Finite Element Analysis for Steel Bifurcation Pipe of Zhanghewan Pumped Storage Power Station

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Abstract—Pressure pipeline's length to diameter ratio is very big, easy to instability, stress situation more complex than the pressure vesse. The numerical simulation study for pressure pipeline on water security is of great significance. Static analysis of pressure pipeline is the foundation of design and construction of pressure pipeline, through static analysis, can get the change law of stress and displacement of the pressure pipeline. The stress and strain of pressure pipeline structure are the index of pressure pipeline structure rigidity. Penstock is an important part of building in the water conservancy and hydropower project. In this paper, finite element analysis software is used to do structural computer simulation analysis for steel bifurcation pipe of Zhanghewan Pumped Storage Power Station, and we have summarized the variation of stress and displacement. We studied the stress and displacement bifurcation structure of complex parts, and had got the results and some useful conclusions.

Keyword- Pumped storage power station; Steel bifurcation pipe; Finite element method; Stress distribution; Stiffness requirement.

I. ENGINEERING SITUATION

Steel bifurcation pipe of Zhanghewan Pumped Storage Power Station is located in near the Zhanghewan village, Ceyu town, Jinglong country, Shijiazhuang city, Hebei province. The straight-line is 53km from the station to the urban, and the highway mileage is 45km from the station to the country[1]. Power station installed capacity is 4 × 250MW, and the overall efficiency of power station is 0.76. The main hub engineering is composed of the upper reservoir, water systems, underground powerhouse system, the ground qualifying games and the lower reservoir sediment weir project, engineering grade first. The upstream total capacity of reservoir is 7.89 million m^3, and the total area is 345,000 m^2. The reservoir downstream is located in mainstream Gantao river of Cemuyu town, Jinglong country, Shijiazhuang city, Hebei province[2]. Plant watercourse diversion system uses the arrangement of a tube and two machines, and tail water system uses the arrangement of a machine and a tube. The internal water pressure of bifurcation pipe design for 5.15MPa, and bifurcation pipe uses the type of the internal strengthen symmetry Y-shaped crescent structure. The diameter of forward main pipe of bifurcation pipe is 5.2m[3]. The diameter of back branch pipe of bifurcation pipe is 3.6m. The diameter of maximum common tangent bull is 3.6m, and bifurcation angle is 70°.

II. CALCULATION MODEL

A Model Parameters

Steel bifurcation pipe of Zhanghewan Pumped Storage Power Station uses concrete strength grade of C30, elastic modulus $E_1 = 30$ GPa, poisson ratio $\mu_1 = 0.167$ [4], bulk density $\gamma_1 = 24$ kN/m^3. Elastic modulus of steel liner $E_2 = 210$ GPa, poisson ratio $\mu_2 = 0.28$, bulk density $\gamma_2 = 78.5$ kN/m^3. Bifurcation pipe section wall rock is metamorphic andesite, slightly weathered, and it is putted as isotropic, linear elastic material. Elastic modulus of rock is $E_3 = 25$ GPa, and poisson ratio is $\mu_3 = 0.22$ [5-6], bulk density $\gamma_3 = 29$ kN/m^3.

B Model Element

Because bifurcation pipe is a complex spatial shell structure, in order to ensure a similar model with the real structure, outsourcing reinforced concrete and wall rock mainly use hexahedral 8-node isoparametric element [7-8]. In order to ensure that the steel bifurcation pipe and crescent meshing with better cell morphology, we use 4-node shell element. The number of elements is 42509, which is divided by the overall model.

C Finite Element Model

When using the finite element method to do the finite analysis for bifurcation structure, we must first establish a finite element model of bifurcation structure. Steel bifurcation pipe and wall rock structure finite element division are shown in Fig .1 and Fig .2.

