

Research on the Stress Characteristics of Wellhead Bolts

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Abstract

Bolts are important connectors in the wellhead oil pipe spool, and the safety of wellhead bolts is an important guarantee for the operation of the oil pipe spool. Taking the wellhead oil pipe spool as the research object, a three-dimensional fluid model and a structural model of the wellhead equipment and its bolts were established. Through finite element numerical simulation, combined with the basic theory of fluid solid coupling, the equivalent stress and dangerous bolt distribution of the oil pipe spool bolts were studied. The study showed that under two different working conditions, the average equivalent stress on the bolt as a whole increased as the bolt position approached the outlet of the side flow channel, The most dangerous bolt in the wellhead tubing spool appears near the outlet; The stress distribution of bolts in different sections is uneven, and the stress at the bolt head, thread, and smooth rod intersects is greater than that at the middle section of the bolt. The bolt also bears both axial and bending stresses.

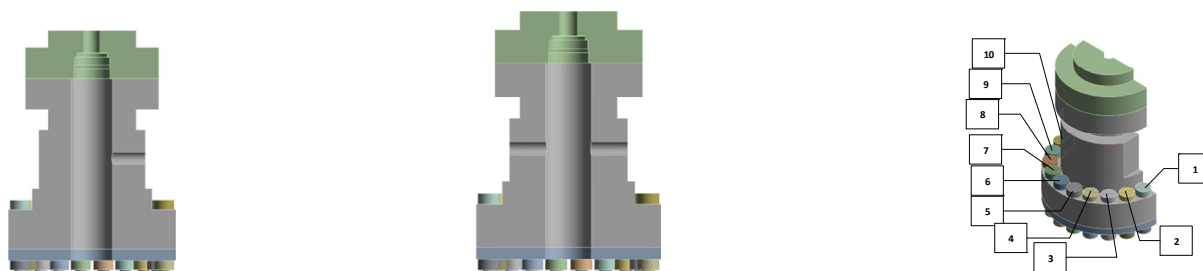
Keywords

Oil Pipe Cross Bolt; Fluid Structure Coupling; Force Characteristics.

1. Introduction

Bolted connections have the characteristics of strong reliability and easy disassembly. [1-3] The long-term action of wellhead bolts under high-pressure conditions directly affects the safety of the wellhead due to the stress on the bolts. [4-11] A finite element analysis numerical model was established based on two different working conditions of the wellhead tubing spool, and the stress distribution of the tubing spool bolts was studied, providing a theoretical reference for the safe use of wellhead bolts.

2. Numerical Model Establishment



(a) side channel is open (b) both sides are open (c) Schematic diagram of bolt markings on

Figure 1. The schematic diagrams of the side channel opening, both sides of the side channel opening, and bolt numbering

Establish a half symmetric model for the wellhead tubing spool under three working conditions, and the results are shown in the following figure. Figure 1 shows the schematic diagrams of the side channel opening, both sides of the side channel opening, and bolt numbering. The bolt adopts a solid modeling method without threads. The number of grids is about 1.17 million, as shown in Figure 2.

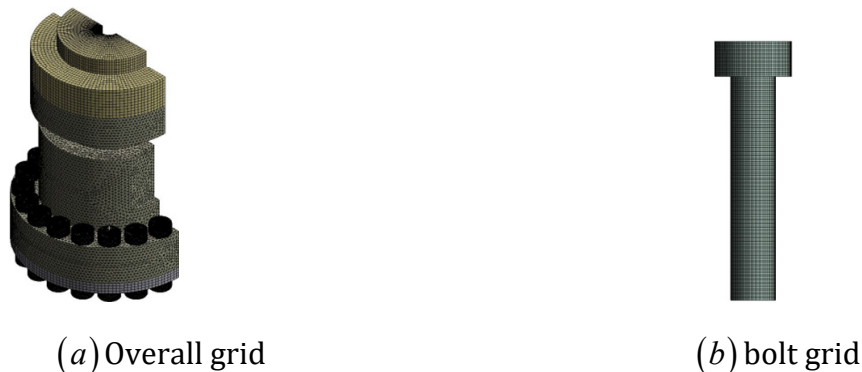


Figure 2. Overall Grid and Bolt Grid Diagram

Boundary condition: Using RNG K- ϵ , the model is designed with an initial velocity of 10m/s at the inlet and a pressure of 140MPa at the outlet. Binding is used between the upper diameter changing flange and the oil pipe spool; The remaining settings are frictional contact, with a friction coefficient of 0.2. The bolt adopts virtual threads, and there is no separation between the bolt and nut through bolt contact pairs. Pre-tightening force of bolt 250kN; The calculation load application of the structural model is divided into two steps: the first step is to apply a bolt pre-tightening force of 250kN, the second step is to lock the bolt pre-tightening force, and the fluid pressure load calculated by the oil pipe cross is transmitted to the oil pipe cross and the diameter changing flange through the coupling surface.

