

Modal Analysis of Rolling Element Bearing by Ansys

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Abstract — Rolling element bearings are important mechanical components used in sugar industry machinery because of their capability to support heavy radial and axial loads with minimum friction. Continuous operation of sugar mill equipment under severe working conditions leads to vibration, wear, and premature bearing failure. In this research work, a spherical roller bearing used in sugar industry machinery is analyzed using ANSYS-Workbench through Finite Element Method (FEM)-based modal analysis. A three-dimensional CAD model of bearing number 22218EK was developed in SolidWorks and imported into ANSYS Workbench for simulation. The bearing model was meshed and analyzed under fixed support boundary conditions. Material of 52100 Chrome Steel and Steel were assigned to different bearing components. The first six natural frequencies and corresponding mode shapes were obtained successfully. The results show that the bearing possesses stable dynamic characteristics and high structural stiffness. The study provides a theoretical basis for vibration prediction, resonance avoidance, and predictive maintenance of sugar industry machinery.

Keywords: Rolling Element Bearing, Modal Analysis, ANSYS-Workbench, Finite Element Method

I. INTRODUCTION

Bearings are essential mechanical elements widely used in rotating machinery for supporting loads and reducing friction between moving parts. Rolling element bearings are extensively applied in sugar industries such as crushing mills, conveyors, turbines, and gearboxes because of their high load carrying capacity and reliability[7]. Under continuous industrial operation, bearings are exposed to vibration, contamination, lubrication failure, and cyclic stresses, which may result in premature failure and machine downtime.

Modal analysis is an effective method for determining the natural frequencies and mode shapes of mechanical systems. Understanding the dynamic behavior of bearings helps in avoiding resonance conditions and improving machine reliability. Finite Element Analysis (FEA) has become a powerful tool for analyzing the vibration and deformation behavior of bearings under operating conditions. In this paper, a spherical roller bearing used in sugar industry machinery is modeled using SolidWorks and analyzed using ANSYS-Workbench. The vibration characteristics and natural frequencies of the bearing are investigated through modal analysis [1].

II. LITERATURE REVIEW

Kumbhar et al. presented an overview of dynamic modeling techniques for rolling element bearings and highlighted vibration analysis as an important tool for fault diagnosis. Zhang et al. developed a dynamic model considering rolling

element defects and analyzed their influence on vibration response.

Guo et al. investigated the stiffness variation and vibration response of rolling bearings with local defects. Liu et al. reviewed various dynamic analysis methods for rolling element bearings with localized and distributed faults. Yan et al. performed modal analysis of spherical plain bearings using GCr15 and TiAl-based alloy materials through ANSYS-Workbench. Their results indicated that TiAl-based alloys showed lower deformation compared to GCr15 material and improved dynamic performance. Several researchers have also applied Finite Element Analysis to sugar mill machinery for predicting stress distribution, vibration characteristics, and thermal behavior. [20]

III. ESTABLISHMENT OF THREE-DIMENSIONAL MODEL

The spherical roller bearing selected for this study is bearing number 22218EK. The three-dimensional assembly model was developed using SolidWorks software. The bearing assembly consists of an inner ring, outer ring, rolling elements, and cage.

A. Bearing Specifications

- Bearing Type: Spherical Roller Bearing
- Bearing Number: 22218EK
- Outer Diameter: 160 mm
- Inner Diameter: 90 mm
- Width: 40 mm

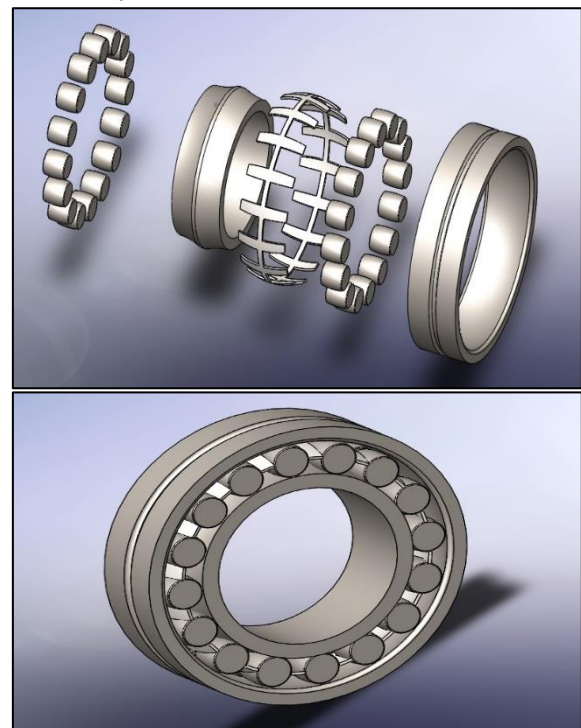


Fig. 1: 3D Assembly Model in Solid works

The CAD model was prepared according to standard bearing dimensions and exported to ANSYS-Workbench for finite element analysis.

