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Analysis of Sealing Performance of Cone Reamer

Bing Li*, Yafei Ji

School of Southwest Petroleum University, Chengdu, Sichuan 610000, China
*Corresponding author: Bing Li

Abstract: When the cone reamer is working, the upper end face of the piston contacts the drilling fluid. The sealing structure is used to isolate the drilling fluid at the upper and lower end faces of the piston, thus ensuring the differential pressure between the upper and lower end faces, so as to realize the axial downward movement of the piston. The sealing between the piston and the body will have a direct impact on the expansion quality of the reamer, and affect the subsequent reaming quality. At the same time, the seal ring may be squeezed into the gap between the body and the piston during the dynamic sealing process, resulting in. Therefore, this section carries out simulation analysis on the sealing structure, discusses its sealing performance and optimizes the structure.

Keywords: Cone reamer, Combined seal structure, Performance analysis.

1. Introduction

Reaming is the process of expanding an existing well into a larger diameter well. It can be used to solve the problems of hole shrinkage and collapse, or increase the clearance between the hole and casing, and improve the cementing quality. The cone reamer is one of the types of reamers frequently used in the reaming technology, which is mainly composed of four parts: upper and lower joints, body, expansion mechanism and cutting mechanism [1]. The expansion mechanism comprises a piston, a spring and a pin; The cutting mechanism includes: cone and reamer arm. After the cone reamer is lowered to the designated position, the drilling fluid is introduced. The drilling fluid creates a pressure difference between the upper and lower end faces of the piston, which drives the piston to move down axially, pushes the cone arm to expand, and presses the teeth into the formation. After reaming, stop the pump. The elastic recovery force generated by the spring helps the piston reset, and the reaming blade retracts the body[2].

In the reaming operation, the piston seal of the cone reamer failed. The piston is sealed with O-ring, which is used to isolate the drilling fluid at the upper and lower end faces of the piston, so as to ensure the differential pressure between the upper and lower end faces. Under the high-speed washing of solid particles of drilling fluid, erosion wear is easily caused, affecting the expansion of the subsequent cone arm. To sum up, in order to solve the above problems, the axisymmetric model of piston seal structure is established, and its simulation analysis is carried out to discuss its sealing performance and structure optimization.

2. Simulation Analysis of Sealing Performance

When the reamer is working, the upper end face of the piston is in contact with the drilling fluid. The sealing structure is used to isolate the drilling fluid on the upper and lower end faces of the piston, so as to ensure the pressure difference between the upper and lower end faces, so as to realize the axial downward movement of the piston. The sealing between the piston and the body will have a direct effect on the expansion quality of the reamer and affect the subsequent reamer quality. At the same time, the sealing ring may be squeezed into the gap between the body and the piston during the dynamic sealing process, resulting in. Therefore, this section carries on the simulation analysis to the sealing structure, discusses the sealing performance and carries on the structure optimization.

2.1. Establish finite element model

In the simulation analysis in this section, the following assumptions are followed:

(1) O-ring material is uniform and continuous and isotropic;

(2) The volume of O-ring remains unchanged during the analysis;

(3) The structure of O-ring is completely centrosymmetric.

The geometry, load and constraint of the seal structure are axisymmetric, so a two-dimensional axisymmetric model is used to simulate the seal structure. A two-dimensional symmetric model is established by Solidworks software. The finite element model diagram is shown in the figure.

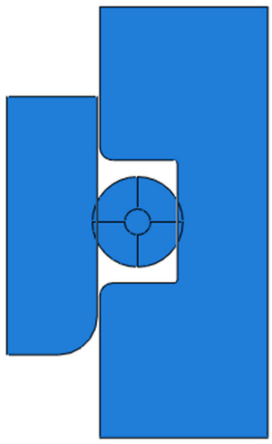

Figure 1. Finite element model of seal structure

2.2. Material setting and meshing

The model was imported into ABAQUS to complete the meshing. The 4-node quadrilateral bilinear axisymmetric reduction integral element CAX4R was used to divide the grid of piston and body. The sealing ring was meshed by 4-node quadrilateral bilinear axisymmetric hybrid element

CAX4H[3]. The grid rendering is shown in the figure.

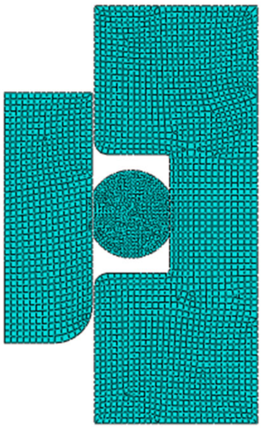

Figure 2. Sealing structure grid division effect

2.3. Boundary conditions and loading modes

There are three contact surfaces between the sealing ring and the body and the piston: contact surface 1 (contact area between O-ring and the side wall of the piston), contact surface 2 (contact area between O-ring and the side wall of the body), contact surface 3 (contact area between O-ring and the bottom of the piston) [4]. As shown in the picture below.

