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FEM Developed for Contact Analysis of Cross-Roller Bearings

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1． Abstract

When designing machinery, it is necessary to determine the support stiffness, load capacity, and service life of bearings in advance; therefore, it is extremely important to be able to theoretically analyze the contact problem of rolling bearings (such as how to calculate support stiffness, contact pressure and shear stress). Among these, cross-roller bearings are 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 cross-roller bearings are in practical use, it is still not possible to accurately determine their support stiffness, bending moment capacity, contact pressure distribution and shear stress beneath the contact surface, and a method for calculating their service life has not yet been established.

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. Furthermore, unlike Abaqus, there is no need to create a model for FEM analysis; simply inputting the bearing dimensions and the radial load, axial load, and bending moment 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 of the bearing is known, it is also possible to calculate the thickness of the oil film between the rollers and the raceways of the inner and outer rings. For details on the analytical theory, please refer to References [1–2].

2． Bearing Structure and Dimensions

Figure 1 shows the structural dimensions of the cross-roller bearing under study. The roller diameter is 11.6 mm, and there are 11 rollers on each side. As shown in Figure 1, contact analysis was performed using seven rollers (No. 1–7).

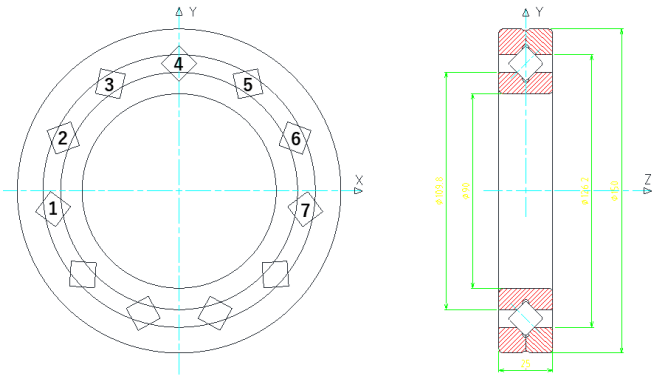

Figure 1: Structural dimensions of the crossed-roller bearing under study

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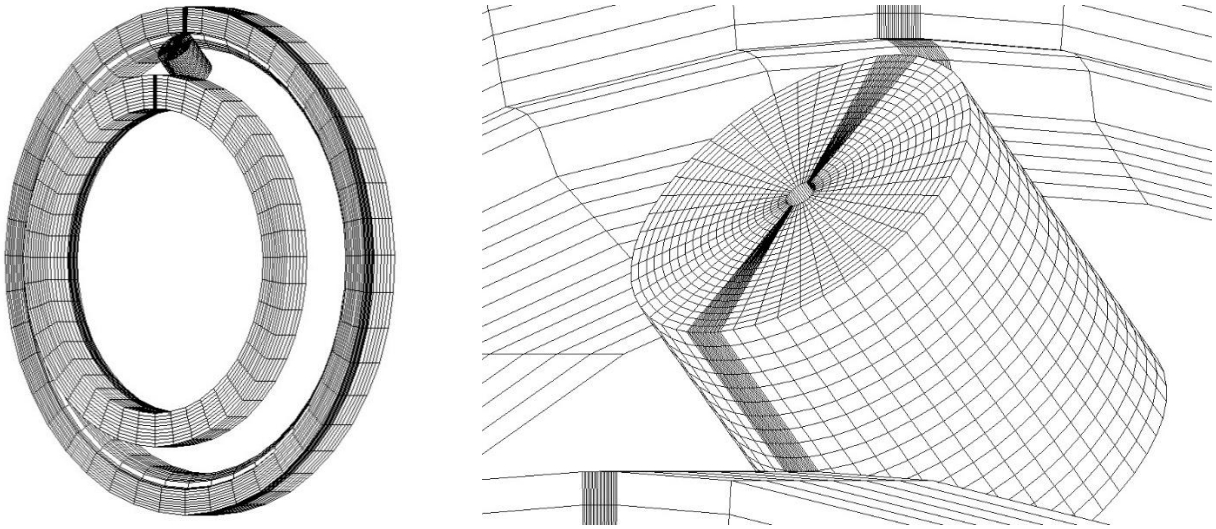
3． FEM Model for Contact Analysis

The contact analysis of a cross-roller bearing is treated as an elastic contact problem. Figure 2 shows the FEM model used for the contact analysis of the cross-roller bearing. The radial contact analysis is performed by applying a downward radial load from the top of the bearing. The axial contact analysis is performed by applying an axial load.

