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FEM Developed for Contact Analysis of Four-point Contact Ball Bearings

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1． Abstract

When designing machinery, it is necessary to determine the bearing's support stiffness, load capacity and service life in advance; therefore, it is extremely important to be able to theoretically analyze the contact problems of rolling bearings (such as how to calculate support stiffness, contact pressure, and shear stress). Among these, four-point contact ball bearings are actively used in machinery where width is limited because they can withstand radial, axial, and bending moment loads within the same space as other single-row bearings. Although four-point contact ball bearings are in practical use, it is still not easy to accurately determine their support stiffness, bending moment capacity, contact pressure distribution and shear stress under the contact surface. But a method for calculating their service life has not yet been established so far.

To analyze bearing contact problems, the author spent more than 20 years developing a numerical analysis method using the three-dimensional finite element method (3D-FEM) to analyze bearing contact problems, as well as dedicated software. A key feature of this software is that it enables the analysis of bearing contact problems on a standard personal computer. Unlike software such as Abaqus, there is no need to create a model for FEM analysis; simply inputting the bearing dimensions and the radial, axial and bending loads applied to the bearing allows the software to automatically analyze the internal loads, contact pressure, shear stress and support stiffness of the bearing.

Once the internal load distribution within the bearing is known, it becomes possible to calculate the thickness of the oil film between the balls and the raceways of the inner and outer rings. For details on the analytical theory, please refer to Reference [1-2].

2． Bearing Structure and Dimensions

Figure 1 shows the structural dimensions of the four-point contact bearing under study. The ball diameter is 11.9062 mm, and there are eight balls. As shown in Figure 1, contact analysis was performed using three balls (No. 1, No. 2, and No. 3).

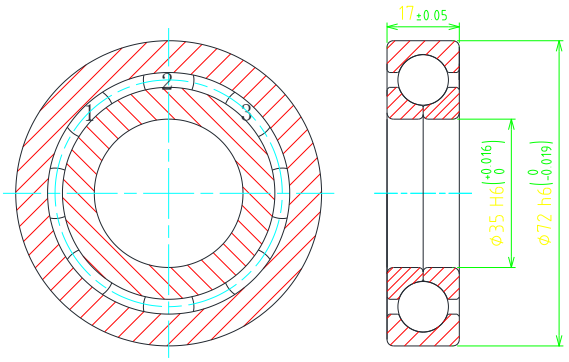

Figure 1: Structural dimensions of the four-point contact bearing

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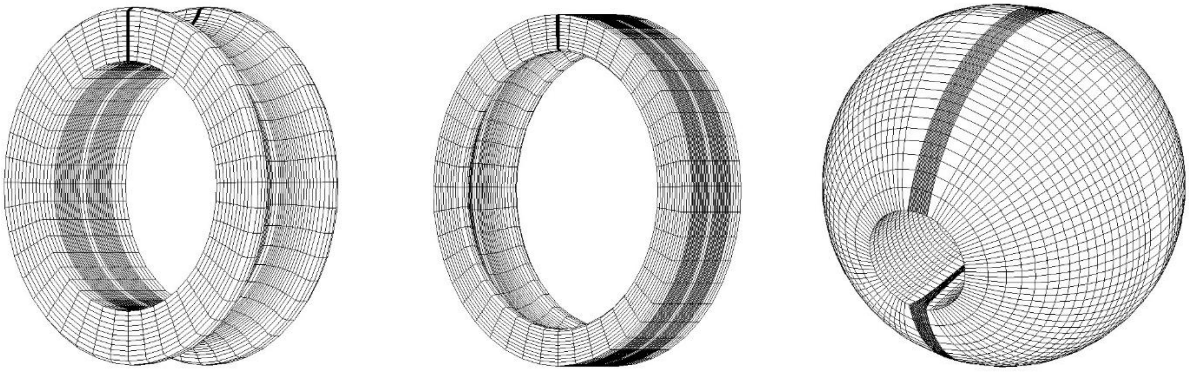
3． Contact Analysis of Four-Point Contact Bearings