3. Numerical Simulation Results

Map the fluid calculation results under two different working conditions to the surface of the flow channel for analysis, as shown in Figure 3(a) and (b) , which shows the overall force distribution under two different working conditions.

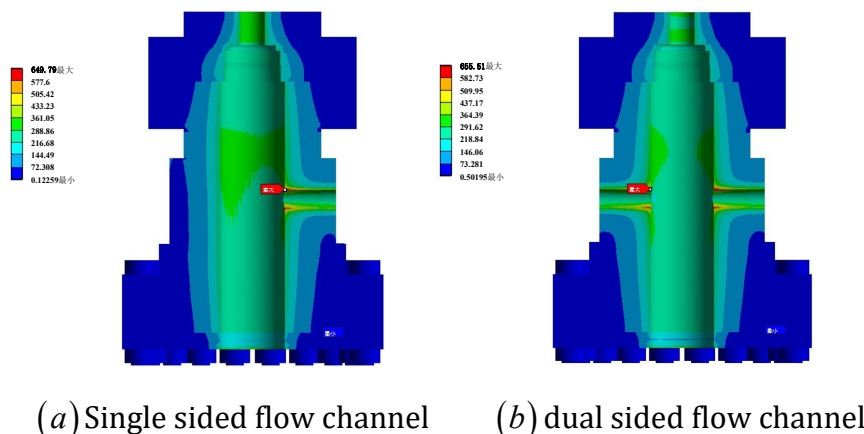


Figure 3. Cloud Chart of Overall Stress Distribution

From Figure 3, The overall force on the tubing spool gradually decreases from the inside out under condition one. Due to the impact of the fluid inside the tubing spool, the maximum stress at the intersection of the flow channel and the main flow channel is 649.79MPa. In condition 2, the overall force on the oil pipe spool decreases gradually from inward to outward. Due to the

presence of flow channels on both sides, the internal force on the oil pipe spool is basically symmetrically distributed and the maximum stress is 655.51MPa. The maximum stress inside the tubing spool under both operating conditions occurs at the shoulder of the spool flow channel, which is consistent with the actual failure location of the tubing spool. From the internal pressure distribution diagram of the tubing spool under both operating conditions, due to the impact effect of the internal fluid on the intersection of the flow channel and the main flow channel, the stress on the bolt at this point increases.

4. Bolt Force Distribution

The average stress magnitude of bolt 1-10 numbering under two working conditions is calculated through fluid structure coupling, as shown in Figure 4.

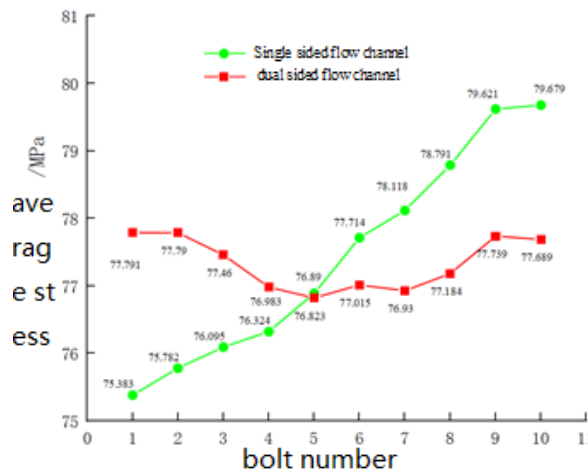
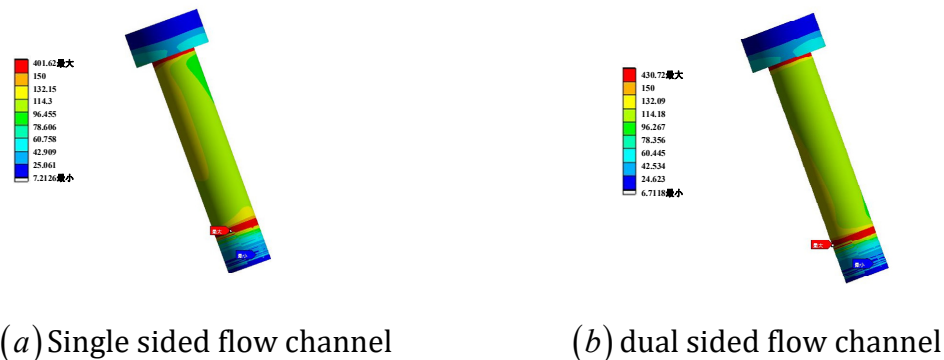


Figure 4. Bolt force diagram under two working conditions

According to the point line diagram shown in Figure 5, under condition one, the average stress of the bolt increases in a broken line. As the bolt position approaches the outlet of the side channel, the average stress of the bolt increases. According to Section 2, the increase pressure in the outlet channel of the oil pipe spool leads to an increase in the working load of the bolt; In the case of dual channel flow in condition 2, the average stress of the bolts is distributed in an axisymmetric manner, and the plot shows high on both sides and low in the middle, indicating that the average stress of the bolts is the highest at the exits on both sides. The wellhead always interacts under two working conditions, and according to Figure 5, the most dangerous bolt is bolt 10. The force cloud diagram of bolt 10 under two working conditions is shown in the figure.



