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Impact Analysis and Formulation of Corrective Measures for Fault Reduction in Roller Bearing Elements

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Abstract*: Roller bearings are widely used in mechanical systems to reduce friction and improve the efficiency of rotating components. However, they are prone to wear and failure under high loads, improper lubrication, or misalignment. This project aims to conduct an* ***impact analysis*** *of roller bearings, specifically focusing on the failure mechanisms and corrective measures for fault reduction. The project involves selecting an* ***existing roller bearing****, analyzing its specifications, and testing it under physical conditions to identify various failure parameters. The bearing will be modeled in* ***SolidWorks*** *and subjected to* ***Finite Element Analysis (FEA)*** *using* ***ANSYS*** *to simulate the failure modes and predict performance. By comparing the experimental and simulation results, corrective measures will be proposed to improve the reliability and lifespan of the bearing. Additionally,* ***composite materials*** *will be modeled and analyzed to evaluate their potential for fault reduction. The goal is to develop a methodology for improving roller bearing performance by optimizing material selection and design modifications.*

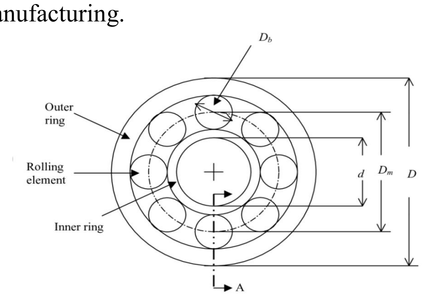
Keywords: *Roller bearings*

I. INTRODUCTION

In mechanical systems, roller bearings play a critical role by reducing friction and supporting rotational movements. However, these components are prone to faults such as pitting, spalling, and surface fatigue due to high loads, misalignment, contamination, and inadequate lubrication. Such faults can lead to vibration, noise, and reduced operational efficiency, ultimately affecting the performance and lifespan of the machinery.

Impact Analysis focuses on identifying the root causes and effects of these faults within roller bearing elements. This involves studying stress distribution, load-bearing capacity, and failure modes through both experimental and numerical methods, including finite element analysis (FEA) and vibration monitoring. Understanding these factors allows engineers to pinpoint where stress concentrations occur, leading to a better grasp of failure mechanisms.

Corrective Measures include enhancing bearing material properties, implementing improved lubrication methods, and optimizing design parameters. Additionally, predictive maintenance practices, like regular vibration analysis and oil debris monitoring, help detect early signs of wear and prevent unexpected failures. This proactive approach aids in reducing fault occurrences, minimizing downtime, and improving reliability in various applications across industries such as automotive, aerospace, and manufacturing.



Rolling Element Bearing macro-geometry.

FIGURE 1. Bearing Geometry

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Bearings encounter various loading conditions

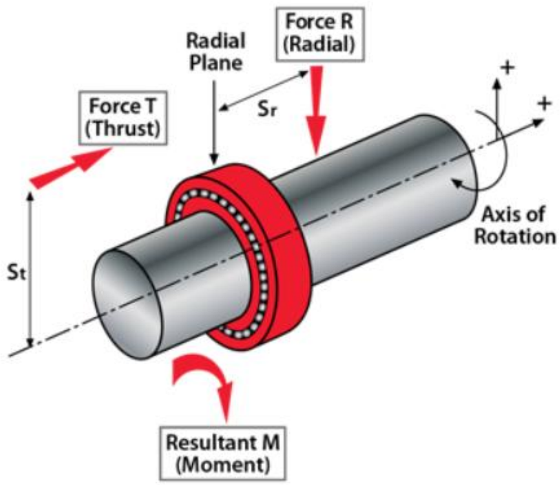

FIGURE 2. Loading on Bearing

Problem Statement

Roller bearings are critical in mechanical systems, but their failure can cause downtime and high repair costs. Common failure modes include wear from friction, fatigue due to cyclic loading, and overheating from poor heat dissipation. Misalignment and improper lubrication further accelerate wear and failure. This project aims to analyze these factors through testing and simulation and propose corrective measures to improve bearing reliability.

Objectives

- **Failure Mode Analysis**: To analyse the failure modes of an existing roller bearing by testing it under various operational conditions.
- **Finite Element Modelling**: To create a 3D model of the roller bearing in SolidWorks and perform **FEA simulations** in ANSYS to predict stress, strain, and failure parameters.
- **Comparison of Experimental and Numerical Results**: To compare the results of physical testing with the simulation outcomes to identify discrepancies and improve the model accuracy.
- **Material Analysis**: To evaluate the impact of different composite materials on bearing performance by modelling and analysing bearings made of alternative materials (e.g., carbon fiber composites, polymers).
- **Optimization and Recommendations**: To propose design and material changes based on simulation results and material performance to reduce failure rates and extend bearing lifespan.

