文責：島根大学総合理工学部機械設計研究室教授　李　樹庭
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Contact Analysis and Stress Calculations of Cylindrical Roller 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 load distribution on the rollers, the contact pressure on the roller surfaces, and the shear stress beneath the contact surfaces of a cylindrical roller bearing analyzed using the developed software; please refer to References [1–2] for details on this research.

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 software such as Abaqus, there is no need to create a model for FEM analysis; simply enter the bearing dimensions and radial load into the software, and it will perform the entire analysis automatically. Additionally, the influence of the roller's crowning can be easily taken into account.

2． Structure and Dimensions of the Cylindrical Roller Bearings Under Study

Figure 1 shows the structural dimensions of the deep-groove ball bearing under study. The model number of this bearing is NU207E; the ball diameter is 10 mm; the number of balls is 11; and the basic dynamic load rating is 50.5 kN.

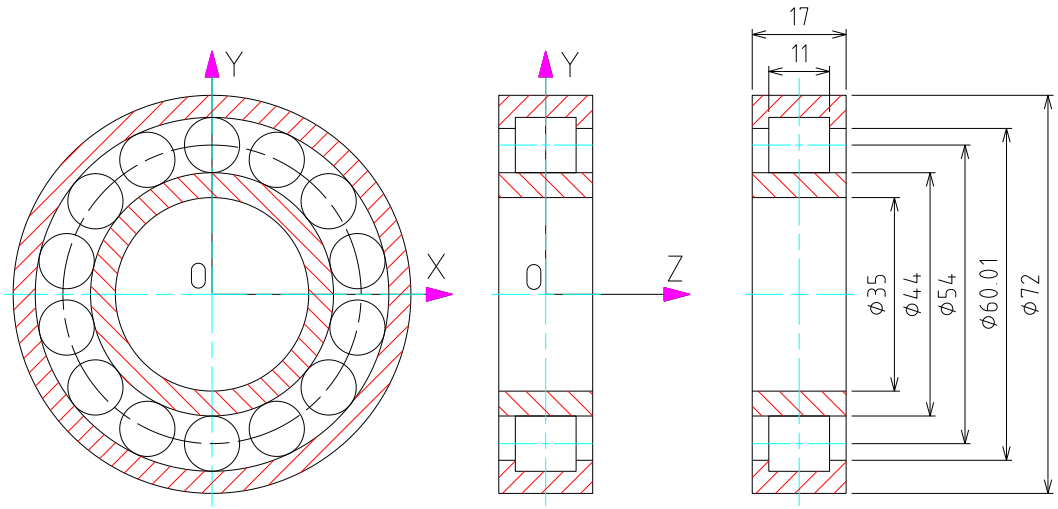

Figure 1: Structural dimensions of the cylindrical roller bearing under study

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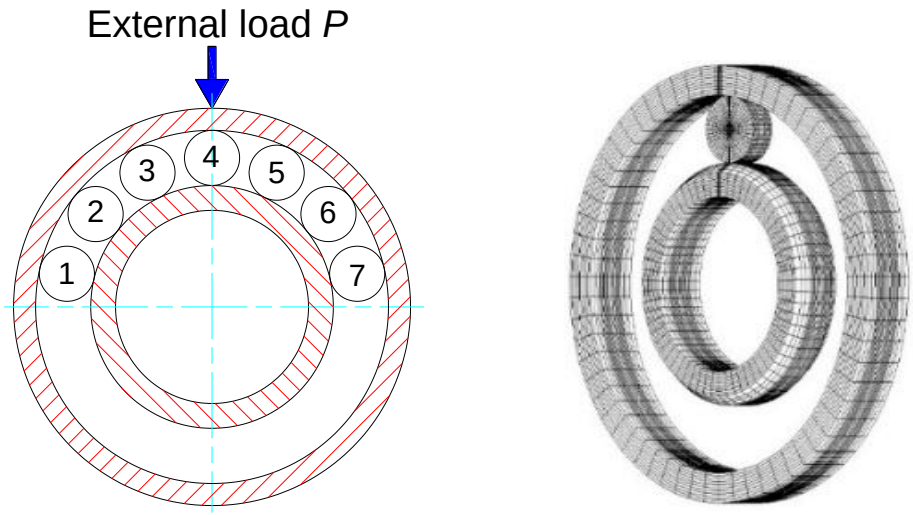
3． Contact Analysis of Cylindrical Roller Bearings

