Numerical simulation on down-hole cone bit seals

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Abstract

Seals are a critical aspect of down-hole tools in the drilling fluid, hard particles will accelerate seals wear and eventual tools failure. In the process of drilling, greater contact pressure leads higher wear rate. Meanwhile, environmental pressure changes with the change of drilling depth, so it is very important to study the relationship between the seal contact pressure and environmental pressure. In this study, the newest generation bearing seal SEMS2 for the different environmental pressures are analyzed by ANSYS. the inner contact pressure is lower than the outer at low environmental pressure, which is opposite to the high pressure condition. The outer surface contact pressure decreases with the decreases of the hardness of the rubber support ring and the O-ring, but increases with sealing contact width.

Keywords

Contact pressure; Drilling; Cone bit; Finite element analysis.

1. Introduction

The bearing seal protects the bearing by excluding drilling fluid and retaining lubricant in the chamber of the cone bit, and the seal has a beneficial impact on drilling costs in abrasive environment [1]. The main reason for the bits failure is due to early bearing damage; however, the statistics indicated that the main reason for the bit failure is the early seal failure [2]. The double metal floating seal was used in cone bit bearing sealing system in 1987, compared with the rubber seal, the working life of the drill bits provided with the metal sealing is increased by 150-200 hours. In the early 1990s, Luo et al. designed a single metal floating seal structure to promote the seal performance [3], the single metal floating seal has the characteristics of simple structure, high temperature and high pressure resistance, which widely used in the field of mine and drilling. On this basis, the first generation single metal seal SEMS had been developed by Baker Hughes in 1998, the SEMS was characterized by a support rubber ring and was used in the Gulf of Mexico area with an average life of more than 55h [4]. In order to increase the seal contact pressure between the metal seal surface, the newest generation bearing seal SEMS2 had been improved by Baker Hughes in 2003. The development of cone bit bearing seal and the schematic of the SEMS2 is shown in Fig.1 [5].

For the SEMS2, the stator, the rubber support ring, and the O-ring are relatively stationary, the rotor rotates together with the cone. Meanwhile, the O-ring and the rubber support ring provide the axial force for the seal interface between the rotor and the stator. Different environmental pressures and structure parameters have a very significant effect on the pressure distribution of the seal interface, which will directly relate to the seal wear conditions, further leads to bit failure.

Due to the drilling condition and the bearing seal parameters is complicated, few studies focus on the down-hole seal, For the down-hole metal seal, Shunhe Xiong [6] established an axisymmetric numerical model of mechanical seal for down-hole tools in 2000, discussing the relationship between the drilling pressure and the distribution of lubricating oil, moreover, the deformation of the bit seal and the film thickness with temperature effect was studied by Shunhe Xiong and Richard F [7].

2. Engineering background

Tuo142 is a high build rate exploration well belongs to the Shengli Oil Field in China, the cone bit has been used in oblique section, and the drilling fluid is mixed with large size gravel. During the initial stages of drilling, the bit seal SEMS2 has a good performance, but the bit teeth wear is relatively serious, then the bearing was stuck due to seal failure. The working parameters are shown in Table 1.

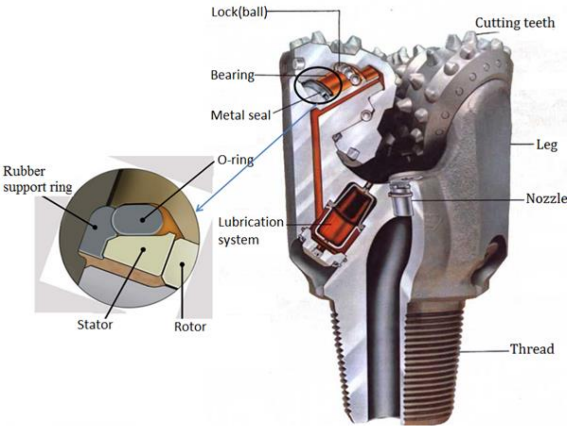

Fig.1 The section view of the bit seal

Table 1: Working parameters of drilling

Well section/m	Performance indicators		Drilling parameters	
	Time/h	Drilling speed m/h	Drilling pressure（KN）	Speed (r/min)
1600~1880	41	6.83	120~160	70

The drilling fluid pressure for this well section is 16-18 MPa, after pulling the string out, the seal interface wear condition and the deformation of the O-ring are shown in Fig 2. It can be seen that the sealing contact area is the middle area of the sealing surface, the outer area has been worn out, the wear area is gradually moving from the outer to the inner. The deflection and deformation of the O-ring are mainly due to the offset of the installation position.

