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Numerical Analysis of Contact Problem of a Ball Bearings

By Prof. Shuting Li

1． Abstract

When designing machinery, it is necessary to determine the support stiffness and service life of the selected bearings. Furthermore, if a bearing used in the machinery fails, it is also necessary to determine the contact pressure on the bearing's contact surfaces, the internal shear stress in the contacting components, and the oil film thickness at the contact surfaces. However, since the support stiffness, contact pressure, oil film thickness, and shear stress of bearings cannot be easily calculated, the author proposed a numerical analysis method using the three-dimensional finite element method (3D-FEM) to analyze bearing contact problems and developed software capable of performing these calculations. Here, we present the calculation results for the ball load distribution, contact pressure on the ball surface, shear stress beneath the ball contact surface, and support stiffness of a deep-groove ball bearing, as calculated using the developed software. For details on this research, please refer to References [1–2].

2． Deep-Groove Ball Bearings Under Study

Figure 1 shows the structural dimensions of the deep-groove ball bearing under study. The part number of this bearing is 6207; the ball diameter is 11.1125 mm (7/16 inch); the number of balls is 9; and the basic dynamic load rating is 25.7 kN.

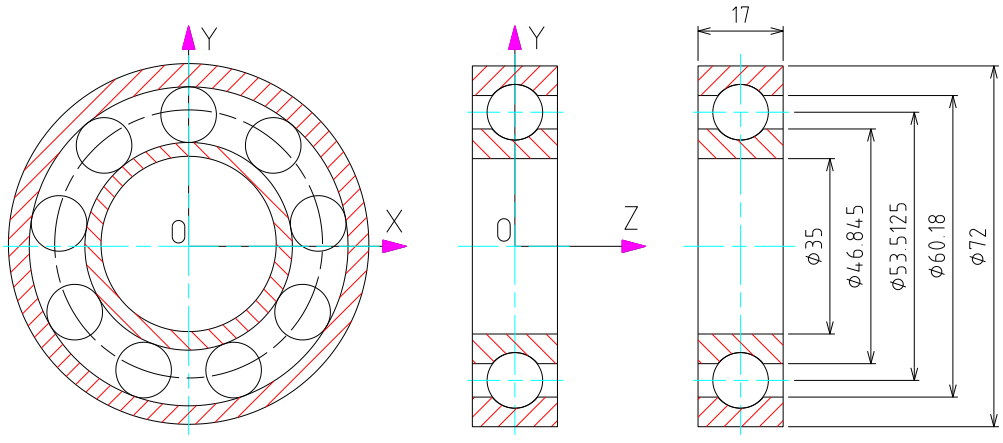


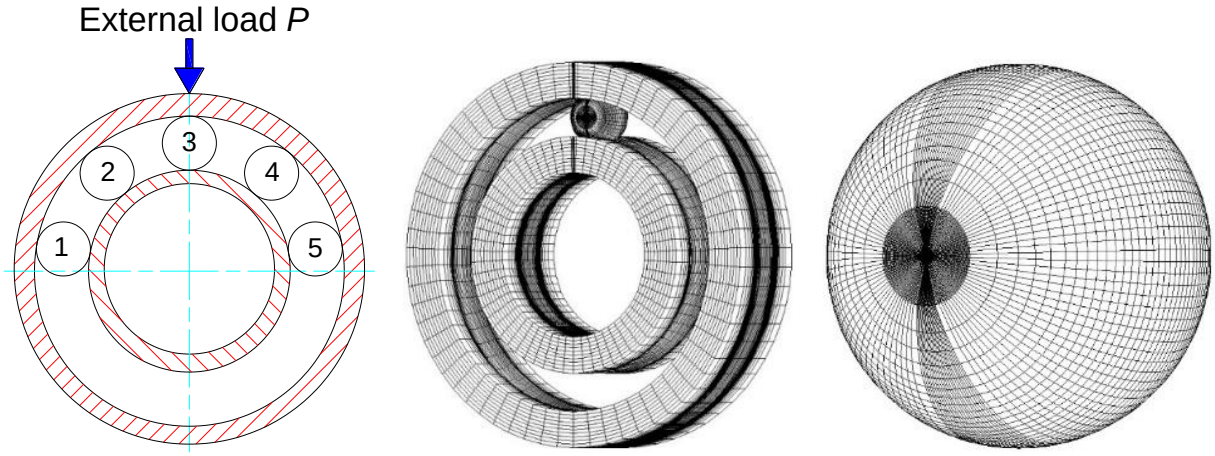
Figure 1: Structural dimensions of the deep-groove ball bearing under study

