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Influence of Inlet and Outlet Load on City Fire Fighting Centrifugal Pump

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Abstract: *In recent years, fires happen frequently, firefighting systems are becoming more and more important, the function of fire fighting centrifugal pump cannot be ignored. In this study, SolidWorks software was used to conduct three-dimensional modeling of centrifugal pump, and the Simulation module in SolidWorks was used, adding external loads at the inlet and outlet of the centrifugal pump， then finite element analysis of centrifugal pump. It can be obtained through analysis, the maximum displacement of the centrifugal pump always appears on the flange, the position of the maximum stress it receives is at the junction of centrifugal pump base and pump shell,the minimum stress is located in the center of the pump shell.The results of this study will provide a basis for further enhancing the stability and reliability of fire pump.*

Keywords: *Fire pump, Load, Finite element analysis*

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I. INTRODUCTION

Centrifugal pump as a transfer or conversion of energy for fluid transport machinery.At present, China's economic capacity level continues to grow and develop; demand for centrifugal pumps is growing.The oil industry needs centrifugal pumps to pump crude oil [1~3],aeronautics and astronautics [4],shipbuilding industry [5] ,nuclear power [6]Etc.Centrifugal pumps are also used in different ways.This shows the application prospect of centrifugal pump is very wide.

With the acceleration of urbanization,people also pay more and more attention to fire safety.To protect the safety of public society,reducing the risk of fire spread andslowing down the spread of fire, fire pump is widely used in urban fire fighting, its role can’ t be underestimated.

When the centrifugal pump is used, it will be affected by the effect of pipeline gravity on the pump body and the effect of bolt on the centrifugal pump when the bolt is tightened.In order to reduce the influence of these factors on the centrifugal pump.In the modeling analysis, the interference of other factors on the centrifugal pump was ignored, and only the force at the inlet and outlet flange of the centrifugal pump was considered,and the finite element analysis of the centrifugal pump was conducted based on SolidWorks [10~11].

At present,analysis software for research and design is becoming more and more mature,the efficiency of design has improved a lot.CFD numerical simulation technology has greatly improved the design level of centrifugal pump.The number of tests can be reduced by using numerical simulation techniques,then reduce manpower and material resources, to save a lot of time for the design.CFD numerical simulation technique is used in this paper, to explore the impact of import and export load on the centrifugal pump for urban fire control, thus revealing the law of stress and strain, to improve the operation reliability of the centrifugal pump.

1 Fire pump model and calculation setup

1.1 Modeling

The basic design parameters of fire pump in this paper are as follows:lift 35m, flow Q=15m^3/h， necessary cavitation allowance 4m，the working medium is water, the density of 1000kg/m^3.By using SolidWorks for stretching, scanning, rotating, arrays, etc.,finish 3D drawing of fire pump（as shown in figure 1）.Aim at city fire centrifugal pump,finite element analysis is made for the simplified centrifugal pump. Firstly,ignore the rounded corners of the centrifugal pump. Secondly,the simplified centrifugal pump is modeled in 3D.This finite element analysis is mainly in the centrifugal pump without considering the impact of some other forces on the case, in the centrifugal pump inlet flange and outlet flange additional pressure.