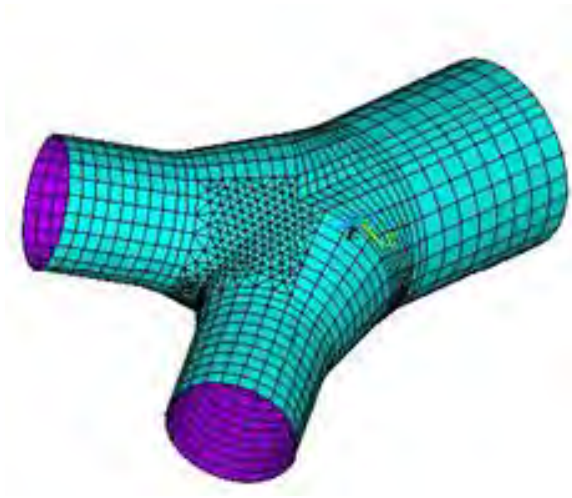

Figure 1. Steel bifurcation pipe FEM division

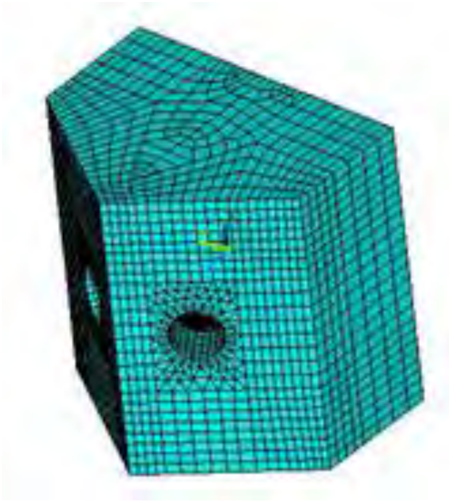

Figure 2. Wall rock FEM division

D Calculation Case

Considering the mechanical characteristics of Steel bifurcation pipe of Zhanghewan Pumped Storage Power Station during operation [9-10], the following three cases are taken into account mainly: case 1, internal water pressure (Consider water hammer pressure 5.15MPa) and rock constraint; case 2, internal water pressure (Consider water hammer pressure 5.15MPa), rock constraint and rock weight; case 3, internal water pressure (Consider water hammer pressure 5.15MPa), rock constraint and external pressure(grouting pressure 0.3MPa).

III. BIFURCATION PIPE STRUCTURE ANALYSIS

A Stress Analysis

The first principal stress cloud of bifurcated pipe, wall rock and ribs are shown in Fig .3 to Fig .8 for each case.