3． Contact Analysis of Deep-Groove Ball Bearings

The strength of ball bearings is treated as a contact problem involving elastic bodies. To solve this contact problem, the author proposed a specialized three-dimensional finite element method and developed the corresponding software. For details on this research, please refer to References [1–2]. Here,

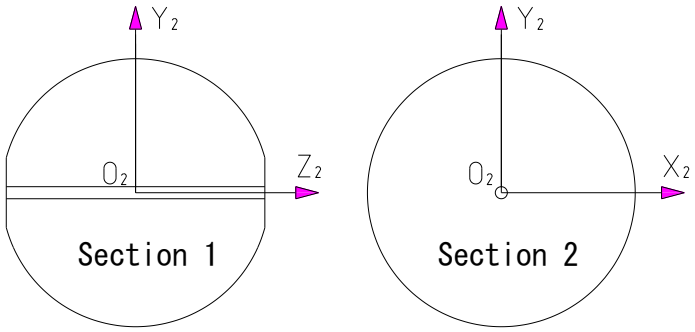
only the analysis results are presented below. The analysis was performed using a basic dynamic load rating of 25.7 kN.

Figure 2(a) shows the mechanical model of the deep-groove ball bearing used to analyze the contact problem under study. Figure 2(b) shows the element mesh-dividing of this bearing using the three-dimensional finite element method (3D-FEM model of the ball bearing), and Figure 2(c) shows an enlarged view of the element mesh for the ball alone. Figure 3 defines the two cross-sections (Cross-section 1 and Cross-section 2) used to output stress. In Figure 3, the Y_2 axis represents the radial direction of the bearing, and the Z_2 axis represents the direction of the bearing's rotational axis.



(a) Contact Analysis Model　　(b) FEM Element Mesh　　(c) Enlarged View of the Ball

Figure 2: Model for contact analysis and FEM element mesh



(a) Section 1　　(b) Section 2

Figure 3: Definitions of cross-sections 1 and 2

Figure 4 shows the load distribution on the ball and the load sharing ratio obtained from the FEM analysis. Figures 5(a) and 5(b) are contour plots of the contact pressure distributed across the contact area on the ball's surface, respectively; the ball numbers correspond to those shown in Figure 2(a).

Figure 6 shows the relationship between the radial deformation of the bearing or its support stiffness and the radial load.

Figure 7 is a contour plot of the vertical stress σ_Y and the shear stress τ_{zx}in cross-section 1.

Figure 8 is a contour plot of the vertical stress σ_Y and the shear stress τ_{xy} in cross-section 2.

