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Safety and Reliability Assessment of Packer Lock Ring Structure

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Abstract

With the continuous development of oilfields, the workload of subdivided oil production, mechanical water shutoff, and formation adjustment has been increasing year by year. As a key tool for segmented fracturing and injection production of separate pay zones in oil and gas production, the demand for packers is increasing. increase. Aiming at the problem of how to fix the compression position of the packer rubber cylinder after the hydraulic setting is completed, a locking device with the lock ring as the core component is designed. In order to verify the safety of the lock ring structure and the reliability of the operation, based on the finite element analysis theory, the finite element analysis of each component of the locking structure was carried out systematically, and the stress distribution of each component was obtained and carried out. Strength check and safety and reliability assessment.

Keywords

Packer; lock ring structure; finite element; reliability.

1. Introduction

Oil and natural gas are mostly liquid and gas mineral resources that are buried hundreds of meters, thousands of meters or more deep underground. They are extremely concealed and cannot be directly mined manually like ordinary solid minerals. Therefore, it is necessary to adopt scientific drilling methods and advanced drilling technology to establish a permanent channel for oil and gas exploitation to meet the long-term production needs of oil and gas fields. A packer is a downhole tool with elastic sealing elements used to seal the annular space between the downhole string and the wellbore to isolate the production zone. By applying axial compression to the packer rubber barrel, it causes the rubber barrel to expand radially , So that a certain contact stress is generated between the rubber cylinder and the casing, and the production layer is sealed [1-2]. With the continuous development of the oil field, the workload of subdivided oil production, mechanical water plugging, and layer adjustment is increasing year by year [3-5].

The principle of the packer is that the liquid acts on the piston through the pressure transmission hole on the anchor body, the pin is cut off, and the locking ring mechanism drives the pipe string down after being stuck, so that the packer rubber cylinder is completely compressed. The locking part keeps the packer sealed at all times. Among them, the packer lock (lock ring) plays an important role in the normal operation of the packer. For this reason, this article aims at the problem of how to fix the compression position of the packer rubber cylinder after the hydraulic setting is completed, and designs a locking device with a lock ring as the core component. In order to verify the safety of the strength of the lock ring structure and the reliability of the operation, based on the finite element analysis theory, the finite element analysis of each component of the locking structure was carried out systematically, and the stress distribution of each component was obtained and carried out. Strength check and safety and reliability assessment.

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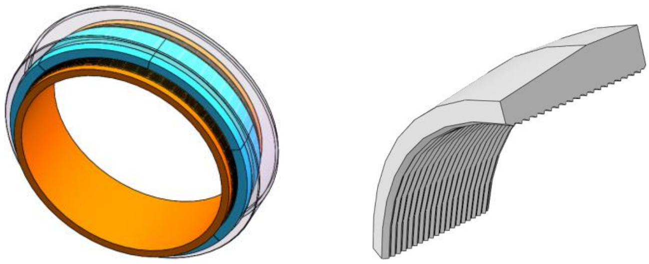
2. Finite element model

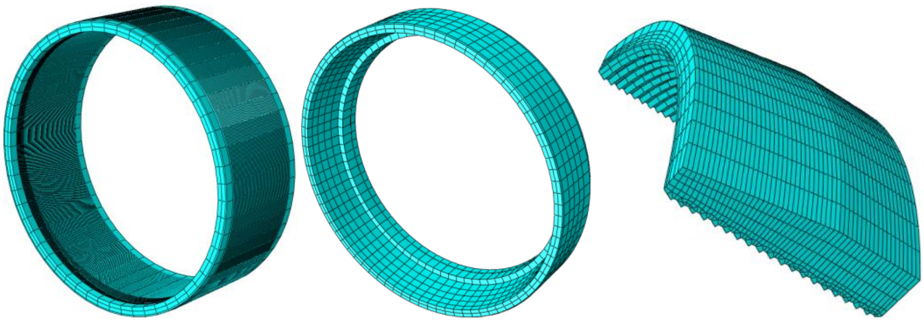
The locking mechanism adopts a ring-shaped body, which is called a lock ring. The inner side of the lock ring has teeth distribution, and the contact end with the rubber cylinder seat is designed as an inclined surface, which can not only prevent the rubber cylinder seat from reversing, but also convert a part of the axial force into the radial force of the lock ring to strengthen the lock ring and the liner. The structure of the radial locking effect is shown in Figure 1 (ab). In this model, the liner, the rubber tube seat and the lock ring material are all made of 42CrMo steel with HRC25.4～HRC29 after quenching and tempering. The density is 7.85g/cm3, the elastic modulus is 2.12×105MPa, and the yield strength is 950MPa. Poisson's ratio is 0.28.

