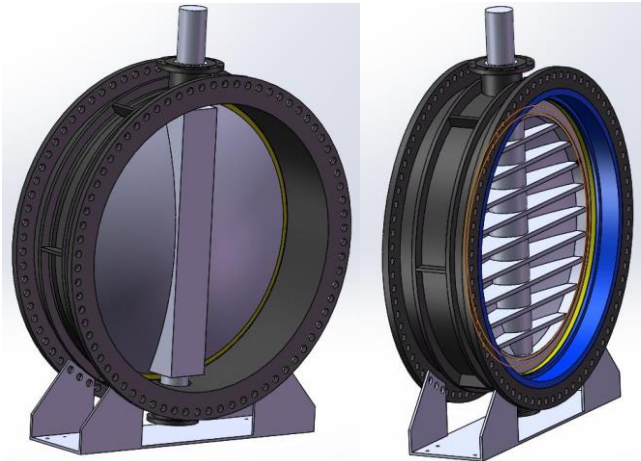


Figure 1. Three dimensional model of three eccentric butterfly valve

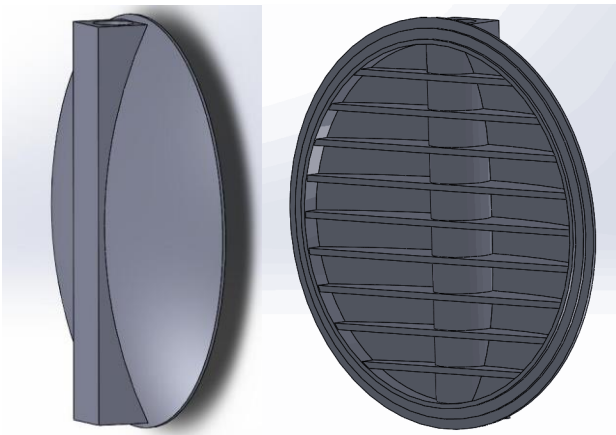


Figure 2. Structural model of arched butterfly plate with large curvature

Table 1. Structural material of triple eccentric butterfly valve

Serial number	Name of main parts and components	Material and type
1	Valve body	Ductile iron ASTM A536 Gr.60-40-18
2	Disc	Ductile iron ASTM A536 Gr.60-40-18
3	Valve shaft	Seawater resistant stainless steel
4	axle sleeve	Seawater resistant stainless steel
5	Bearing	Self lubrication
6	Body liner	EPDM/ Butadiene rubber / Natural rubber / Anticorrosive coating
7	Sealing surface of butterfly plate	EPDM/ Butadiene rubber / Natural rubber / Anticorrosive coating
8	Internal over-current fastener	Seawater resistant material

3. Finite element structure analysis

Compared with the traditional butterfly valve, the three eccentric butterfly valve designed in this paper adopts the turtle back arch structure with large curvature, and the back of the butterfly plate adopts the reinforced rib structure, while the design of other parts such as the valve body follows the design experience accumulated in the earlier stage, so it has enough

strength. Therefore, the key point of structural strength analysis is to ensure that the butterfly plate still has enough strength when the pressure is maximum. The stress of the butterfly plate is the largest when it is in the fully closed state, and the test pressure is 1.5 times of the design pressure according to the verification requirements. Therefore, this paper analyzes the stress and deformation of the butterfly plate under 1.5 times of the pressure load, and puts forward optimization measures according to the simulation results.

3.1. The finite element model of three eccentric metal seal butterfly valve was established

Finite element analysis software provides abundant CAE interfaces which can be compatible with Solidworks, Pro / E, UG and other 3D modeling software. In this paper, the solid model of three eccentric metal seal butterfly valve is established by SolidWorks. On the basis of ensuring the accuracy of simulation results, considering the efficiency of simulation, some unimportant structures are simplified or omitted. The established three-dimensional solid model is imported into the finite element analysis software, and each structure is given appropriate material properties, and then meshed to form a finite element simulation model. It is shown in Figure 3.