(a) Single sided flow channel

(b) dual sided flow channel

Figure 5. Cloud Chart of Bolt Stress

From the stress distribution cloud diagram of bolts in Figure 6, it can be seen that the most dangerous positions for bolt stress under each working condition occur at two positions: the junction of the lower end face of the bolt head and the intersection of the thread and the polished rod. The maximum stress of the bolt under two working conditions is 401.62MPa and 430.72MPa, respectively, which do not exceed the yield limit of the material of 780MPa, meeting the requirements for strength and stiffness.

In order to further study the stress danger of bolts, four possible dangerous sections were selected under two working conditions, taking the most dangerous bolt No. 10 as an example: axial section of the bolt, section at the lower end of the bolt head, section at the middle of the bolt, and interface between the thread and the polished rod. The stress cloud map of the section was obtained as shown in the figure 6 (a) and 6 (b).

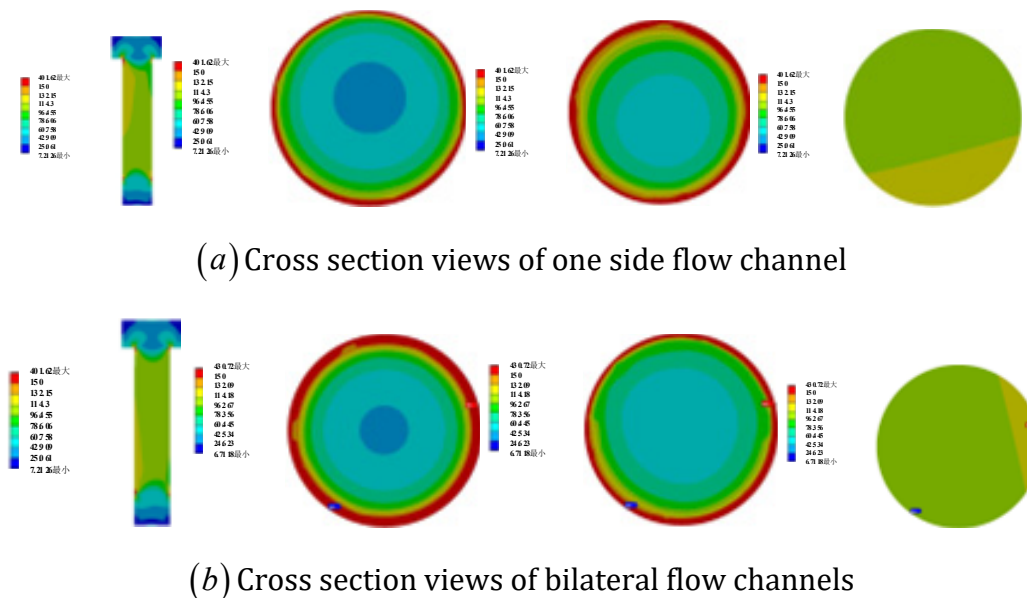


Figure 6. Equivalent stress cloud diagram of bolt cross-section

From Figure 6, it can be seen that the equivalent stress is the highest at the junction of the bolt head and the threaded rod. Further verification has been made that the most dangerous cross sections of bolts under both working conditions occur at the junction of the bolt head and thread with the polished rod, which is consistent with the two positions where bolts are most likely to be damaged in engineering practice. The equivalent stress distribution of the axial and mid section of the bolt is not symmetrical. Based on the overall stress cloud diagram shown in Figure 5, the bolt bears axial stress while also experiencing eccentric loads caused by internal fluid pressure under actual working conditions.

5. Conclusion

Based on the method of fluid structure coupling, calculations and analysis were conducted on the full flow channel and bottom bolts of the wellhead oil pipe spool, and the force analysis characteristics of the bolts under different working conditions were studied. The main results are as follows:

- (1) Through fluid solid coupling numerical simulation calculation, it was found that under the working conditions of both sides of the flow channel, the stress distribution of the bolts at the bottom of the oil pipe spool is concave, and the bolts near the outlet of both ends are subjected to the maximum force, indicating that they are dangerous bolts; Under the condition of single channel flow, the bolt stress increases as the bolt position approaches the outlet bolt stress, and the most dangerous bolt appears at the outlet; Based on a comprehensive analysis of the stress

conditions of the bolts under two working conditions, it can be concluded that the bolt located near the side outlet is the most dangerous bolt.

(2) The stress diagram of the bolt cross-section indicates that the dangerous interface of the bolt occurs at the bolt head and at the intersection of the thread and the polished rod, and the bolt is subjected to both axial and bending stresses.

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