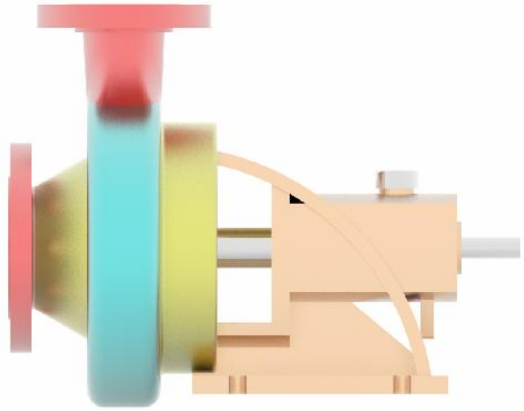
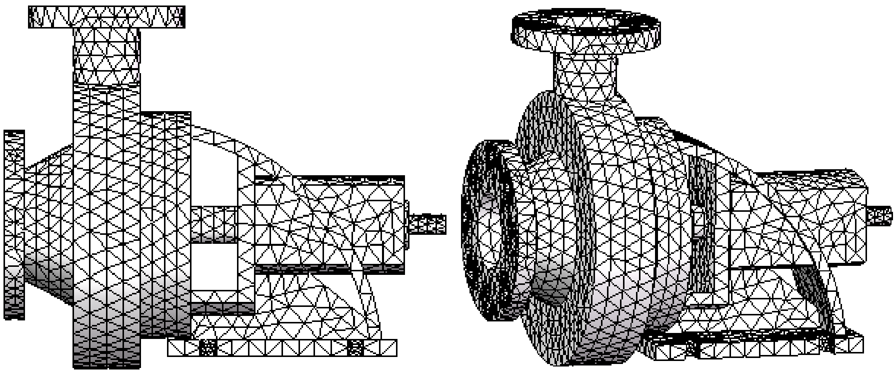


Figure 1 3D view of the centrifugal pump

1.2 Computational grid

There are many software for finite element analysis,this design use SolidWorks Simulation.Similar to other finite element analysis software, there is no essential difference. Firstly,the material used for the centrifugal pump needs to be determined. Secondly, choose to use the constant geometry in the fixture,add an external load to the selected action surface, then select generate grid (grid size is set as needed).Finally, click "start" on the toolbar to calculate the deformation result, generating reports.

Meshing is a very important step in finite element analysis,selecting different mesh density sizes will result in different precision results.Meshing of fire-fighting centrifugal pump,choose a curvature-based mesh,generating grids with good grid density. As shown in figure 2,it is the grid graph generated by our grid division.



(a) Front view (b) Side view

Figure 2 Fire centrifugal pump mesh division

1.3 Determine fixture and external load

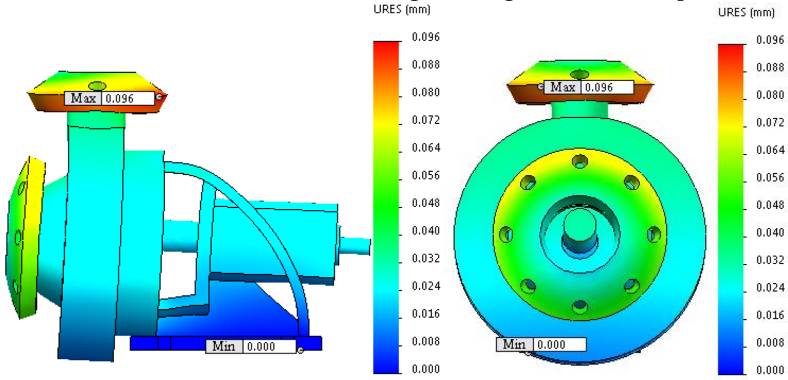
The selected centrifugal pump material is gray cast iron, the elastic modulus of gray cast iron is 120GPa, mass density is 7340kg/m^3, Poisson's ratio is 0.25.Fixture fixed geometry selected position: centrifugal pump base surface.

When the influence of other factors on the centrifugal pump is not considered,adding pressure of different sizes to the inlet flange of the centrifugal pump first,the additional pressure on the outlet flange remains constant. Then adding pressure of different sizes to the outlet flange of the centrifugal pump first,the additional pressure on the inlet flange remains constant.Respectively to observe,analysis of stress and displacement of centrifugal pump changes. Change the size of the additional pressure, observe the centrifugal pump before and after the change.