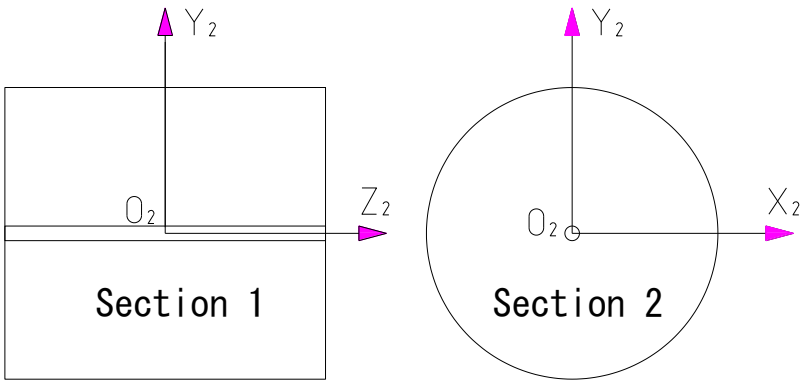
The strength of cylindrical roller bearings is treated as an elastic contact problem. To solve this contact problem, the author proposed a dedicated three-dimensional finite element method and developed the corresponding software. For details, please refer to References (1–2). Here, only the analysis results are presented below. The analysis was performed using a basic dynamic rating of 50.5 kN.

Figure 2(a) shows the mechanical model used for the contact analysis of the cylindrical roller bearing. Figure 2(b) shows the element mesh-dividing (3D-FEM model) of the cylindrical roller bearing. Figure 3 shows the definition of cross-sections 1 and 2 for stress output. 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-dividing

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 (o_2-x_2 y_2 z_2)

Figure 4 shows the load distribution and load sharing ratio on the rollers of a cylindrical roller bearing, as obtained from FEM analysis.

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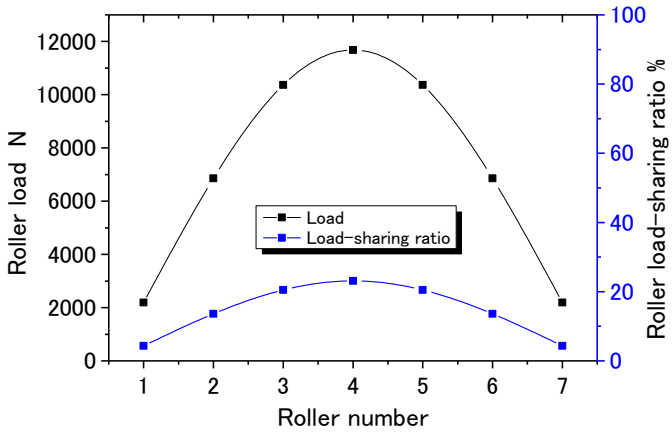
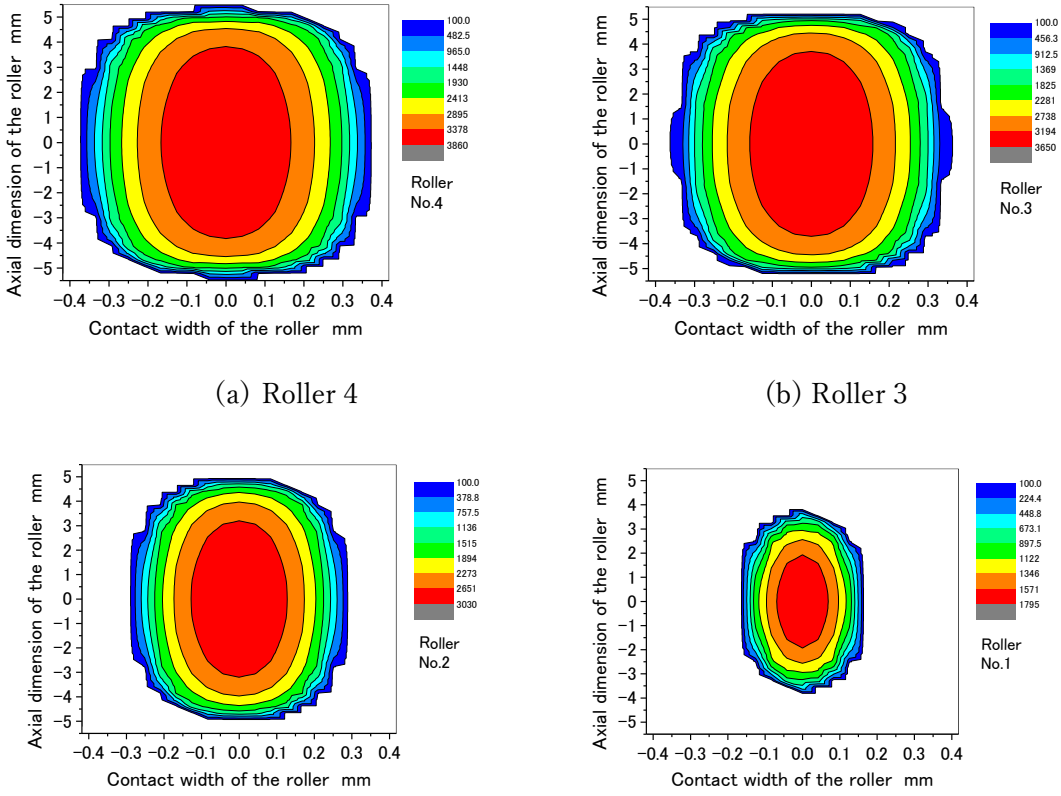