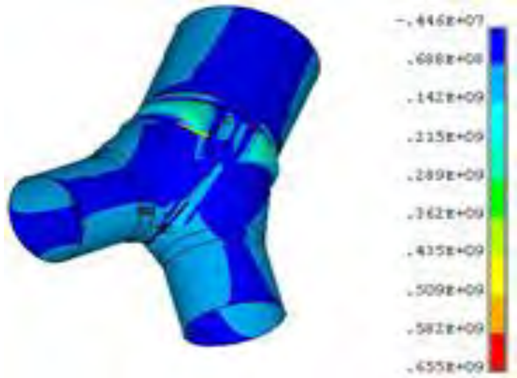

Figure 3. Cloud map of bifurcated pipe's first principal stress under case 1（Pa）

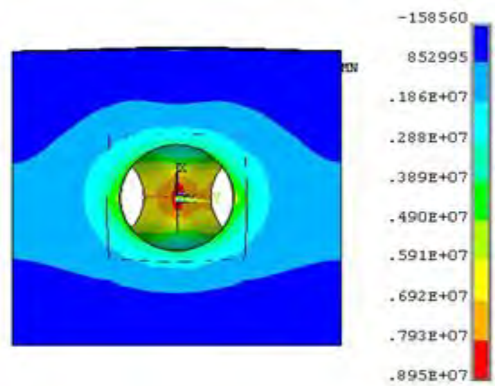

Figure 4. Cloud map of wall rock's first principal stress under case 1（Pa）

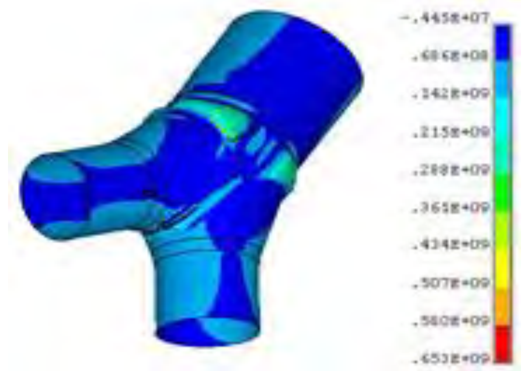

Figure 5. Cloud map of bifurcated pipe's first principal stress under case 2（Pa）

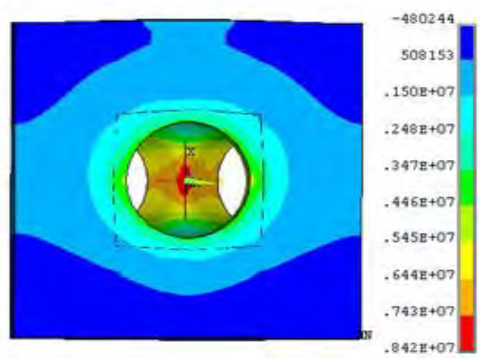

Figure 6. Cloud map of wall rock's first principal stress under case 2（Pa）

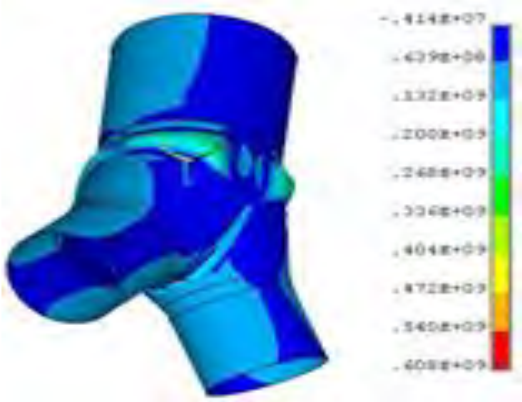

Figure 7. Cloud map of bifurcated pipe's first principal stress under case 3（Pa）

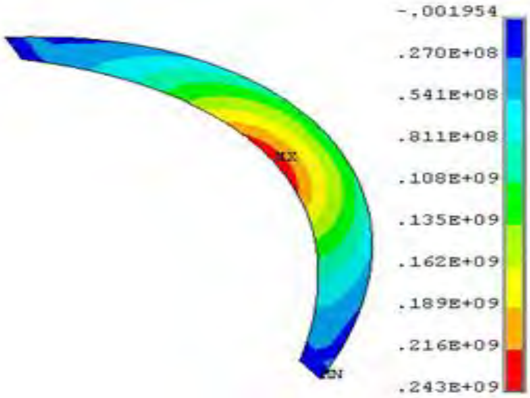

Figure 8. Cloud map of crescent rib's first principal stress under case 1（Pa）

As can be seen from Fig .3 to Fig .8, under internal water pressure, the maximum first principal stress of steel bifurcation first mainly appears in the steel bifurcation bifurcation′s point, and the maximum first principal stress increases gradually with the weakening of bifurcated pipe the peripheral constraint. This is mainly the presence of sharp corners here. Under load action, there is more serious stress concentration. The first principal stress on the surrounding rock is small, and the first maximum principal stress occurred mainly in the bifurcation pipe bifurcation′ sharp site. The maximum first principal stress of the rib mainly appears in the central rib.

B Deformation Analysis

The total displacement of bifurcated pipe and wall rock is shown in Fig .9 to Fig .12 for each case.