3. Model and Finite element simulation

3.1 Metal seal simulation analysis

Contact pressure is an important factor for the seal surface wear and failure analysis. For the complex construction and working condition, it is difficult to obtain the seal interface contact pressure through experiments, however, the FEM is the most reliable and effective method to solve this contact problem.

There are two steps for this analysis, the seal assembly process for the 3mm axial displacement on the stator is completed firstly, then the lubricant pressure and the drilling fluid pressure are applied to the inner and the outer of the seal respectively in the second step, as shown in Fig.3. the lubricant pressure being sealed is significantly greater than the drilling fluid pressure, resulting in a high differential pressure of 0.3~0.5 MPa[8], which can prevent the drilling fluid particles from entering the lubricant system through the seal interface .

Fig.2 The wear condition of the stator

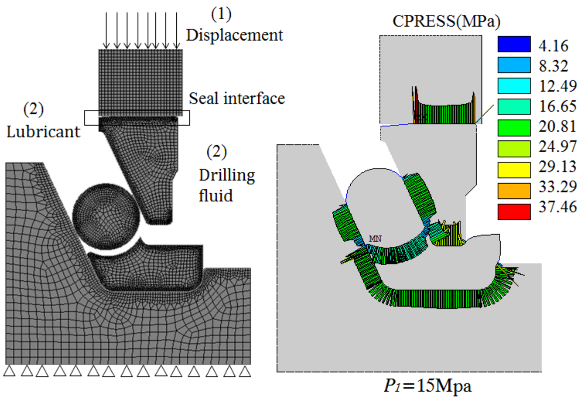

Fig.3 The steps of the finite element analysis.

The seal contact pressure under different drilling fluid pressures are shown in Fig.4. When the drilling fluid pressure is 3 MPa, the maximum contact pressure is located at the outer interface(19.39MPa), with the increase of drilling fluid pressure, the inner contact pressure increases more quickly than that of the outer, especially on the high drilling fluid pressure, the inner contact pressure is significantly greater than the outer, which will lead to the drilling fluid easily enter into the outer interface.

Fig.4 also shows that contact pressure distribution is uneven, the outer contact pressure is bigger than that of the inner at high drilling fluid pressure, therefore, the outer interface is prone to wear in the drilling process.

3.2 Effect of the seal parameters on contact pressure

3.2.1 Hardness of head energizer

The influence of rubber support ring hardness on the contact pressure are obtained at high pressure condition, as shown in Fig.5. Increasing the down-hole temperature, the hardness of rubber decreases gradually. The outer contact pressure decreases rapidly with the decreases of the hardness of the rubber support ring, causes the contact pressure distribution is more uneven and the inner surface wear speeding up. So the down-hole temperature increases will cause the abrasive particles penetrate into the seal outer edge more easily.

3.2.2 Hardness of O-ring

Fig.6 shows the contact pressure distribution along seal surface width, varying the hardness of O-ring. As shown, the peak value of the inner contact pressure decreased but the outer contact pressure increased as the hardness of O-ring increased. The higher outer contact pressure are favorable to prevent penetration of abrasive particles. For the middle region, Fig.6 also shows the contact pressure distribution is more evenly with the hardness of O-ring increased and beneficial to prolong the seal life.