Figure 4: Load distribution on the roller and load sharing ratios

Figures 5(a), 5(b), 5(c), and 5(d) are contour plots of the contact pressure distributed across the contact area on the roller surface, respectively. The roller numbers are shown in Figure 2(a).



(a) Roller 4　(b) Roller 3

(c) Roller 2　(d) Roller 1

Figure 5: Contact pressure on the roller surface (MPa) (normal crowning)

Figure 6 shows a contour plot of the vertical stress $\sigma_Y$and the shear stress τ_{yz} in cross-section 1. Figure 7 shows a contour plot of the vertical stress σ_Y and the shear stress τ_{xy} in cross-section 2.

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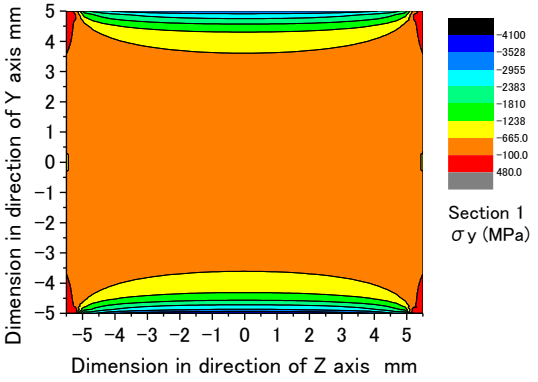
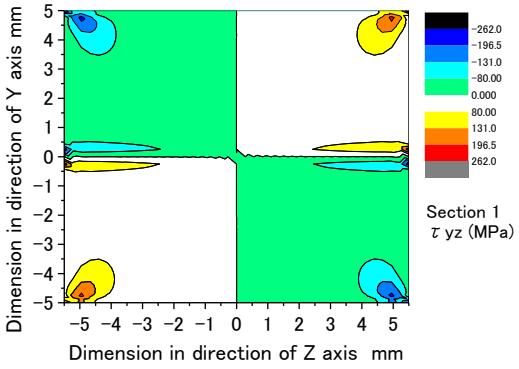
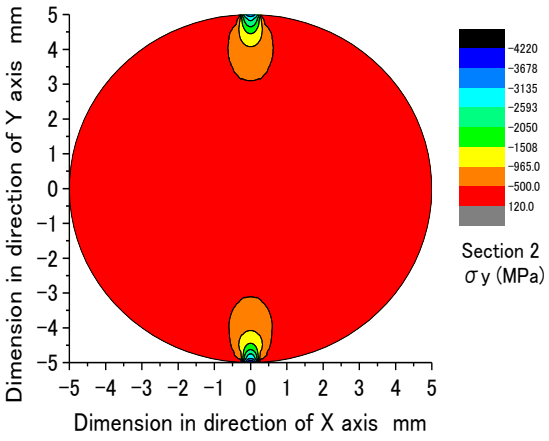


(a) The normal stress σ_y

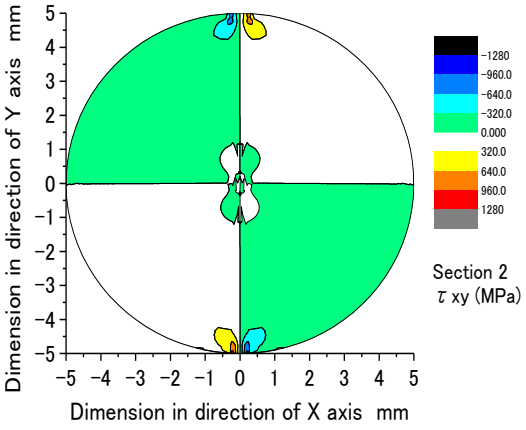


(b) The shear stress τ_{yz}

Figure 6: 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 7: Stress distribution on cross-section 2 (see Figure 3 for cross-section 2)

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