II. RESULTS ANALYSIS

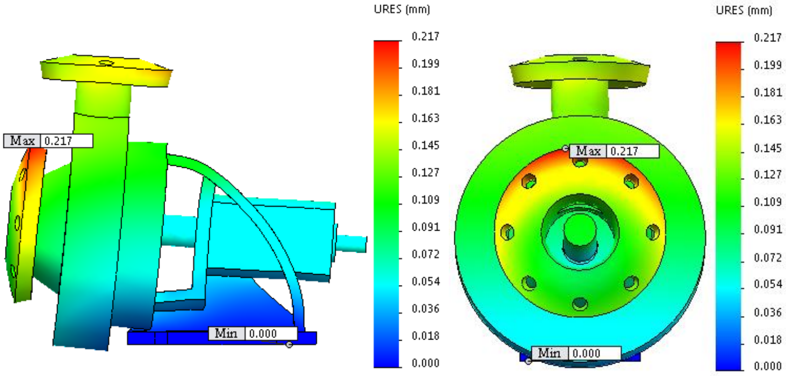
2.1 Displacement effect

Keep the additional pressure of 1MPa on the outlet flange of the centrifugal pump unchanged,when 1MPa pressure is applied to the inlet flange of the centrifugal pump, get the front and left view of centrifugal pump displacement diagram, as shown in figure 3. In brackets in the title of the first number is import load, the second number is export load. Increase the pressure added to the inlet flange of the centrifugal pump from 1MPa to 2MPa and 3MPa in turn, get the figure 4 to 5 of displacement diagram. Increase the pressure added to the outlet flange of the centrifugal pump from 1MPa to 2MPa and 3MPa in turn, get the figure 6 to 7of displacement diagram.



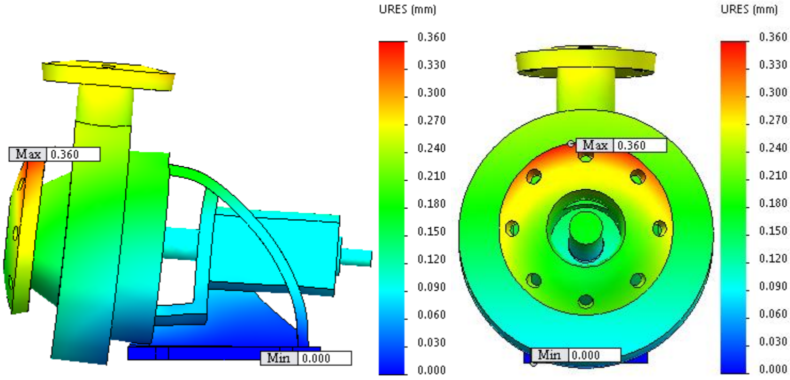
(a) Displacement front view (b) Displacement left view

Figure 3 Displacement of the view (1~1MPa)



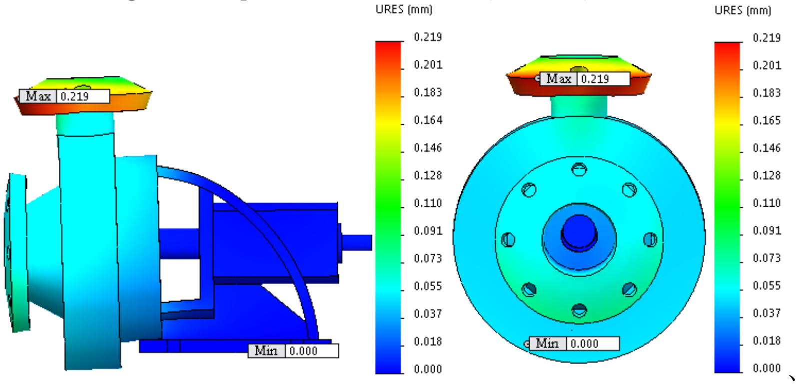
(a) Displacement front view (b) Displacement left view

Figure 4 Displacement of the view (2~1MPa)