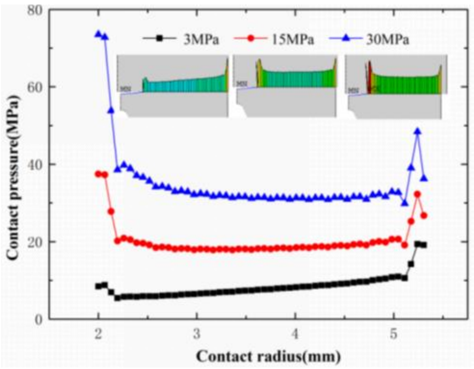

Fig.4 The contact pressure under different fluid pressure

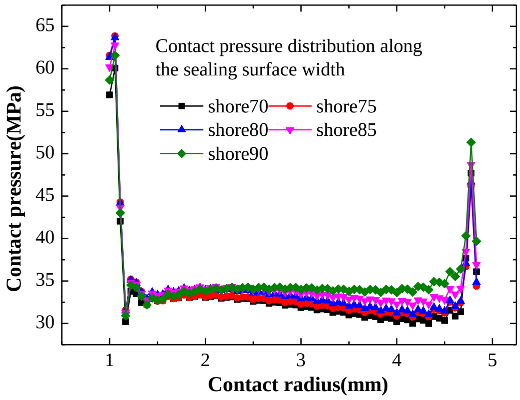

Fig.5 Influence of support ring hardness on the contact pressure

3.2.3 Sealing contact width

Fig.7 shows contact pressure distribution versus seal surface width, varying the sealing contact width. Unlike to figure 10, the peak value of the inner contact pressure increased but the outer contact pressure decreased as the seal surface width increased. For the middle region, contact pressure has a trend of gradual decrease from the inner to the outer, and the pressure difference between is increasing. Therefore, the contact width should be increased to satisfy the requirement for more evenly contact pressure distribution on condition of meeting seal design strength and durability.

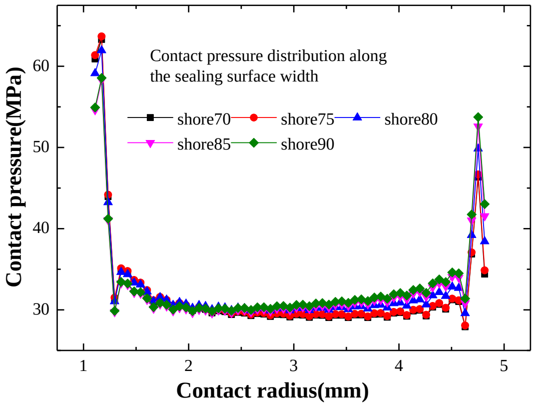

Fig.6 Contact pressure distribution along seal surface

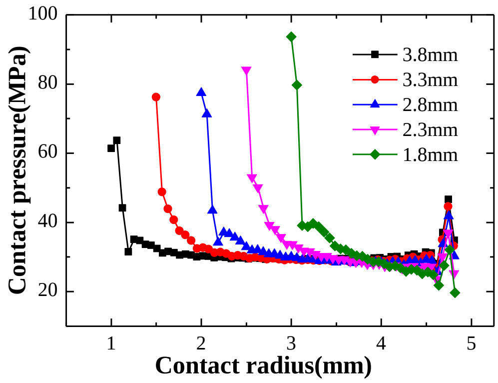

Fig.7 Contact pressure distribution versus seal surface

3.2.4 Drilling fluid pressure

Results for the temperature distribution under different drilling fluid pressure are present in Fig.8. With the increase of drilling fluid pressure, the amplitude of the inner temperature increase is higher than that of the outer, which will further aggravated the seal thermal fatigue.

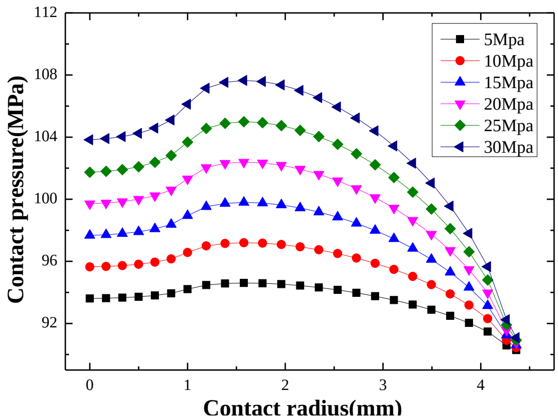

Fig.8 Temperature distribution versus seal surface

4. Conclusion

This paper has studied the failure mechanism of bit bearing seal SEMS2 by means of numerical simulation to extend the seal life in the down-hole drilling environment. The drilling fluid pressure and the hardness of rubber have great influence on the contact pressure distribution.

With the increase of drilling fluid pressure, the inner contact pressure increases rapidly, and the abrasive particles easily enter into the outer interface. The contact pressure distribution is more evenly with larger hardness of rubber support ring and O-ring, which is beneficial to reduce the inner seal wear.

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