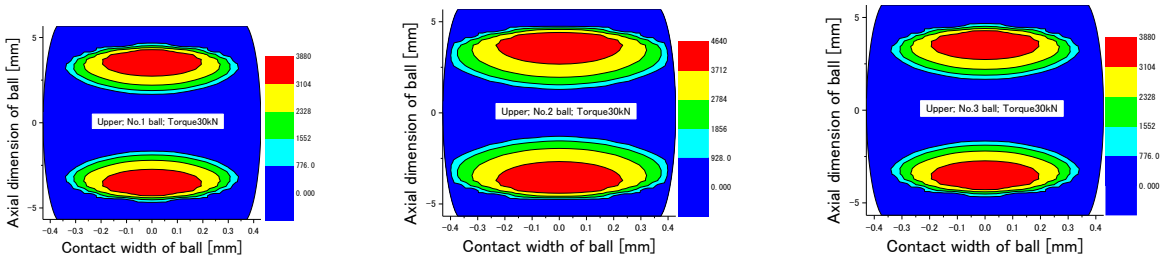
We treat the contact problem of a four-point contact bearing as an elastic body contact problem. Figure 2 shows the element mesh for the inner ring, outer ring and balls.



(a) FEM model of inner ring　　(b) FEM model of outer ring　　(c) FEM model of ball

Figure 2: FEM element meshing pattern for contact analysis

When performing a radial contact analysis on the bearing shown in Figure 1, taking into account the downward radial load applied from the top of the bearing, the resulting contact pressure distributions on the upper and lower surfaces of the balls are shown in Figures 3 and 4, respectively. Figures 3(a) to (c) are contour plots of the contact pressure distributions on the upper surfaces of balls 1, 2 and 3, respectively, as shown in Figure 1. Figures 4(a) to (c) are contour plots of the contact pressure distributions on the lower surfaces of balls 1, 2, and 3 respectively, as shown in Figure 1. As shown in the figures, the pressure distributions for balls 1 and 3 are identical, and the analysis revealed that the maximum contact pressure occurs on the surface of ball 2. It can also be seen that the contact pressure on the lower surface of the balls is greater than that on the upper surface.



(a) No.1 ball　　(b) No.2 ball　　(c) No.3 ball

Figure 3: Contact pressure distribution (MPa) on the upper surface of the balls

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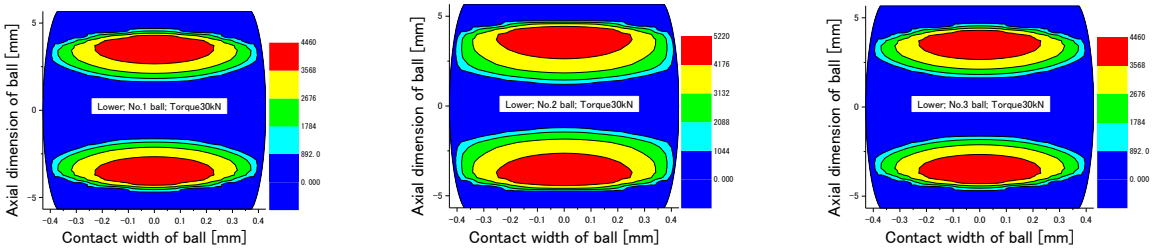

(a) No.1 ball　(b) No.2 ball　(c) No.3 ball

Figure 4: Contact pressure distribution (MPa) on the lower surface of the balls

References：

(1) Shuting Li, “Strength analysis of the roller bearing with a crowning and misalignment error”, **Engineering Failure Analysis**, Vol. 123, 2021, pp.1-15

(2) Shuting Li, “A mathematical model and numeric method for contact analysis of rolling bearings”, **Mechanism and Machine Theory**, Vol. 119, 2018, pp.61-73