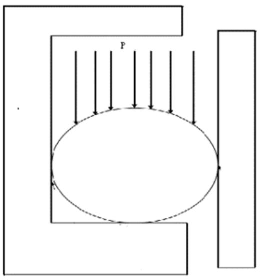

Figure 3. O-ring contact surface diagram

All the three contact surfaces are set as frictional contact, the tangential contact property is set as penalty function, the friction coefficient is set as 0.7, and the normal direction is set as hard contact, allowing separation after contact. The contact pair associated with the O-ring is set as the pressure penetration contact pair. The sealing state is divided into three conditions: compression process, static sealing state, reciprocating motion state. Therefore, the load application of the sealing ring is divided into three steps to apply:

The first step: the sealing ring installation process, the piston, body to impose fixed boundary conditions, set the sealing ring and body interference fit, to simulate the sealing ring installation process.

Step 2: Set the pressure penetration interaction, apply the liquid pressure to one side of the sealing ring along the axial direction, simulate the situation of the sealing ring under the medium pressure, and simulate the static sealing state of the reamer.

Step 3: Remove the fixed boundary conditions of the body and apply the axial downward velocity V=1.5mm/s to the body to simulate the dynamic sealing state of the sealing ring.

2.4. Finite element analysis

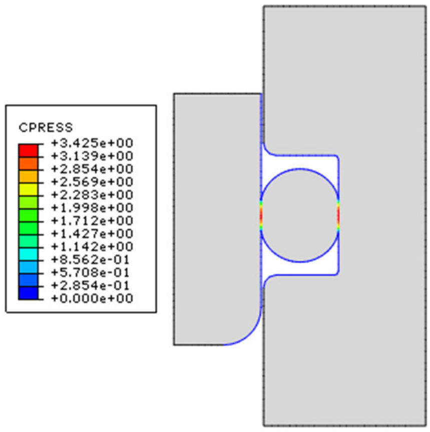

Figure 4. Nephogram of contact stress in preloaded compression

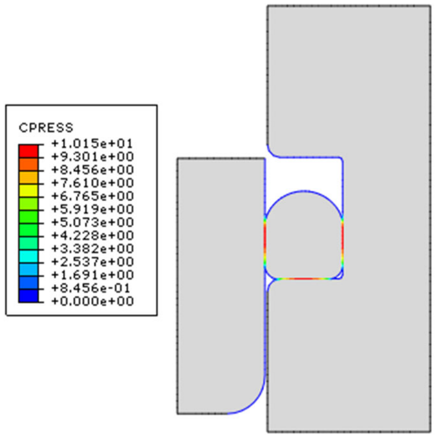

Figure 5. Contact stress nephogram of static seal

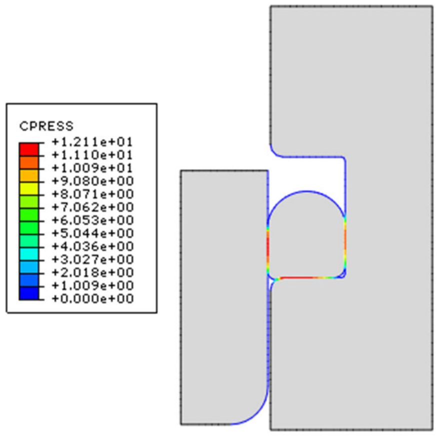

Figure 6. Dynamic seal contact stress nephogram

The finite element simulation results of the contact stress of the seal structure are shown in the figure. It can be seen from the figure that the maximum contact stress of the piston after installation is 3.54Mpa, the maximum contact stress of the static seal is 10.1Mpa, and the maximum contact stress of the dynamic seal is 12.1 Mpa. In the process of pre-tightening installation, the maximum contact stress is on both sides of the contact between the O-ring and the body and the piston; When the medium pressure is applied, the contact stress increases significantly, and the maximum contact stress occurs at the lower part of the contact between the O-ring and the piston. When the piston is moved, the contact stress continues to increase compared to the static seal. The minimum contact stress of static and dynamic seal is greater than the medium pressure, which can play a sealing effect.

3. Combined Seal Structure Design

3.1. Combined seal structure design

It can be seen from the analysis results of the upper section that the O-ring can achieve a certain sealing effect, but when the O-ring is used for reciprocating dynamic sealing, the starting friction resistance is large, easy to produce distortion, easy to occur distortion damage. There is a gap between the piston and the body, and the O-ring will be squeezed into the gap and produce stress concentration, which leads to shear failure. At the same time, the sealing ring and the piston, the body wear, thus affecting the sealing effect. Therefore, this section makes use of the advantages of double triangle retaining ring combination seal to make up for the deficiency of O-ring seal. The double triangle retaining ring is made of polytetrafluoroethylene composite material, which has small friction coefficient with metal and good wear resistance. At the same time, the retaining ring adopts a center symmetric structure, which can prevent the O-ring from being squeezed into the gap between the piston and the body. Designed combination seal includes: piston, O - ring, slip ring, body. The sealing ring structure is shown in the figure[5].

