Analysis of the influence of the contact mode of the rolling elements of the slewing bearing on its stability

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Abstract. The stability of the rolling elements in the slewing bearing is an important factor that determines the smooth rotation of the slewing bearing. The slewing radius of the slewing bearing is large and the load is complicated. In this paper, the contact relationship between the rolling elements and the raceway is established by establishing a slice model of the slewing bearing. Considering the effects of axial load and radial load, respectively, the contact deformation and displacement changes of the rolling elements are analyzed. The simulation results show that the rolling elements of the two-point contact slewing bearing rotate during the load process, and the four-point contact slewing bearing is in the axial direction. Under load, the rolling contact state in the raceway with the raceway is stable without spinning; under radial load, the contact relationship between the rolling element and the four-point contact raceway at this time is essentially two-point contact, but compared to the one used Two-point contact raceway, the rolling elements have better radial stability in the newly designed raceway.

1. Introduction
The slewing ring is large in size and can withstand complex heavy loads[1]. Compared with rolling bearings in structure, it has raceways and rolling elements. Compared with the cages commonly used in rolling bearings, discrete spacers are usually used in slewing bearings to keep the rolling elements moving smoothly[2]. However, the unstable dynamic contact between the discrete spacer and the rolling elements makes the spacer and the rolling elements move abnormally in the raceway.

Based on the dynamic analysis of rolling ball bearings, Meeks[3] established an equation that takes the minimum contact stress between cage pockets and rolling elements as the optimization objective. The results show that when the ratio of cage pocket clearance to guide clearance is greater than At 1 o'clock, it will cause the instability of the cage movement, and the collision between the rolling elements and the pockets will increase. Ghaisas[4] comprehensively considered the motion state of the cage in space, and established the six-degree-of-freedom motion equation of the cage to analyzed the influence of various factors such as pocket clearance on its motion stability. Ge Shidong[5] and others divided the movement process of the cage into two stages. One is the energy consumption stage of the rolling element charging the cage and the energy consumption stage of its own frictional vibration, and the energy of the cage and the rolling element collision process is established. The equation of change found that the cage's charging energy greater than the energy consumption during the collision is a sufficient condition for the cage's stable motion. Yao Tingqiang[6] et al. established dynamic equations for cages through ADAMS, and analyzed the effects of changes in cage clearance and lubrication state on the smoothness of motion under various working conditions. Deng Sier[7] took...
angular contact ball bearings as the research object, and established a flexible dynamic motion analysis model of its cage. The research results showed that the ratio of angular contact ball bearing guide clearance to pocket clearance is not conducive to the cage Stability of rotation. Shao Yimin[8] considered the influence of the deformation of the bearing seat and the ring on the bearing motion characteristics, and found that the radial stiffness of the bearing changes nonlinearly as the load increases; the larger the radial clearance, the greater the vibration kinetic energy of each component of the bearing. The lower the smoothness of the rolling elements.

This paper takes four-point contact and two-point contact slewing bearings as the research object, and studies the law of the radial displacement of the rolling body under the action of axial load and radial load.

2. Establishment of finite element model

2.1. Mesh generation

The quality of meshing directly affects whether the ABAQUS finite element model can converge, which is a prerequisite for ensuring the accuracy of settlement results. Inappropriate selection of element attributes and too sparse or dense meshes are not conducive to the convergence of the finite element model. In order to improve the quality of the mesh, make the model as a hexahedral mesh as much as possible. The model needs to be segmented before meshing. During the segmentation process, ABAQUS can automatically identify the mesh quality and then select the element type.

The slewing bearing only produces limited elastic or plastic deformation under working load, and the raceway area is defined as a three-dimensional eight-node solid non-coordinating element C3D8I. Compared with the C3D8R-8 node hexahedral linear reduction integration unit, the C3D8I unit uses linear elements to enhance the additional freedom of the element displacement gradient, so that when the element is slightly distorted, it can not only overcome the shear self-locking problem, but also calculate The displacement, stress and other results obtained are more accurate.

In order to take into account the number of meshes and the accuracy of the calculation results, in the ABAQUS-MESH module, the raceway is appropriately divided, the model size is set to 3mm through the global seed, and the mesh size is set to 0.4mm using edge seeds for the contact surface, Perform local densification; the rolling ball adopts the global seed setting and the unit size is set to 0.8mm, as shown in Figure 1.