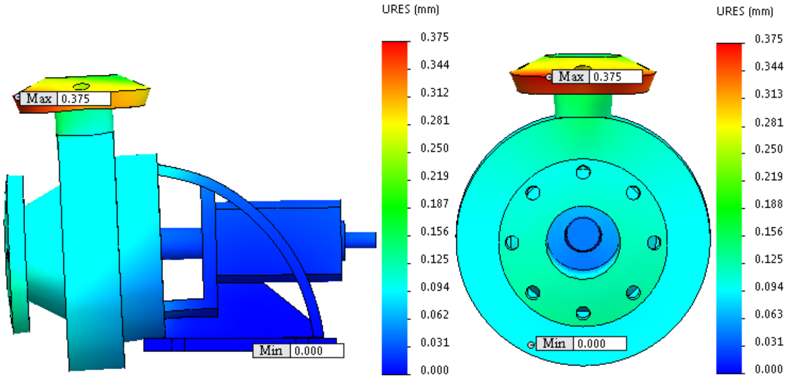
(a) Displacement front view (b) Displacement left view

Figure 5 Displacement of the view (3~1MPa)



(a) Displacement front view (b) Displacement left view

Figure 6 Displacement of the view (1~2MPa)



(a) Displacement front view (b) Displacement left view

Figure 7 Displacement of the view (1~3MPa)

As shown in figure 3 (a),the maximum displacement can be clearly observed on the lower left edge of the outlet flange, the displacement is 0.096mm,the minimum displacement appear around the edge of the base of the centrifugal pump,the size of the minimum displacement is 0mm.It can be seen that the centrifugal pump body position changes evenly, the size of the displacement change near 0.024 mm.The displacement of the base of the centrifugal pump does not change much, the size of the displacement change near 0.008mm. As shown in figure 3 (b),It can be found that the maximum displacement on the inlet flange is 0.072mm and the minimum displacement is 0.024mm.

As shown in figure 4 (a),it can be clearly found that the maximum displacement is transferred from the original outlet flange edge to the top of the inlet flange edge, the displacement is 0.217mm,the displacement increased by 0.121mm compared to 0.096mm when 1MPa pressure was applied.The minimum displacement appears around the edge of the base of the centrifugal pump, the size of the minimum displacement is 0mm.The displacement of the pump body changes greatly,from uniform displacement size is 0.024 mm, to now gradually from bottom to top, the maximal displacement is 0.145 mm, and minimum displacement is 0.018 mm.The displacement of outlet flange becomes uniform, the maximal displacement is 0.163mm, minimum displacement is 0.127mm,and the minimum displacement is 0.031mm larger than the maximum displacement 0.096mm when 1MPa is added. As shown in figure 4(b), it can be seen that the displacement of inlet flange increases gradually from bottom to top, the maximum displacement is 0.217mm and the minimum displacement is 0.091mm.

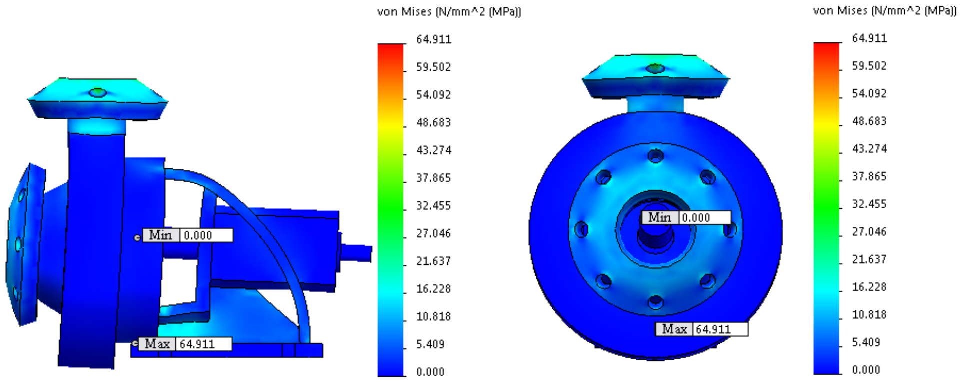
As shown in figure 5(a),it can be seen that the displacement distribution diagram of the centrifugal pump is similar to that of the centrifugal pump with additional pressure of 2MPa,the position of the maximum displacement occurs at the highest point of the edge of the outlet flange,the displacement is 0.360mm， the displacement increased by 0.143mm compared to 0.217mm when 2MPa pressure was applied.It is the same as the additional pressure of 2MPa, the position where the minimum displacement occurs is on the base edge of the centrifugal pump, and the size of the minimum displacement is 0mm.From the top view of the combined displacement of the centrifugal pump, it can be clearly found that the displacement change of the outlet flange is much more uniform than the previous maximum displacement of 0.163mm and the minimum displacement of 0.127mm, and most of the displacement is 0.270mm. As shown in figure 5(b), it can be seen that the displacement of inlet flange increases gradually from bottom to top, the maximum displacement is 0.360mm and the minimum displacement is 0.150mm.

