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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FEM Developed for Contact Analysis of Tapered Roller Bearings

By Prof. Shuting Li

1． Abstract

When designing machinery, it is necessary to determine in advance 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 internal contact pressure, shear stress, and oil film thickness of the selected bearing. However, since the support stiffness, contact pressure, oil film thickness, and shear stress of bearings cannot be easily calculated, the author developed a numerical analysis method using the three-dimensional, finite element method (3D-FEM) to analyze bearing contact problems, and also developed software based on many years of research. Here, I 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 tapered roller bearing analyzed using the developed software; please refer to References [1–2] for details on the analysis method.

A key feature of the developed 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 enter the bearing dimensions and external loads into the software, and the contact analysis is performed entirely automatically. The influence of the roller's crowning can be easily accounted for also.

2． Structure and Dimensions of Tapered Roller Bearings

Figure 1 shows the structural dimensions of the tapered roller bearing under study. The bearing contains 16 rollers, and as shown in Figure 1, the positions of the rollers used in the contact analysis are numbered 1 through 7.

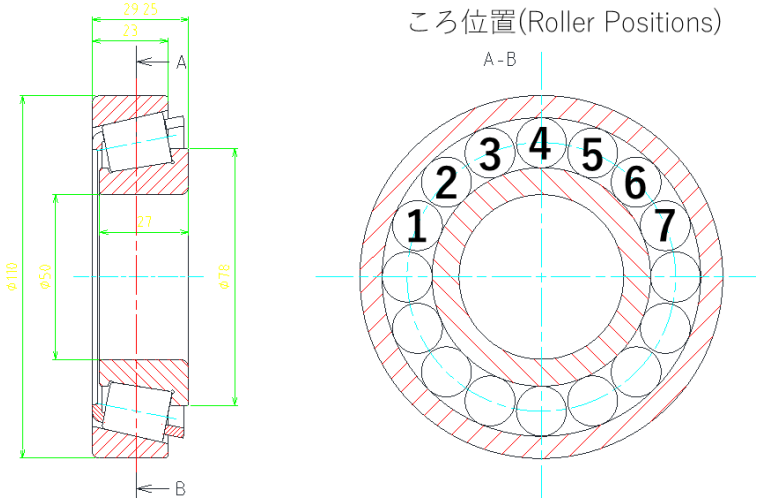

Figure 1: Structural dimensions of a tapered roller bearing

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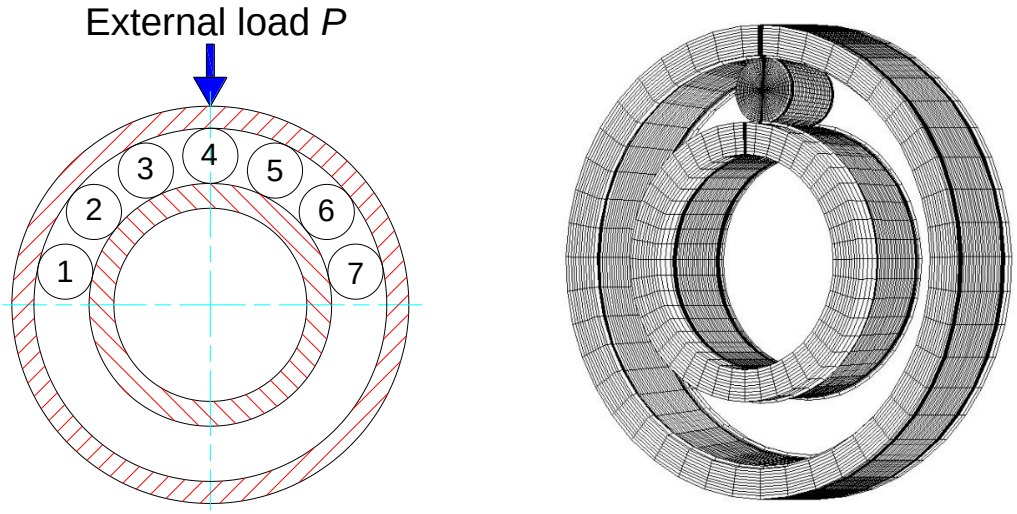
3． Radial Contact Analysis

We treat the contact problem of a tapered roller bearing as an elastic body contact problem. Figure 2(a) shows the mechanical model used to perform a radial contact analysis of the tapered roller bearing. Figure 2(b) shows a mesh-dividing of the tapered roller bearing (3D-FEM model). Figure 3 shows an enlarged view of the mesh in the contact region.