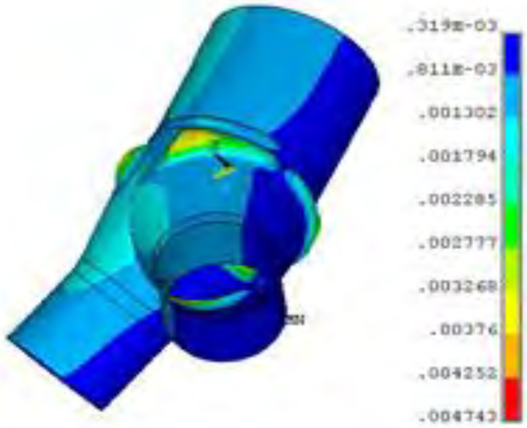

Figure 9. Cloud map of bifurcated pipe's total displacement under case 1（Pa）

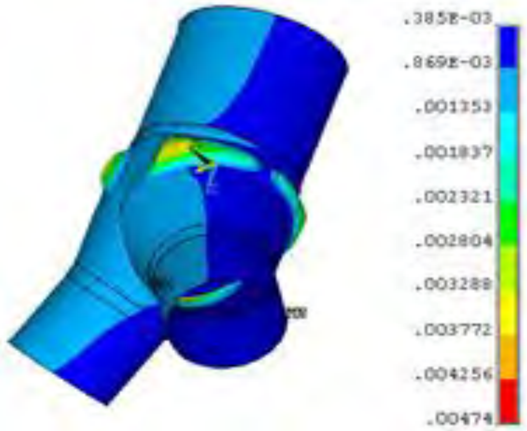

Figure 10. Cloud map of bifurcated pipe's total displacement under case 2（Pa）

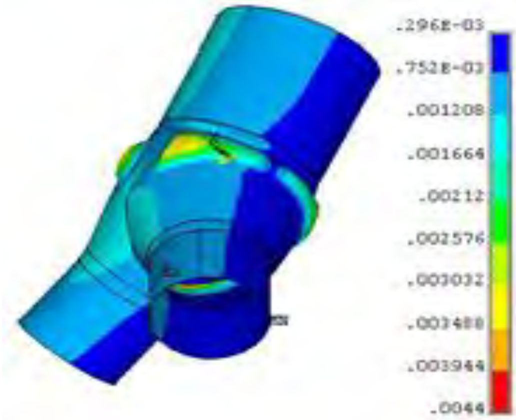

Figure 11. Cloud map of bifurcated pipe's total displacement under case 3（Pa）

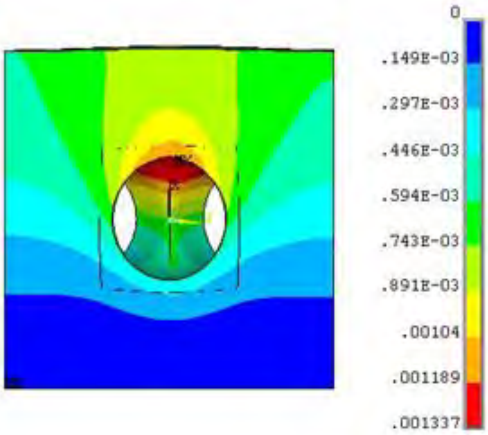

Figure 12. Cloud map of wall rock's total displacement under case 1（Pa）

From Fig .9 to Fig .12 can be seen, under internal water pressure, the total value of steel bifurcation displacement is smaller, and the maximum total displacement is 4.743mm, appears at the bifurcation of the bifurcation for case 1. The total displacement of wall rock is smaller, and the maximum displacement's direction is upward under case 1, appear at the top of the fork tube, which is caused by mainly upward displacement of the bifurcation pipe inner water pressure.

IV. CONCLUDING REMARKS

In summary, the design of steel bifurcation pipe of Zhanghewan Pumped Storage Power Station is reasonable, the maximum tensile stress on the bifurcation pipe is less than the yield strength of steel, meet the strength requirements. The wall rock can effectively reduce the stress of steel bifurcation pipe, and the rock stress is small, will not crack. The deformation steel bifurcated pipe and wall rock is small, meet stiffness requirements.

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