IV. MODAL ANALYSIS OF ROLLING ELEMENT BEARING

A. Establishment of Simulation Model

The CAD model imported into ANSYS-Workbench was simplified by removing unnecessary geometric features such as chamfers and minor surface details to reduce computational time and improve analysis efficiency. The simplified geometry was directly used for modal analysis.

B. Adding Material Properties

In ANSYS-Workbench, two materials were used: 52100 Chrome Steel for inner ring, outer ring, and rolling elements. Steel for bearing cage, 52100 Chrome Steel was selected because of its high hardness, fatigue resistance, and wear resistance properties suitable for dynamic applications

Material	Young's Modulus (GPa)	Poisson Ratio	Density (kg/m ³)
52100 Chrome Steel	210	0.3	7810
Steel	200	0.3	7850

Table 1: Material Property

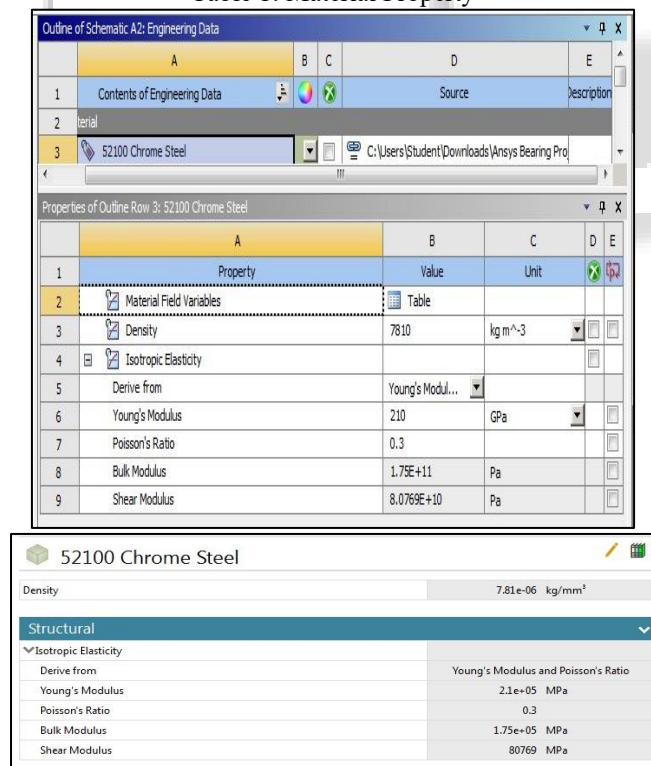


Fig. 2: Adding a New Material (52100 Chrome Steel)

C. Meshing

The bearing assembly was discretized into finite elements using tetrahedral meshing in ANSYS-Workbench

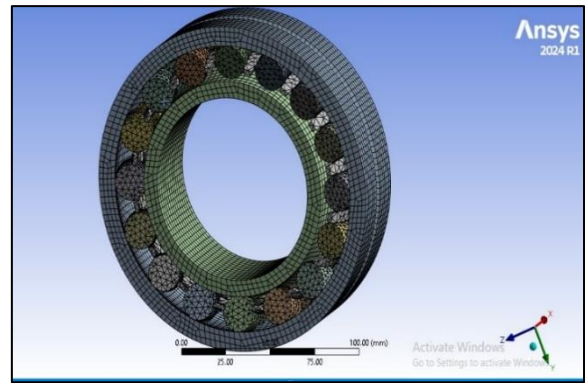


Fig. 3: Meshing

Mesh Details

Parameter	Value
Total Nodes	135,828
Total Elements	51,302
Element Size (Critical Regions)	3 mm
Element Size (Cage Region)	5 mm

Table 2: Mesh Detail.

Fine mesh refinement was applied near contact regions to improve the accuracy of modal analysis and vibration response prediction.

The mesh quality was verified and found suitable for finite element analysis.

D. Boundary Conditions

For modal analysis, the outer ring of the bearing assembly was fixed to simulate actual housing conditions. All translational and rotational degrees of freedom were constrained on the outer ring while allowing the inner ring and rolling elements to vibrate freely.