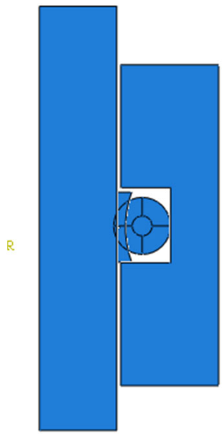

Figure 7. Schematic diagram of double triangle retaining ring combined seal structure

3.2. Finite element analysis of composite seal structure

The model was imported into ABAQUS to complete the meshing. The 4-node quadrilateral bilinear axisymmetric reduction integral element CAX4R was used to divide the grid of piston, body and retaining ring. The sealing ring was meshed by 4-node quadrilateral bilinear axisymmetric hybrid element CAX4H. Set the friction coefficient between O-ring and piston groove as 0.7, set the friction coefficient between stop ring and piston, stop ring and body as 0.1, and set the friction coefficient between stop ring and O-ring as 0.5.

The sealing state is divided into three conditions: compression process, static sealing state, reciprocating motion state. Therefore, the load application of the sealing ring is divided into three steps to apply:

Step1: the sealing ring installation process, the piston, body to impose fixed boundary conditions, set the sealing ring and body interference fit, to simulate the sealing ring installation process.

Step 2: Set the contact pair of pressure penetration interaction, apply liquid pressure to one side of the sealing ring along the axial direction, simulate the situation of the sealing ring under medium pressure, and simulate the static sealing state of the reamer.

Step 3: Remove the fixed boundary conditions of the body and apply the axial downward velocity V=1.5mm/s to the body to simulate the dynamic sealing state of the sealing ring.

3.3. Finite element analysis

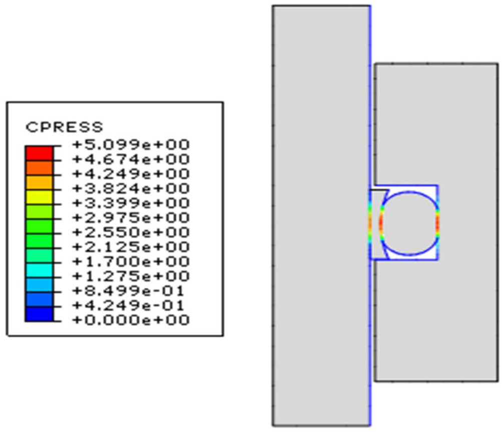

Figure 8. Nephogram of contact stress in preloaded compression

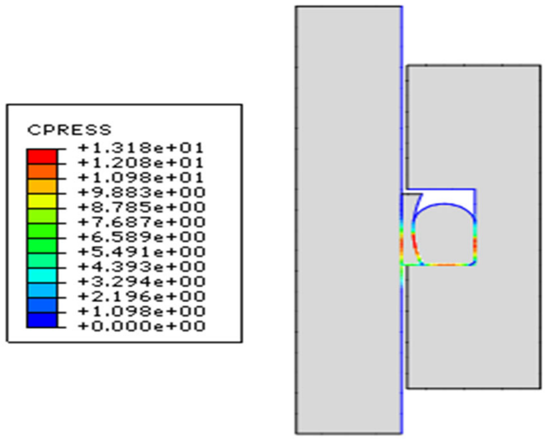

Figure 9. Contact stress nephogram of static seal

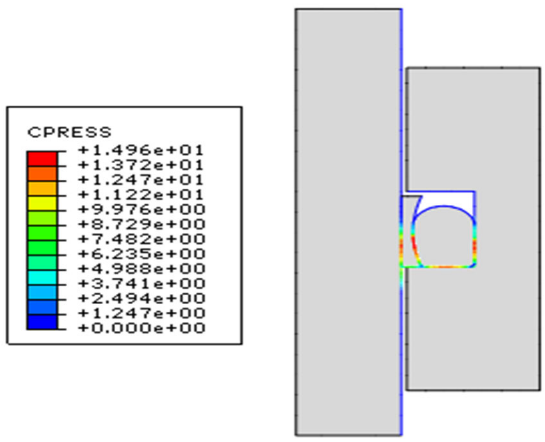

Figure 10. Dynamic seal contact stress nephogram

The finite element simulation results of the contact stress of the seal structure are shown in the figure. It can be seen from the figure that the maximum contact stress of the piston after installation is 5Mpa, the maximum contact stress of the static seal is 13 Mpa, and the maximum contact stress of the dynamic seal is 15 Mpa.

4. Summary

In this paper, the simulation analysis of O-ring seal and combinatorial seal was completed, and the contact stress and Mises stress distribution were obtained respectively.

It can be seen that the contact stress increases after the combination seal is adopted, indicating that the sealing performance is improved. After the combination of sealing, lubrication conditions become better resulting in O-ring friction and wear smaller, sealing ring life extension, and ring material between piston and O-ring, wear is very small, its replacement life is generally greater than the O-ring replacement life. At the same time, the double triangle combination seal can not only protect the O-ring, but also achieve good lubrication.

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