(a) Contact analysis model　　(b) FEM element meshing

Figure 2: Mechanical model and FEM element mesh for contact analysis

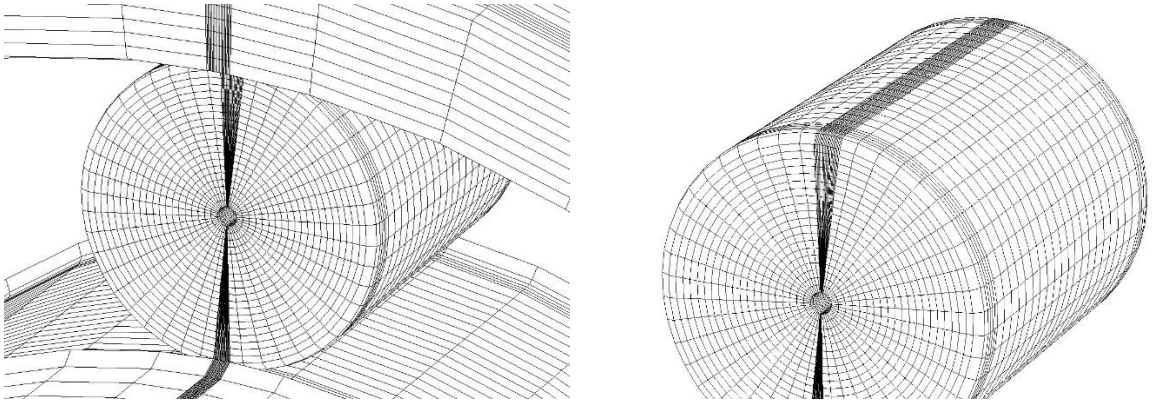


Figure 3: Enlarged view of the element subdivision at the contact point

As shown in Figure 2(a), a downward radial load is applied to the top of the tapered roller bearing to perform a radial contact analysis. Figures 4 and 5 show the contact pressure distributions on the upper and lower surfaces of each roller, respectively, obtained from this analysis. Figures 4(a) through (d) are contour plots of the contact pressure distributed across the contact areas on the upper surfaces of tapered rollers 1 through 4, as shown in Figure 2(a). Figures 5(a) through (d) are contour plots of the contact pressure distributed across the contact areas on the lower surfaces of tapered rollers 1 through 4.

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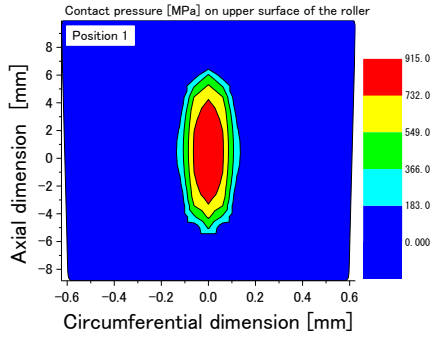
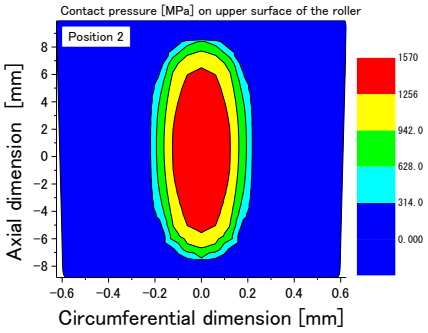
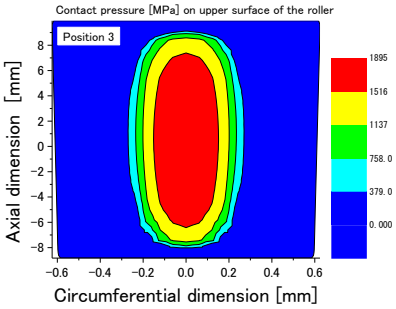