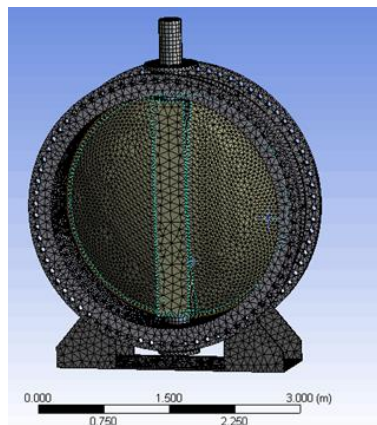
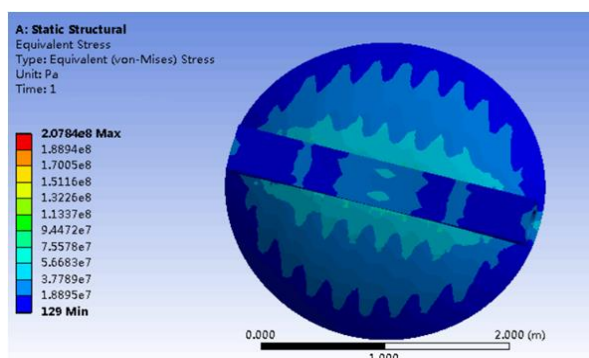


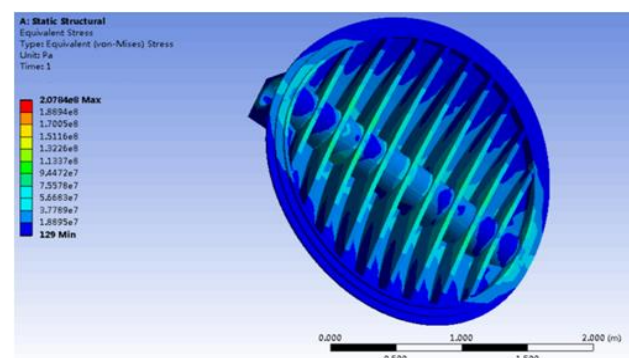
Figure 3. Finite element model of triple eccentric butterfly valve

3.2. Structural strength analysis of triple eccentric metal seal butterfly valve

The static analysis method is used in the structural strength analysis. The butterfly plate is loaded with 1.5 times of the design pressure. The stress distribution, displacement value and structural deformation of the butterfly plate are extracted to obtain the maximum stress area and the maximum deformation area to verify the structural strength and further guide the optimal design of butterfly valve.



(a) Front stress distribution



(b) Back stress distribution

Figure 4. Stress distribution of butterfly plate

Figure 4 shows the stress nephogram of front and back of butterfly plate. It can be seen from the figure that the maximum stress occurs at the back of butterfly plate near the stem shaft hole, and the maximum value is about 132mpa, which is far less than the yield strength of butterfly plate material (ASTM a536) of 276mpa, and the safety factor is greater than 2. In addition, it can be seen from Figure 4 (a) that the design of large curvature bow back can effectively reduce the stress of butterfly plate, and the maximum stress is near the rotary hole of the valve rod, which is because the bow surface protrusion is caused to ensure the rotation of the valve rod, resulting in large stress at this point. Therefore, the optimization scheme of the bow back is to integrate the rotary hole of the valve stem into the butterfly plate as much as possible, instead of protruding at the bow surface. It can be seen from Figure 4 (b) that the stiffeners fully bear the pressure load and reduce the weight of the butterfly plate. If the pressure load increases, the thickness of stiffener can be considered first.

4. Flow field analysis

The change of the structure shape of the butterfly plate is bound to affect the distribution of the flow field and the flow resistance coefficient, and ultimately affect the over-current performance and opening and closing performance under the full open state. Therefore, the structure design of the butterfly plate should also consider the influence of the structure on the flow field performance under the condition of meeting the strength requirements. In this paper, based on FLUENT software, the flow field of butterfly plate in different opening is simulated and analyzed, and the influence of back stiffener on flow field is compared.

4.1. Fluent Finite element model

The three-dimensional model of dn2700 triple eccentric butterfly valve was established by SolidWorks software. Considering that the pipeline in front of and behind the valve is too short, the flow disturbance through the butterfly valve is not stable, which may lead to the calculation results inconsistent with the reality. In order to fully simulate the whole flow field, the upstream pipe length of butterfly valve is 10 m, and the downstream pipe length is 10 m.

In addition to the standard scheme for pressure interpolation, the second-order upwind scheme is used to solve the convection terms such as momentum, turbulent kinetic energy and dissipation rate.

The whole media flow domain is taken as the computing domain, and the global meshing setting is adopted, and the correlation center parameter is set to fine. The model after meshing is shown in Figure 5.

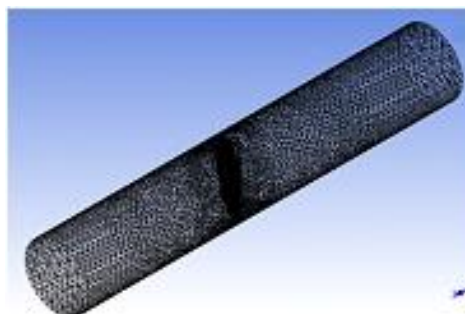


Figure 5. Flow field analysis model

4.2. Boundary condition setting

The pipeline axis is z-axis, the flow direction is along the z-axis, the inlet is set as the velocity inlet, the outlet is set as the pressure outlet, and the contact surface between butterfly plate and

medium is set as wall. According to the flow rate of the pipeline, the velocity at the inlet is 6m / s and the pressure at the outlet is 0.