As shown in figure 6(a),it can be clearly found that the maximum displacement of the centrifugal pump is at the far right of the edge of the outlet flange, and the displacement is 0.219mm.The position where the minimum displacement occurs is on the base edge of the centrifugal pump, and the size of the minimum displacement is 0mm.The displacement distribution behind the pump body is relatively uniform, the size of the displacement change near 0.018mm.The displacement on the pump body changes greatly, from 0.024mm to 0.037mm. As shown in figure 6(b),It can be seen that the displacement change on the inlet flange of the centrifugal pump is 0.072mm compared with the maximum displacement when 1MPa pressure is applied before,The minimum displacement becomes more uniform, is 0.024mm.Now most of the displacement of the size is 0.055 mm, flange part under displacement is larger, is 0.091 mm.

As shown in figure 7(a),it can be found that the position of the maximum displacement of the centrifugal pump appears at the far right of the edge of the outlet flange, the same as that of the additional 2MPa pressure. The displacement is 0.375mm, which is 0.156mm larger than that of 0.219mm when the additional 2MPa pressure is applied. As the same, it is the same as the additional pressure of 2MPa, the position where the minimum displacement occurs is on the base edge of the centrifugal pump, and the size of the minimum displacement is 0mm.The displacement behind the centrifugal pump body changes evenly, most is 0.031mm.Because of the stress concentration,the displacement at the junction of the pump body is relatively large, is 0.094mm。 As shown in figure 7(b), it can be seen that the displacement on the inlet flange changes evenly, is 094mm.The displacement under the flange is larger, is 0.125mm.

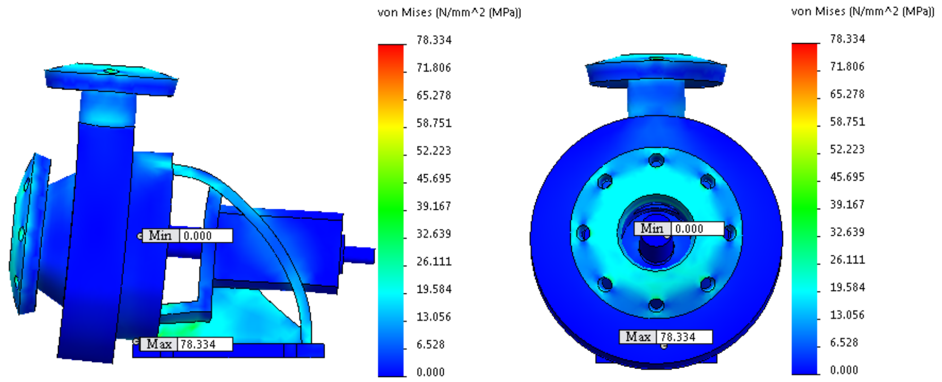
2.2 Stress effect

Keep the additional pressure of 1MPa on the outlet flange of the centrifugal pump unchanged, when 1MPa pressure is applied to the inlet flange of the centrifugal pump, get the front and left view of centrifugal pump stress diagram, as shown in figure 8. In brackets in the title of the first number is import load, the second number is export load. Increase the pressure added to the inlet flange of the centrifugal pump from 1MPa to 2MPa and 3MPa in turn, get the figure 9 to 10 of stress diagram. Increase the pressure added to the outlet flange of the centrifugal pump from 1MPa to 2MPa and 3MPa in turn, get the figure 11 to 12 of stress diagram.