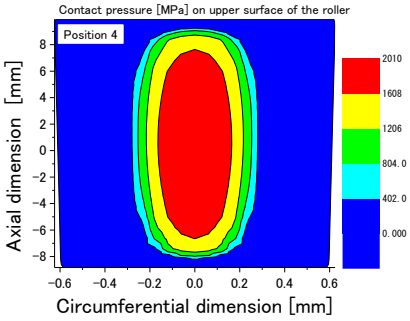
(a) Roller No.1



(b) Roller No.2

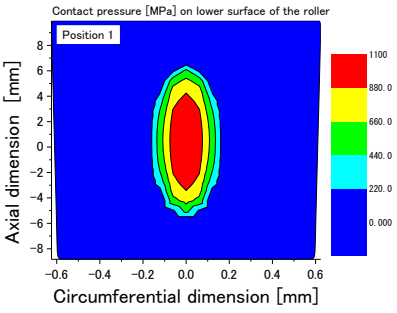


(c) Roller No.3

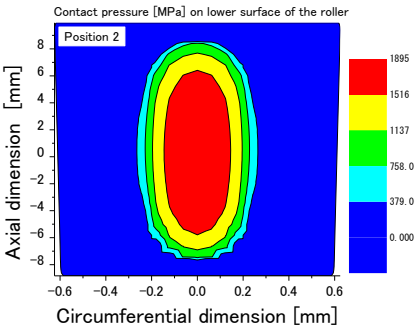


(d) Roller No.4

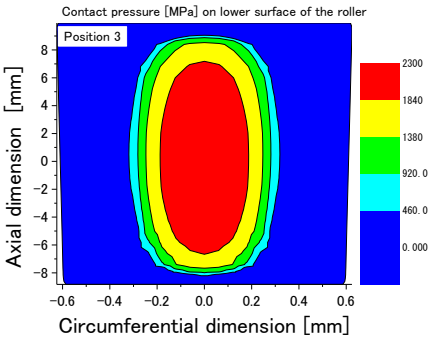
Figure 4: Contact pressure on the upper surface of a tapered roller (MPa)



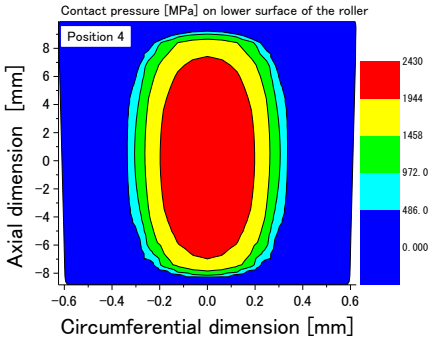
(b) Roller No.1



(b) Roller No.2



(c) Roller No.1



(b) Roller No.2

Figure 5: Contact pressure (MPa) on the lower surface of a tapered roller (MPa)

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4． Axial Contact Analysis of Tapered Roller Bearings

Figure 6 shows the mechanical model used to perform an axial contact analysis of a tapered roller bearing. As shown in the figure, the contact analysis was performed by applying an axial load from left to right to the left side of the bearing. The element meshing pattern used for the analysis was the same as that shown in Figure 3.

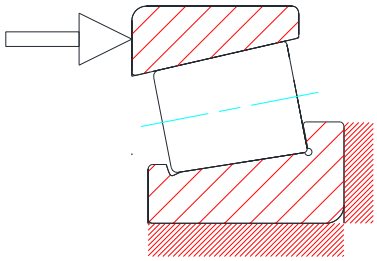
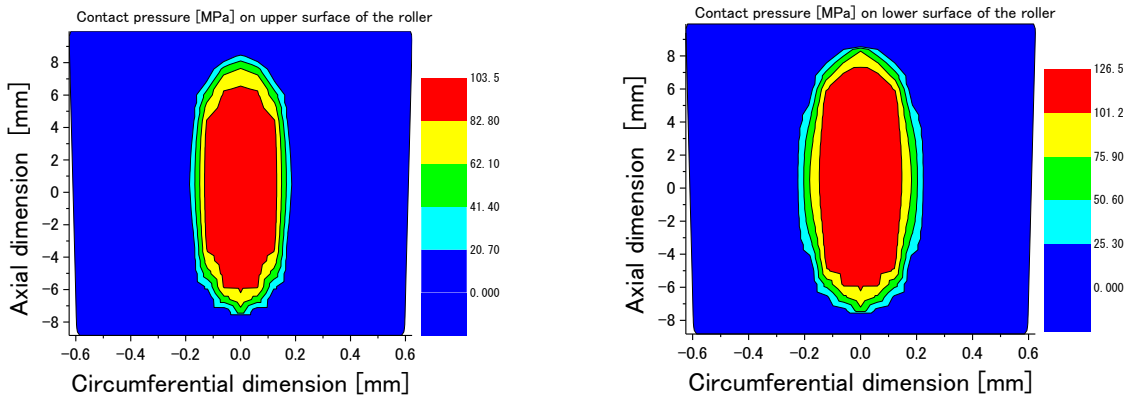


Figure 6: Mechanical model for axial contact analysis of tapered roller bearings

Figures 7(a) and (b) show the surface pressure distributions on the upper and lower contact surfaces of the tapered roller, respectively, as obtained from this analysis. Since this contact analysis assumed that the contact surface pressure is the same on each roller surface, it is sufficient to use one roller in the axial contact analysis.



(a) Contact pressure on upper surface of roller　(b) Contact pressure on lower surface of roller

Figure 7: Distribution of contact pressure on the roller surface

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