4.3. Simulation result

4.3.1. Simulation results of flow field with different openings

The flow field distribution simulation results are shown in Figure 6 when the opening of butterfly plate is 15 ° 30 ° 45 ° 60 ° 75 ° and 90 ° respectively.

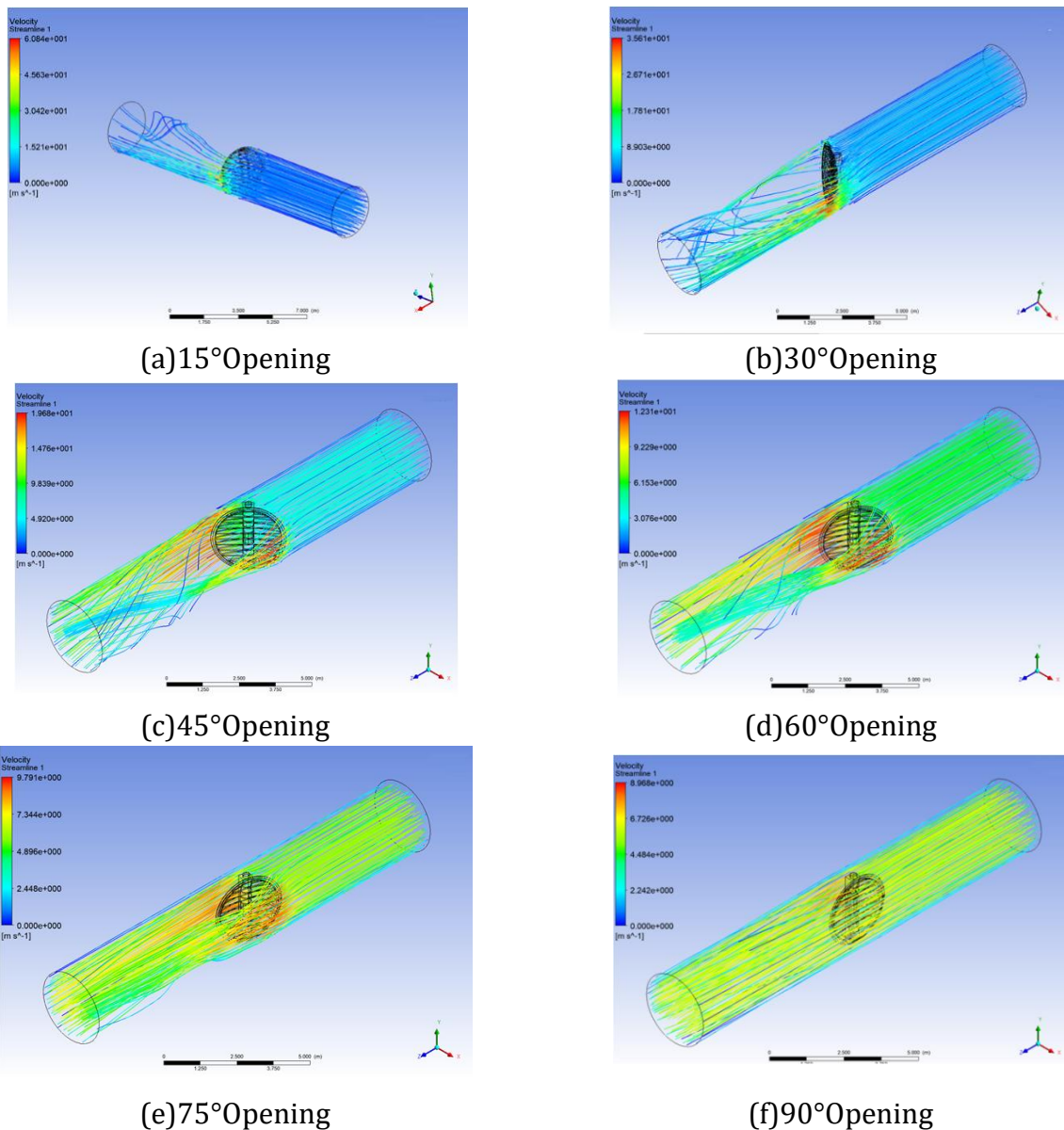


Figure 6. Flow field at different opening

It can be seen from the figure that when the butterfly plate is opened from the closed state, the fluid basically flows from one side at 15 ° due to the small opening, and the flow velocity is the maximum at the edge of the opening. When the opening increases, at 30 ° and 45 ° the flow in the back of the butterfly plate is disturbed obviously, which may lead to vibration of the butterfly plate. When the opening is further increased, the disturbance on the back of the butterfly plate decreases at 60 ° and 75 ° and presents steady flow at 90 °. Therefore, the butterfly plate designed in this paper has good over-current performance when it is fully open, but it should be avoided when it is in the state of 15 ° to 60 ° for a long time.