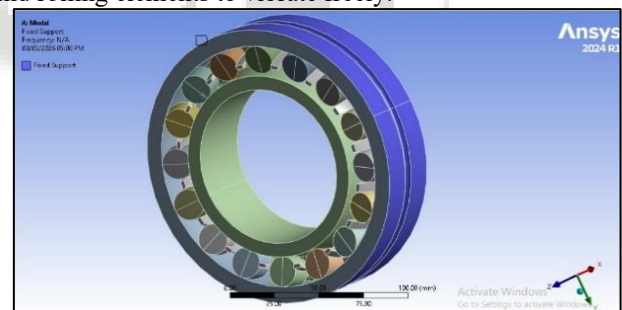


Fig. 4: Boundary Condition

E. Results

Modal analysis was carried out in ANSYS-Workbench to determine the natural frequencies and corresponding mode shapes of the rolling element bearing.

1) Natural frequencies

The first six natural frequencies obtained from modal analysis are shown below.

Mode Number	Natural Frequency (Hz)
1	8965.6
2	9720.9
3	9847.2
4	12395
5	12980
6	13096

Table 3: Natural Frequencies

The natural frequencies depend on:

- Structural stiffness
- Material properties
- Mass distribution

They are independent of external loading conditions.

Mode shapes

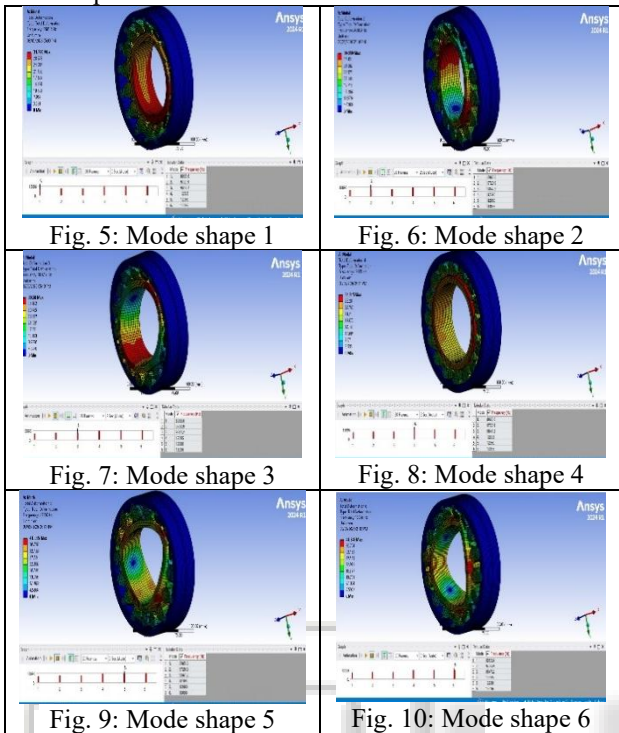


Fig. 5: Mode shape 1

Fig. 6: Mode shape 2

Fig. 7: Mode shape 3

Fig. 8: Mode shape 4

Fig. 9: Mode shape 5

Fig. 10: Mode shape 6

Mode Number	Description of Mode Shape
Mode 1	Fundamental bending mode of the bearing structure
Mode 2	Oval deformation of bearing rings
Mode 3	Orthogonal oval deformation pattern
Mode 4	Localized deformation near roller-raceway contact
Mode 5	Higher-order bending deformation
Mode 6	Complex coupled vibration of rings and rollers

Table 4: Mode shapes

The modal analysis results indicate that the bearing possesses high stiffness and stable dynamic behavior. The higher modes correspond to more complex vibration patterns and localized deformation. The fixed support condition on the outer ring effectively simulated practical operating conditions. Fine mesh refinement near contact regions improved the accuracy of frequency prediction. The obtained frequencies help identify resonance-sensitive operating conditions in sugar industry machinery and support predictive maintenance planning.

V. CONCLUSIONS

A three-dimensional CAD model of a spherical roller bearing was successfully developed using SolidWorks and analyzed using ANSYS Workbench. Finite Element Method-based modal analysis successfully determined the natural frequencies and mode shapes of the bearing assembly. The bearing exhibited stable vibration characteristics and high

structural stiffness under fixed support conditions. The study demonstrates that modal analysis is an effective tool for predicting vibration behavior and avoiding resonance conditions in sugar industry machinery. [7]

ACKNOWLEDGEMENT

The authors would like to thank the Department of Mechanical Engineering and laboratory staff for their valuable support during this research work.

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