Figure 1 (c-f) is the meshing diagram of the simulation model. The eight-node linear hexahedral element is used to reduce the integral element (C3D8R) simulation, and the default hourglass control is used to prevent the hourglass value problem that may occur in the linear reduction element. For this model, the contact between the lock ring teeth and the liner teeth after the lock ring is locked is considered, so the mesh of the contact part is refined.

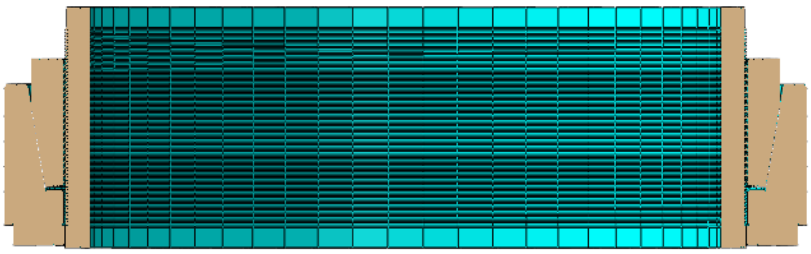
At the same time, load is added to the model according to actual working conditions. After the setting hydraulic pressure is removed at the end of the setting, the elastic force of the rubber cylinder acts on the lower rubber cylinder seat to drive the lock ring to lock the liner, and the force is equal to the setting pressure. Therefore, in a short period of time, pressure is applied to the lower part of the lower rubber cylinder seat and stabilized, and its action area is equal to the area of the hydraulic action piston.



a Three-dimensional locking mechanism b Lock ring



c Liner d Glue tube seat e Lock ring



f Locking mechanism finite element

Fig 1 Parts and meshing diagram

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3. Safety and reliability assessment of lock ring structure

3.1. Finite element results

The casing wall thickness is 10.03mm, the setting hydraulic pressure is 18MPa, and the unsealing force is 22T (extreme conditions), and the calculation results are analyzed.

3.1.1 Analysis of stress cloud diagram

When the setting hydraulic pressure is 18MPa, the structure and component stress cloud diagram after the liner is locked by the lock ring and stabilized is shown in Figure 3-1:

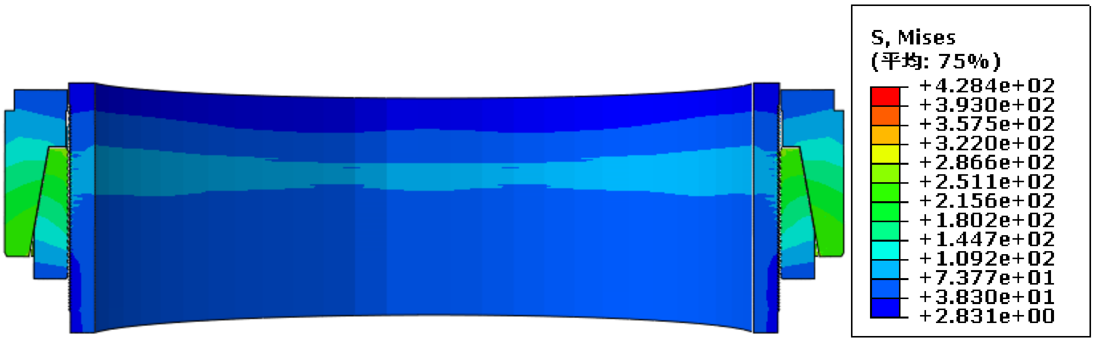

Fig 3-1 Structural stress cloud diagram after stabilization

3.1.2 Analysis of stress distribution data

By analyzing the stress distribution of the lock ring during the locking process, a certain basis can be provided for the design of a more reasonable lock ring tooth structure. For ease of description, the teeth of the lock ring are numbered from the left to the right of the lock ring according to the grid as the first tooth, the second tooth, the third tooth,..., the twentieth tooth; each tooth is sequentially from top to bottom Select the nodes, the numbers are 1, 2, 3..., 20, as shown in Figure 3-2:

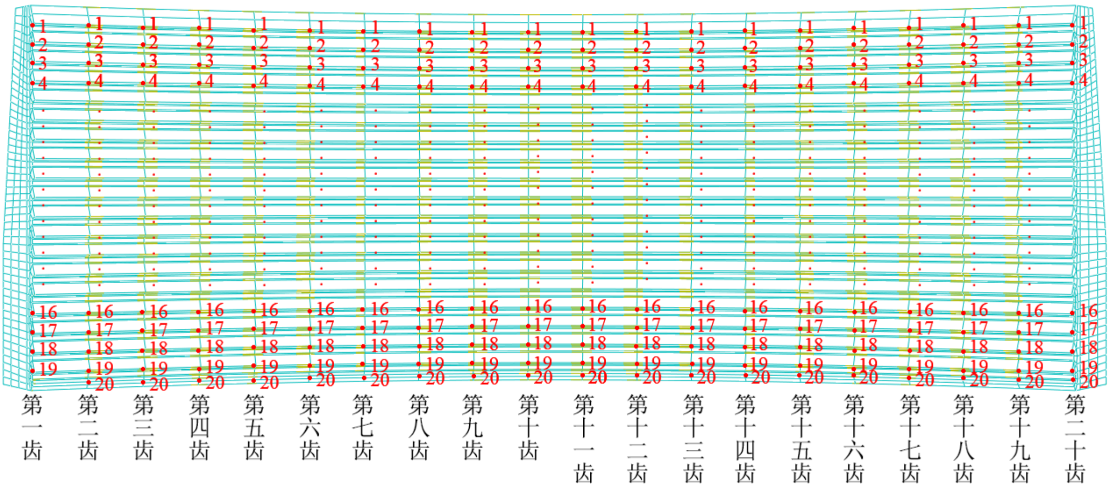

Fig 3-2 Tooth number and node number of the lock ring

The material of the lock ring is 42CrMo, the yield strength Re(σs)=950MPa, and the tensile strength Rm(σb)=1080MPa. According to the stress in the red dot area in the above figure, two graphs are drawn after the lock ring is locked and stabilized: (1) Figure 4-3a shows the stress distribution of different nodes on each tooth; (2) Figure 4-3b shows The stress distribution of each node in the tooth width direction on different teeth.

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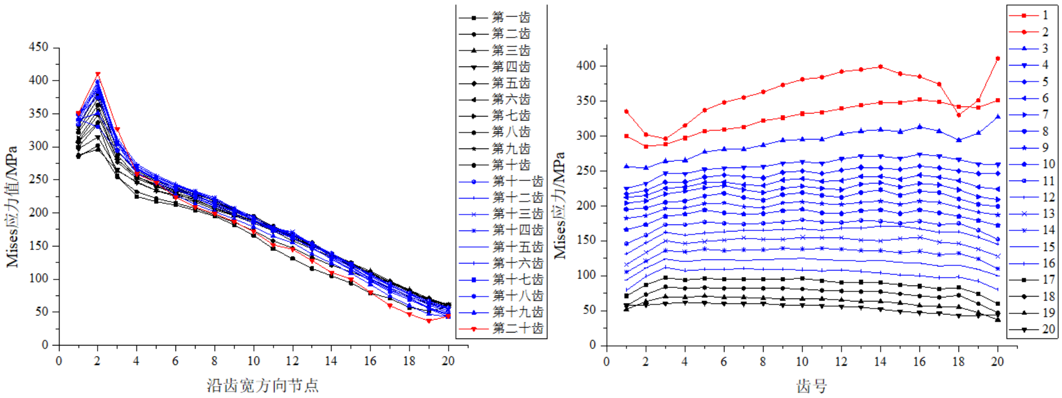

a Different nodal stress on each tooth b Stress of different tooth numbers at the same node

