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Original article

Spherical contact mechanical analysis of roller cone drill bits journal bearing

Wei He [a], Yang Chen [a, *], Junchao He [a], Weiling Xiong [b], Tong Tang [a], Hao OuYang [a]

[a] School of Mechatronic Engineering, Southwest Petroleum University, Chengdu 610500, China
[b] Sichuan Special Equipment Inspection Institute, Chengdu 610061, China

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ABSTRACT

Fang contact model is introduced to analyze stress of the spherical fixed ring journal bearing. Developed calculation programs in the MATLAB software which are utilized to calculate the contact characteristics of roller cone drill bits spherical fixed ring journal bearing. In addition, effects of external load, radius clearance values, and material parameter on the mechanics performance were investigated. The results show that the value of external load has a direct pronounced effect on the contact characteristics of journal bearing. There is a significant positive correlation between contact pressure and external load, radius clearance value, and the Young's modulus of material. However, there is an evident negative correlation between contact radius of journal bearing and radius clearance value, and the Young's modulus of material. The smaller radius clearance value of journal bearing is, the more centralized contact region will be, so the corresponding contact pressure will be higher. From the perspective of reducing friction and wear, we need select the materials which have high strength and good toughness. Not only might this can improve the wear resistance, it also effectively decreases the contact pressure. In this case, we can prolong the service life of roller cone drill bits journal bearing.

1. Introduction

The problem that life of roller cone drill bits journal bearing doesn't match the cemented carbides is restricting the life of roller cone drill bits. At present, the bearing that extensively used for roller cone drill bits is journal bearing. The downhole complicated conditions and uneven bearing load will further cause the journal bearing failure [1–3]. In order to prolong the journal bearing's life, so many experts and scholars have gotten a lot of academic research results through their shared efforts. Chen proposed a kind of variable curvature of roller cone drill bits journal bearing [4]. This new kind of structural design can improve the bearing friction properties of the friction pairs. Huang et al. analyzed the failure journal bearing of roller cone drill bits, which shows that the load in the bearing is excessively and extremely uneven. Higher temperature will reduce the metal material surface strength and abrasion resistance. Moreover, the uneven shaking of roller cone drill bits in the course of working will bring the bearing uneven stress [5,6,7]. So the optimization and improvement of roller cone drill bits journal bearing are particularly significant.

The principal failure modes of journal bearing are adhesive wear and abrasive wear [8–13]. Wear and tear will damage the surface quality of the material. Ability of abrasion resistance determines the journal bearing's life of roller cone drill bits. In order to reduce friction and wear, we need to enlarge the contact region and enhance the wear resistance. He et al. proposed a kind of spherical fixed ring journal of roller cone drill bits (ZL201320364808.9) [14]. This is a newly-designed idea. There is a spherical fixed ring in the big journal bearing which is made of cemented carbide after carburizing and quenching, and being assembled in the big journal through thermal expansion method.

* Corresponding author.
E-mail address: 201421000412@stu.swpu.edu.cn (Y. Chen).
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At the same time, the inner hole of roller cone drill bits is being designed to be spherical accordingly (Fig. 1).

2. The load analysis of the bearing

Roller cone drill bits journal bearing has the following main parts: the big radial journal bearing, the smaller one, and two plane thrust bearing. The dimension of roller cone drill bits journal bearing is limited. Roller cone drill bits journal bearing is a special bearing, which is in a slow and overload condition. Zhang et al.'s experiment confirmed that the load in the II# roller cone drill bits journal bearing is the largest, and the journal bearing's wearing rate is the biggest [15,16]. The failure of bearing speeds up the overall failure of roller cone drill bits. In terms of many experts and scholars' academic research achievements, the distributed forces in the journal bearing can be simplified as a concentrated force (Fig. 2). To calculate those forces, we get the formulas as follows [5,15,16]:

$$\begin{cases} F_{r1} = 9800 \times \alpha_{123} \times 0.9 \times \sin\beta \times \omega = 8820\omega\alpha_{123}\sin\beta \\ F_{r2} = 9800 \times \alpha_{123} \times 0.1 \times \sin\beta \times \omega = 980\omega\alpha_{123}\sin\beta \\ F_a = 9800 \times \alpha_{123} \times \cos\beta \times \omega = 9800\omega\alpha_{123}\cos\beta \end{cases} \quad (1)$$

The friction torque along the circumferential of the bearing:

$$M_n = F_{r1} \times f \times R_{j1} \times F_{r2} \times f \times R_{j2} \quad (2)$$

where F_{r1} is the radial force in the big journal; F_{r2} is the radial force in the smaller journal; F_a is the force in the thrust bearing; ω is the external load in the roller cone drill bits journal bearing; β is the angle degree between bearing axis and the roller cone drill bits journal bearing axis; R_{j1} and R_{j2} are the radii of the big journal and the smaller one, respectively; f is the friction coefficient between the bearing friction pairs.