Figure 1 Seed layout of slice model

The final meshing result of the slice model is shown in Figure 2. The number of upper raceway units is 39165, the number of lower raceway units is 44065, the number of rolling element units is 107200, and the total number of units for the slice model of the slewing bearing is 190430.
Since the lower raceway of the slewing bearing is fixedly connected by bolts, full restraint is imposed on the bottom surface of the lower raceway of the slice model to limit all the degrees of freedom at the bottom; when the slewing bearing is under load, the normal load on any section of the raceway is symmetrical, so symmetrical constraints are imposed on the four sides of the upper raceway to constrain the normal degrees of freedom of the nodes on the four surfaces. Direct application of concentrated force on the surface of the upper raceway is prone to ill-conditioned stiffness matrix causing the model to not converge. Therefore, a reference point is established directly above the upper raceway to couple with the upper surface. The relationship between the control point and the control is motion, and the three-dimensional space is constrained. Six degrees of freedom inside. Apply a load Q to the slice model through the control points, as shown in Figure 3.

![Figure 2 Meshing result of slice model](image1)

![Figure 3 Boundary conditions and load settings of the slice model](image2)

3. Analysis of Displacement of Rolling Elements of Slewing Bearing

3.1. Motion changes of rolling elements in two-point contact slewing bearings

The slewing bearing used in the active launching pad is equipped with spacers to make the rolling elements orderly distributed in the raceway. During the loading process of the slewing bearing, the rolling elements will be displaced inside the raceway, which is not conducive to the rolling elements and raceways in the slewing bearing. And the smooth contact of the isolation block. In the slice model of the slewing bearing, the lower raceway is a fixed constraint, and the upper raceway only releases the degrees of freedom in the same direction as the force. Under the action of axial load, the displacement distribution of the rolling elements is shown in Figure 4, and the axial displacement at the center of the rolling elements changes to 0.122mm. The radial displacement of the rolling elements varies from -0.060 to -0.057. Compared with the radial load, it can be considered that the stability of the radial displacement of the rolling elements under the axial load is better.
Figure. 4 Displacement of rolling elements of two-point contact slewing bearing under axial load

The cloud diagram of the radial displacement of the rolling element is shown in Figure 5. On the connecting line of the contact points between the rolling elements and the upper and lower raceways, the distribution changes linearly. When only the radial load is considered, the radial displacements of the contact points between the rolling elements and the upper and lower raceways are -0.575 and -0.054mm, respectively, and the displacement at the center of the rolling element is -0.282. The contact point of the rolling element relative to the lower raceway rotates counterclockwise, and the center of the ball moves radially outward. The changes in the axial displacement of the rolling elements are distributed in equal directions on both sides. Therefore, under the action of radial load, the rolling elements rotate in the raceway through the center of the sphere and the vertical raceway section as the axis.

Figure. 5 Displacement of rolling elements of two-point contact slewing bearing under radial load

3.2. Analysis of the displacement of the rolling element of the four-point contact slewing bearing

Under the action of axial load, the cloud diagram of the displacement change of the rolling element is shown in Figure 6, and the radial displacement of the spherical center of the rolling element is 0.00074mm. The maximum radial displacement is 0.01792mm, which occurs in the contact area between the rolling element and the raceway. The rolling element is deformed by the extrusion between the raceway and the rolling element. Under the action of the axial load, it can be considered that the rolling element has no radial direction. Displacement. The axial displacement cloud diagram of the rolling element is shown in Figure 5. The axial displacement of the sphere center and the main body of the rolling element is -0.18mm due to the compression of the upper rolling track. Compared with the two-point contact slewing bearing, under the same axial load, the four-point contact slewing bearing has better radial rigidity, the sphere center of the rolling element does not deviate in the radial direction, and the axial displacement is reduced by 9%. The rolling element does not rotate on its own
Figure 6 Displacement of rolling element of two-point contact slewing bearing under axial load

Under the action of only radial load, the rolling elements are displaced, as shown in Figure 7. In the four-point contact slewing bearing, the rolling and rolling element movement changes are consistent with the two-point contact slewing bearing. The rolling elements are relative to the lower raceway contact point. Rotation occurs in a rolling motion. Compared with the active two-point contact slewing bearing, the radial displacement at the center of the rolling element is -0.1569 mm, and the radial position is reduced by 45.32%.

Figure 7 Displacement of rolling elements of two-point contact slewing bearing under radial load

4. Conclusion

This paper uses ABAQUS to establish contact models between the single rolling elements and raceways of single-row four-point contact slewing bearings and single-row two-point contact slewing bearings. At the same time, the two sets of models are applied with axial force and radial force. In contrast, the simulation results show that when the single-row two-point contact slewing bearing is loaded, the rolling elements roll along the contact surface, and the center of the ball undergoes a large radial displacement; the finite element model of the four-point contact slewing bearing is under axial load and Under composite load, the contact state of the rolling elements and the raceway is four-point contact. At this time, the rolling elements are in stable contact in the raceway, and the center of the sphere only has axial displacement. When the radial direction is loaded, the contact state of the rolling elements and the raceway is In two-point contact, the sphere center of the rolling element produces radial displacement, but compared with the two-point contact slewing bearing in service, the radial displacement of the sphere center of the rolling element is reduced by 45.32%.

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