Fig 3-3 Mises stress distribution diagram after the lock ring is locked and stabilized

It can be seen from Fig. 4-3a that for the same tooth, the stress at the node increases first and then decreases along the tooth width direction. After node 3, the decrease is stable. The maximum stress is concentrated on the second tooth, which is due to the first The design height of the tooth and the twentieth tooth is smaller than the other teeth, and the height of the other teeth is equal, so the force area of the first tooth is smaller than the second tooth; under the driving force of the rubber cylinder seat, the six-piece lock ring will gather toward its center, resulting in There is contact pressure between each lock ring, and because the lower part of the lock ring is suspended, the stress is the largest near the upper part of the lock ring, and it decreases evenly along the lower part.

It can be seen from the second figure that, except for nodes 1 to 3, the stress distribution in the other nodes along the tooth number direction is uniform. The stress growth rate of the nodes with the same tooth number is stable, and there is no stress concentration phenomenon. Node 2 is the maximum stress node on all teeth except the eighteenth tooth, and the maximum value is 411.6MPa.

The stress distribution of the liner teeth in contact with the lock ring teeth is similar to that of the lock ring teeth. The stress value of the liner teeth in the contact area with the No. 2 node of the lock ring teeth is the same as the maximum stress on the liner, and its value is 236.9.

According to the above conclusions, when optimizing the tooth structure, it is possible to appropriately increase the tooth height and tooth width of nodes 1 to 3 to ensure safer strength; appropriately reduce the tooth pitch of 3 to 20 nodes to increase the overall force of the teeth. Evenly.

The liner is occluded by the teeth of the lock ring, and the maximum stress of its components varies with time as shown in Figure 4-4a. The maximum stress of the lock ring changes with time as shown in Figure 4-4b. The curve of the maximum stress of the upper rubber tube seat over time is shown in Figure 4-4c. It can be seen that the curve of the maximum stress value of all components changes with time is very similar. It increases steadily in the early stage of the pressurization stage, and stabilizes in the later stage. It is because the rubber cylinder seat squeezes the lock block to gather it toward the center during the pressurization stage and push it. The lock block makes the lock block teeth and the liner teeth occlude, and the maximum stress of each component increases as the pressure on the rubber cylinder seat increases. In the late stage of the pressurization phase, after the top of the lock block reached the end of the boss in the rubber cylinder seat under the push of the rubber cylinder seat, the maximum stress value of each component changes slowly with the increase of pressure and gradually stabilizes, because At this stage, the glue cylinder seat cannot continue to gather the lock block, the contact area between the lock block tooth and the liner tooth remains unchanged, the components have no relative movement, and the stress of the components tends to be stable after that.