3. Hertz contact model

On the basis of photoelastic mechanical, Hertz proposed the two objects contact pressure distribution and deformation through researching the half space contact elastomer. It is necessary for Hertz contact model to make the following assumptions:

(1) The materials are homogeneous and isotropic;
(2) Contact surface is considered to be smooth, and the lubricating medium is ignored;
(3) Elastic deformation occurs only in contact region, conformed to the Hooke's law, and do not exceed the elastic limit of material;
(4) The size of contact region is so small compared with the two contact bodies.

In terms of the above assumptions, spherical fixed ring journal bearing approximately satisfies Hertz contact model. Contact region is a point without external load. Contact region turns into a circular region under the external load. And contact bodies only

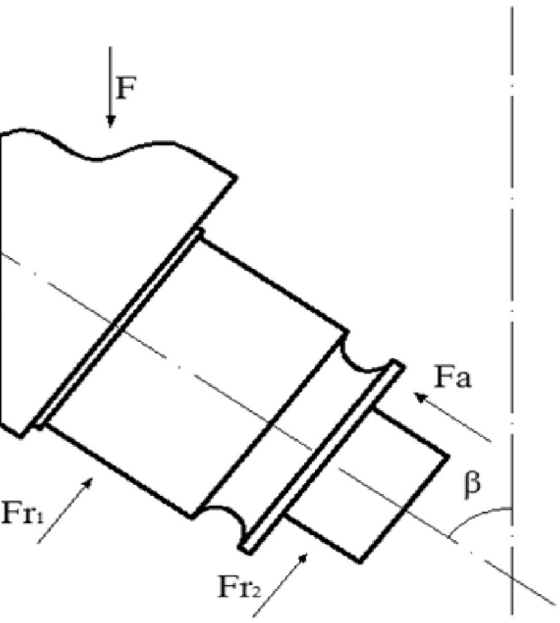
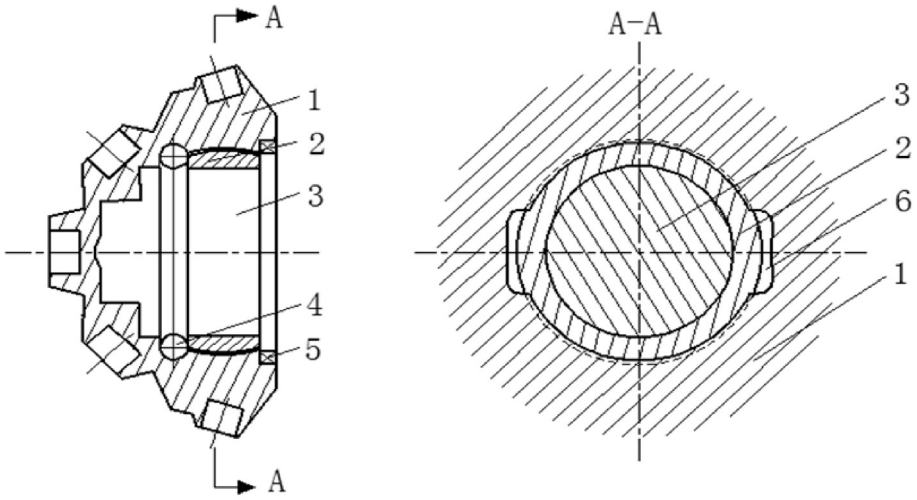


Fig. 2. Schematic diagram of the journal bearing forces.



1-roller cone, 2-spherical fixed ring, 3-journal, 4-steel ball, 5-seal ring, 6-assembling groove

Fig. 1. Structures of spherical fixed ring bearing of roller cone drill bits.