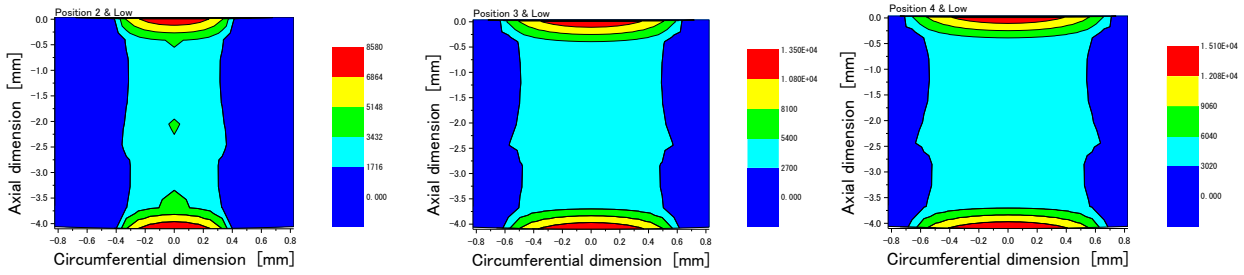


(a) FEM Model　　(b) Close-up of the contact area

Figure 2: FEM model and element meshing pattern for contact analysis

4． Radial Contact Analysis Results

Figure 3 shows the contact pressure distribution on the underside of the rollers of a cross-roller bearing, obtained through radial contact analysis. Figures 3(a) through (c) show the contact pressure distributions on the undersides (the surfaces in contact with the inner ring raceway) of rollers 2, 3, and 4, as shown in Figure 1.



(a) No.2 roller　　(b) No.3 roller　　(c) No. 4 roller

Figure 3: Surface pressure distribution (MPa) at the contact area on the underside of the roller

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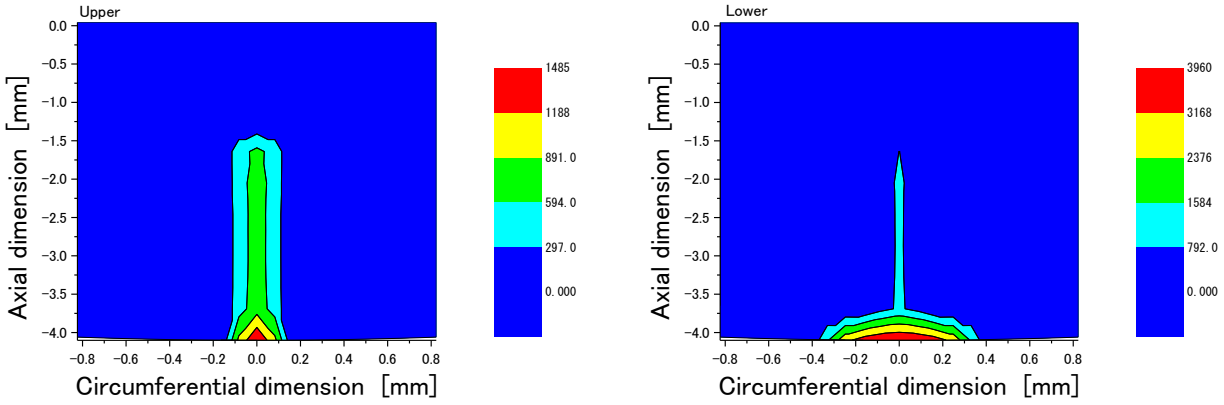
5． Axial Contact Analysis Results

Figure 4 shows the contact pressure distribution on the upper and lower surfaces of the rollers in a cross-roller bearing, as obtained from an axial contact analysis. Figures 4(a) and (b) show the contact pressure distributions on the upper and lower surfaces of the rollers, respectively.



(a) Top surface of the cylinder　　(b) Lower surface of the roller

Figure 4: Surface pressure distribution (MPa) at the contact points between the upper and lower surfaces of the roller

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