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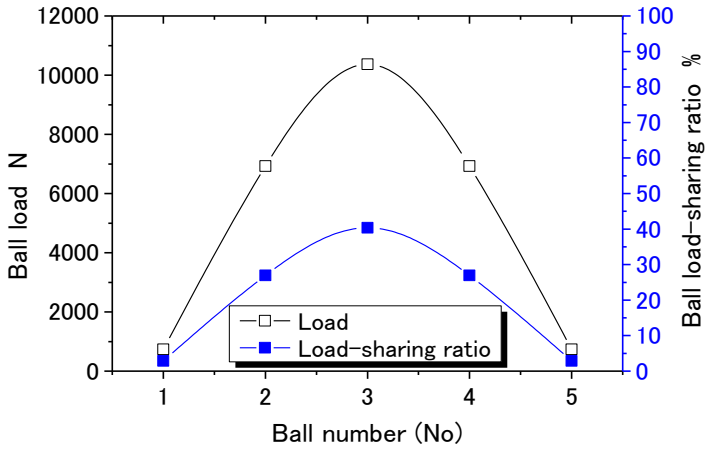
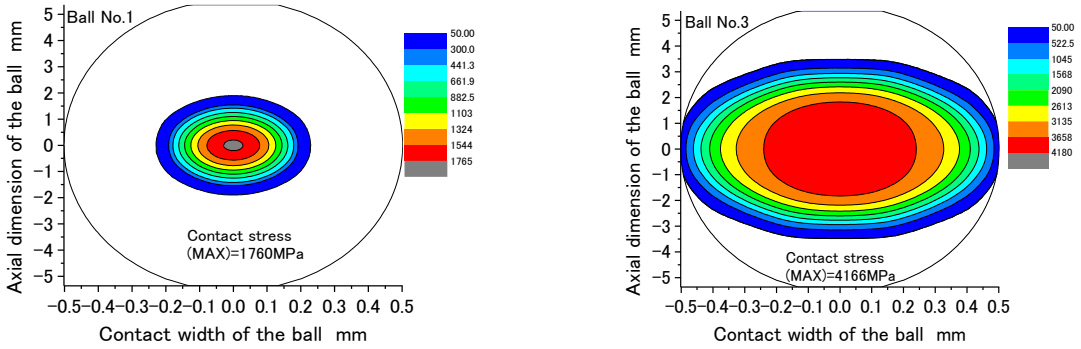


Figure 4: Load distribution on the ball and load sharing ratios



(a)　Ball No. 1　　(b)　Ball No. 3

Figure 5: Contour lot of the contact pressure distribution on the ball surface
(see Figure 2(a) for ball numbers)

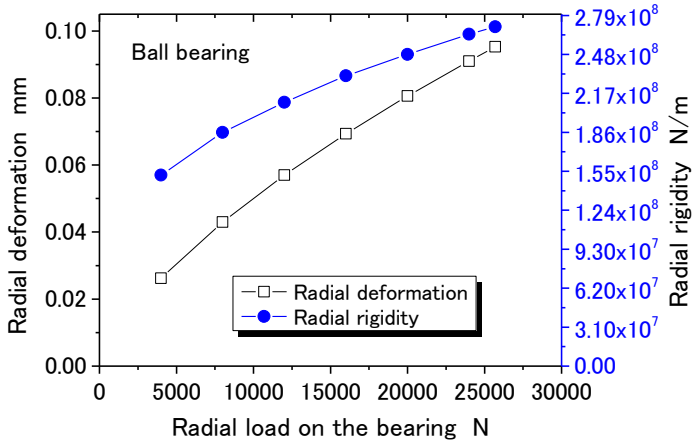


Figure 6: Bearing deformation and support stiffness

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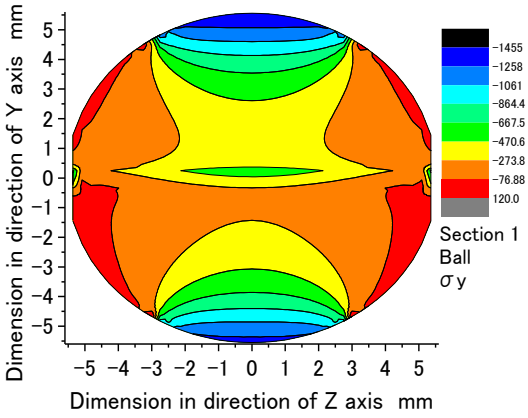
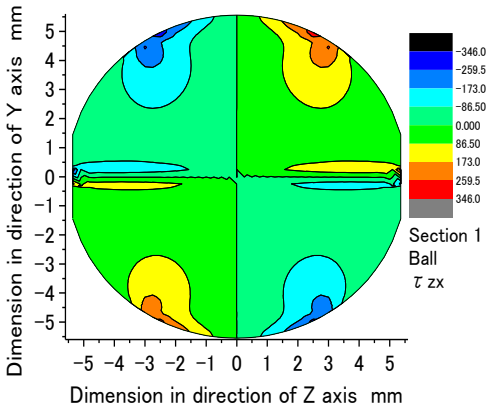
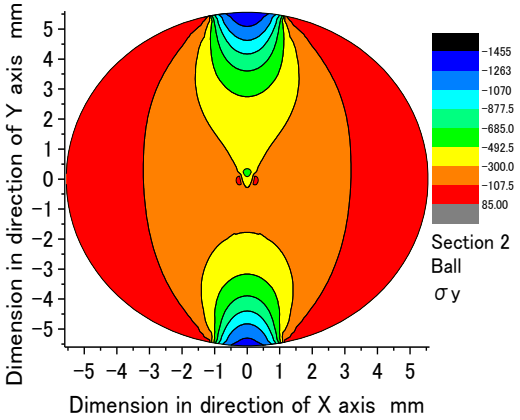