4.3.2. Effect of back stiffener on flow field

In order to study the influence of the back stiffener on the flow field of the butterfly plate, this paper further studies the butterfly plate with the back plane in the fully open state, and compares the analysis results with figure 6. Figure 7 shows the structure model of butterfly plate with plane back, and figure 8 shows the influence of stiffener on flow field.

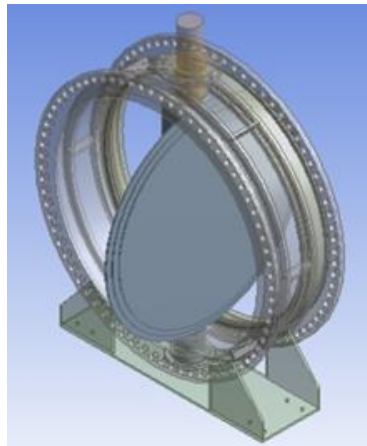
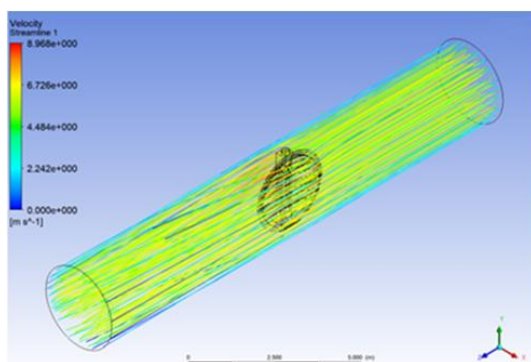
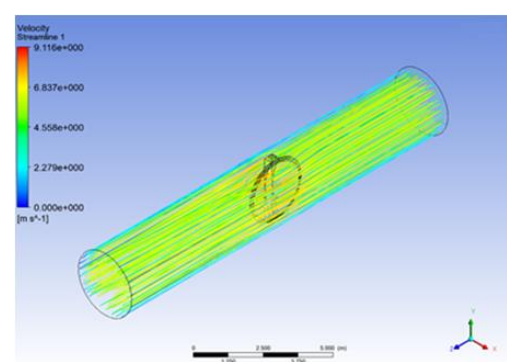


Figure 7. Butterfly valve without stiffener on the back of butterfly plate



(a) The back of butterfly plate is reinforced rib structure



(b) The back of sphenoid plate is flat

Figure 8. Influence of stiffeners on flow field in fully open state

It can be seen from figure 8 that the presence of stiffeners on the back of the butterfly plate will increase the flow field disturbance, flow resistance coefficient and pressure loss. Therefore, from the perspective of flow field, the optimization scheme of butterfly plate structure is that the structure of butterfly valve is as smooth as possible, reducing the complexity of structure and avoiding mesh. Therefore, the stiffener designed in this paper is only distributed along the flow direction of the fluid, and there is no vertical stiffener, which avoids the grid structure and is the most effective design scheme to ensure the structural strength.

5. Summary

In this paper, based on the finite element analysis method, the structure analysis and flow field analysis of the designed large diameter three eccentric butterfly valve are carried out, and the feasible optimization direction is proposed according to the analysis results. The main conclusions are as follows:

(1) The ANSYS finite element model of three eccentric large diameter butterfly valve is established. The static structure analysis is carried out when the pressure load is 1.5 times of the design pressure. The stress and stress distribution of the butterfly plate of the arch back

structure with large curvature are mainly studied. The results show that the designed butterfly plate has enough structural strength at 1.5 times of design pressure.

(2) According to the results of the static analysis of the butterfly plate structure, the optimal design scheme is given for the distribution of the butterfly plate Stiffeners under higher pressure conditions, that is, the thickness of the stiffeners should be considered first.

(3) Based on FLUENT software, the flow field analysis model with different opening degrees is established. The simulation results show that the butterfly valve designed in this paper has good over-current performance when it is fully open.

(4) The influence of stiffeners on the flow field distribution is further analyzed. According to the simulation results, the stiffener scheme designed in this paper is an optimal layout scheme for the flow field, that is, the stiffeners are along the flow direction.

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