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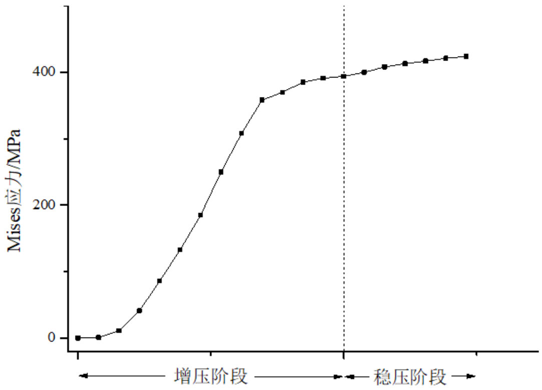
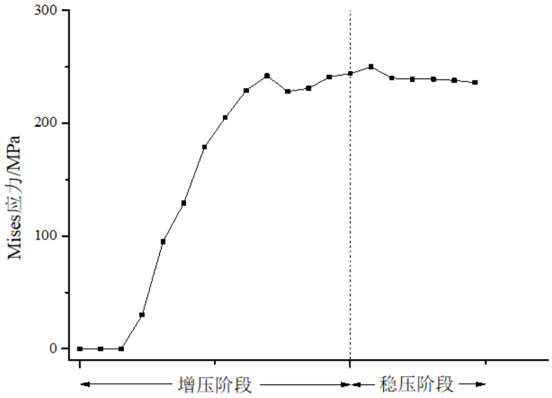
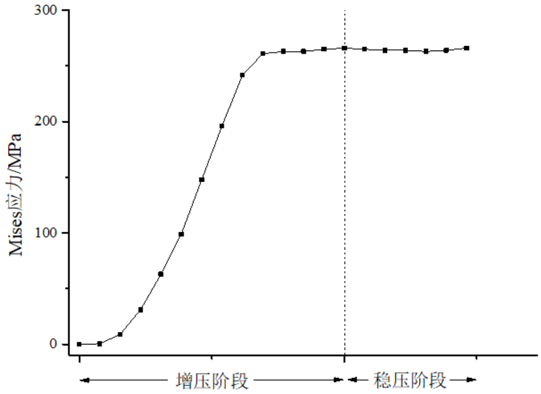


a Liner



b Lock ring



c Liner

Fig 3-4 Curve of maximum stress of structural parts over time

The slip of the lock ring as shown in Figure 4-5 reflects whether the locking force of the lock ring meets the working requirements. The amount of slip in the process is the sliding distance during the lock ring locking force test. The smaller the distance, the lock ring is locked. The stronger, and vice versa, the larger, indicating that the lock ring is easier to slip off. It can be seen from the figure that due to the initial gap between the locking ring teeth and the casing teeth in the early stage of the pressurization phase, the locking ring is in contact with the casing teeth after being pushed by the rubber cylinder seat and moving upward by 0.022mm, and in the subsequent process The degree of engagement gradually deepens. In this process, the degree of engagement deepens due to the angle of the tooth profile and the lock ring descends. Therefore, the slip distance of the lock ring first increases and then decreases; the slip amount of the lock ring after the liner is locked in the middle of the pressurization phase It tends to be stable, and it can be seen that the amount of slippage in the whole process is small, and the lock is firm.

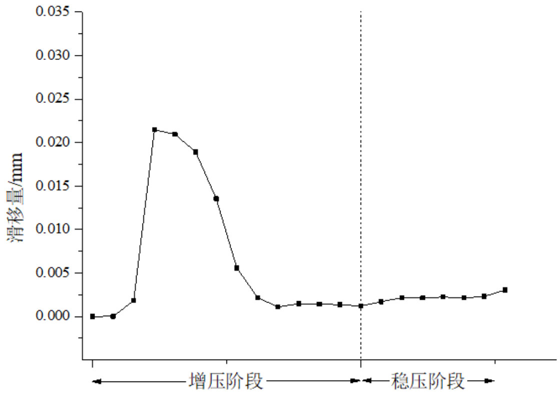


Fig 3-5 Curve of the slip of the lock ring over time

Therefore, under the working condition of setting hydraulic pressure of 18MPa, the maximum stress value of each component is less than its allowable stress, the strength is safe and reliable, and the locking performance of the lock ring is stable.

4. Summary

Aiming at the problem of how to fix the compression position of the packer rubber cylinder after the hydraulic setting is completed, a locking device with a lock ring as the core component is designed. In order to verify the safety of the strength of the lock ring structure and the reliability of the operation, based on the finite element analysis theory, the finite element analysis of each component of the locking structure was carried out systematically, and the stress distribution of each component was obtained and carried out. Strength check and safety and reliability assessment.

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