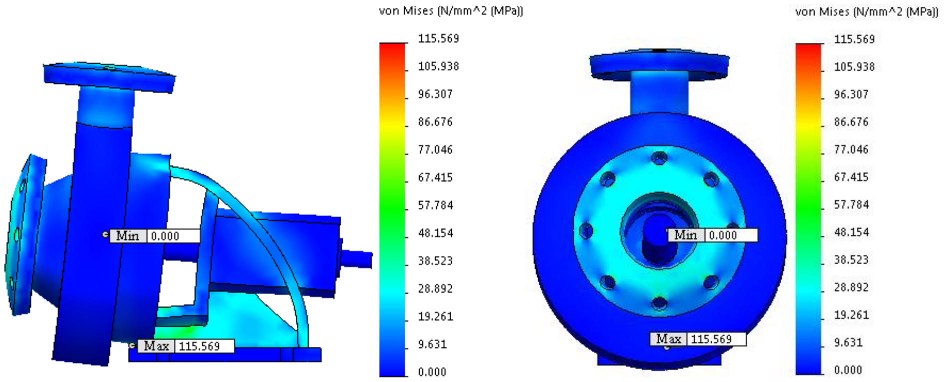
(a) Stress front view (b) Stress left view

Figure 8 Stess of the view (1~1MPa)



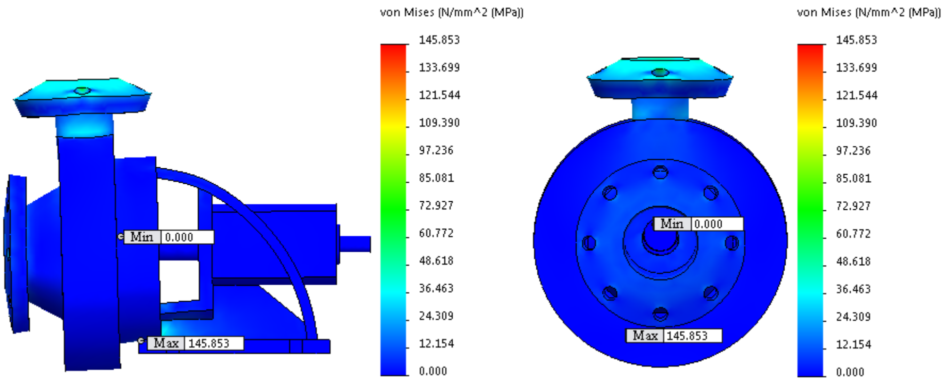
(a) Stress front view (b) Stress left view

Figure 9 Stess of the view (2~1MPa)



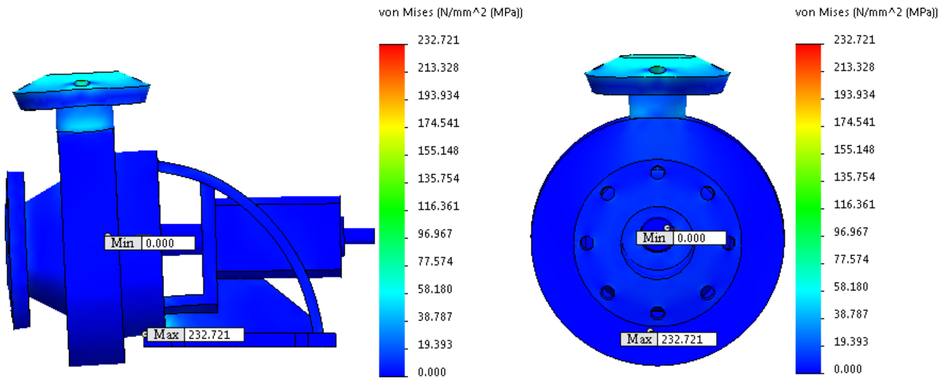
(a) Stress front view (b) Stress left view