(a) The normal stress σ_y

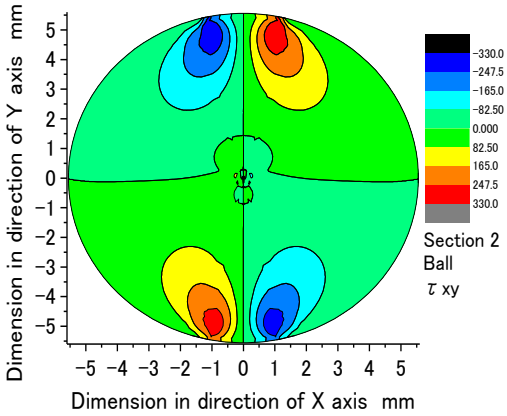


(b) The shear stress τ_{zx}

Figure 7: Stress distribution on cross-section 1 (see Figure 3 for cross-section 1)



(a) The normal stress σ_y



(b) The shear stress τ_{xy}

Figure 8: Stress distribution on cross-section 2 (see Figure 3 for cross-section 2)

4. Validation of Analysis Results

To verify the validity of the analysis results, the radial deformation and contact surface pressure of the deep-groove ball bearing shown in Figure 1 were analyzed under the same conditions using Abaqus software and the Hertz equation, and the results had been compared each other. Figures 9 and 10 show comparisons of the radial deformation and contact surface pressure of the bearing, respectively. In Figures 9 and 10, “FEM” represents the results obtained in this study, “Abaqus” represents the results obtained using the Abaqus, and “Hertz” represents the results obtained using the Hertz equation. Figures 9 and 10 show that the results obtained in this study are in good agreement with those obtained using Abaqus.

A key feature of the software developed in this study 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 entering the bearing dimensions and radial load into the software allows it

to perform the entire analysis automatically.

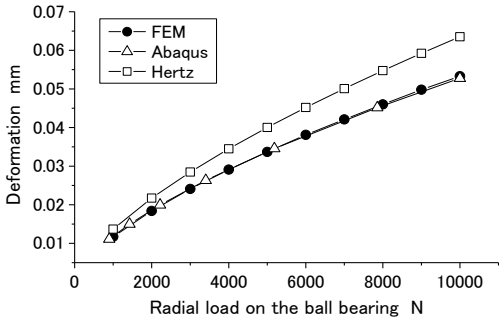


Figure 9: Comparison of radial deformation

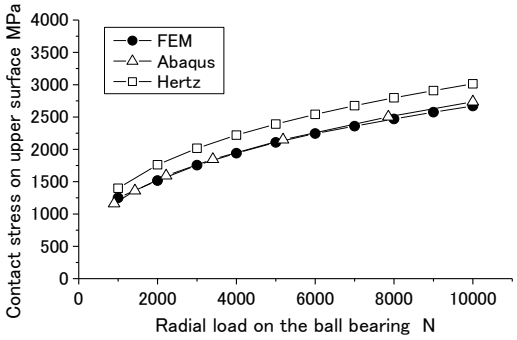


Figure 10: Comparison of maximum contact pressure

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