Figure 10 Stess of the view (3~1MPa)



(a) Stress front view (b) Stress left view

Figure 11 Stess of the view (1~2MPa)



(a) Stress front view (b) Stress left view

Figure 12 Stess of the view (1~3MPa)

As shown in figure 8(a),you can see the centrifugal pump overall stress distribution more uniform,due to the stress concentration, the maximum stress received by the centrifugal pump is at the junction of the centrifugal pump base and pump shell, and the stress size is 64.911MPa. But the minimum stress of the centrifugal pump is located in the center of the pump shell, the size is 0MPa。 The minimum stress on the outlet flange is 5.409MPa, the maximum stress is 37.865MPa, and the stress of most space is 16.228MPa. It can be known from the figure 8(b),it can be found that the stress of inlet flange changes little, the maximum stress is 10.818MPa, and the minimum stress is 5.409MPa.

As shown in figure 9(a),Stress of the pump body floor can be found in most 10.818 MPa increased a lot than before, now most of 19.596 MPa.The position of the maximum stress received by the centrifugal pump is the same as the additional pressure of 1Mpa, the maximum stress is 78.384MPa,and Centrifugal pump by the size and location of the minimum stress and additional 1 MPa pressure is the same.The stress distribution of the outlet flange is more uniform than that of the additional 1MPa, with the maximum stress is 19.584MPa and the minimum stress is 6.528MPa.However, the maximum stress on the pump shell is 8.766mpa higher than 10.818mpa when 1MPa is added, and the maximum stress is 19.584mpa. It can be known from the figure 9(b),the stress distribution on the inlet flange is relatively uniform, most of them is19.584MPa.

As shown in figure 10(a),it can also be found that the maximum stress received by the centrifugal pump is at the junction of the centrifugal pump base and pump shell,stress magnitude is 115.569MPa.The minimum stress received by the centrifugal pump did not change with the additional 2MPa. It can be known from the figure 10(b),import flange on the stress distribution more uniform, the stress size is 28.892MPa.

As shown in figure 11(a), you can find that the position of the maximum stress received by the centrifugal pump does not change and the size becomes 145.853MPa, the minimum stress on the centrifugal pump remains unchanged. It can be known from the figure 11(b),centrifugal pump inlet flange stress uniform the stress value is small, about 12.154mpa.

As shown in figure 12(a), it can be seen that the position of the maximum stress and the minimum stress received by the centrifugal pump has not changed, the maximum stress is232.721MPa, and the minimum stress is 0MPa. It can be known from the figure 12(b),centrifugal pump inlet flange stress uniformity, about 19.393MPa.

III. CONCLUSION

With the increase of the pressure attached to the flange, the maximum displacement and maximum stress of the centrifugal pump increase correspondingly,the change of overall displacement and stress also increase.That is, the maximum displacement and maximum stress of the centrifugal pump is proportional to the pressure,the change of overall displacement is proportional to the change of stress.

The maximum displacement always appears on the flange,centrifugal pump overall stress distribution is more uniform. Because of stress concentration, the position of the maximum stress it receives is at the junction of centrifugal pump base and pump shell, the minimum stress is always on the base of the centrifugal pump. So, to make the fire pump can achieve the desired effect when using it, the change of the stress at the junction of base and pump shell should be considered in the design. At the same time, the designer should analyze the displacement change of flange, to develop the most perfect fire pump design and manufacturing program.

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