II. LITERATURE REVIEW

1] Ali et al. (2020), "Wear and fatigue analysis of roller bearings under dynamic loading conditions," *IEEE Transactions on Industrial Applications*.
Investigates the fatigue failure in roller bearings under dynamic loads, highlighting the importance of material selection and lubrication in preventing wear.
2] Li et al. (2019), "Failure analysis and life prediction of roller bearings under varying loads," *Journal of Mechanical Engineering Science*.
Analyses the impact of varying loads and operating conditions on roller bearing failure, using a combination of experimental and numerical methods for life prediction.
3] Zhao et al. (2021), "Finite element analysis of stress distribution in roller bearings," *Computers and Structures*.

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This study uses FEA to analyse the stress distribution and failure mechanisms in roller bearings, providing insights into the key factors contributing to bearing failure.

4] Sharma et al. (2018), "Wear mechanisms in roller bearings and their correlation with material properties," *Tribology International*.

Discusses the wear mechanisms such as abrasive, adhesive, and fatigue wear in roller bearings, and how they correlate with material properties and operating conditions.

5] Patel et al. (2020), "Fatigue failure analysis of roller bearings using ANSYS," *Mechanical Systems and Signal Processing*.

A study using ANSYS for simulating fatigue failure in roller bearings, identifying high-stress regions that lead to premature failure and suggesting corrective measures.

6] Bose et al. (2022), "Comparative analysis of materials for roller bearings: Steel vs. composite materials," *Wear*.

Compares traditional steel roller bearings with composite materials such as carbon fiber, analysing their wear and fatigue resistance.

7] Kumar et al. (2019), "Numerical simulation and experimental validation of roller bearing behavior under high loads," *Journal of Tribology*.

This paper provides experimental validation of numerical simulations and the behaviour of roller bearings under high load conditions, revealing key design improvements.

8] Jain et al. (2020), "Optimization of roller bearing performance using material science," *Materials Science and Engineering*.

Discusses the potential of composite materials like polymers and ceramics in reducing bearing failures by improving wear resistance and lowering operational temperature.

9] Yadav et al. (2021), "Analysis of lubricant effects on roller bearing failure modes," *Tribology Letters*.

Investigates the role of lubrication in preventing bearing failures, with a focus on the types of lubricants that optimize roller bearing performance.

10] Singh et al. (2022), "Impact of design modifications on the failure rate of roller bearings," *International Journal of Mechanical Sciences*.

Focuses on design modifications (geometry and material changes) to reduce the failure rate of roller bearings, providing a roadmap for optimizing bearing performance.

III. METHODOLOGY

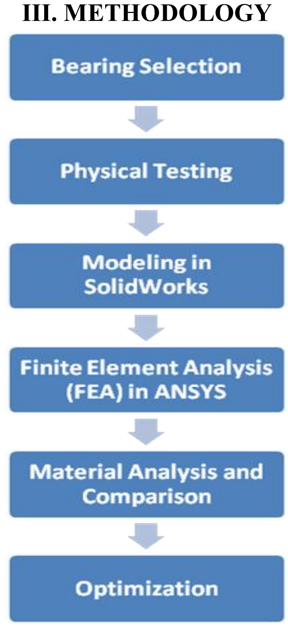

FIGURE 3. Methodology

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IV. DESIGN

Selected bearing is
Automobile front wheel tapered roller bearing
Timken Tapered Roller Bearing
Cad model

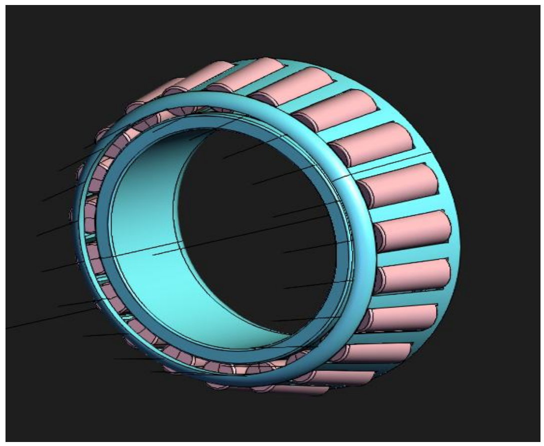

FIGURE 4. Tapered Roller Bearing

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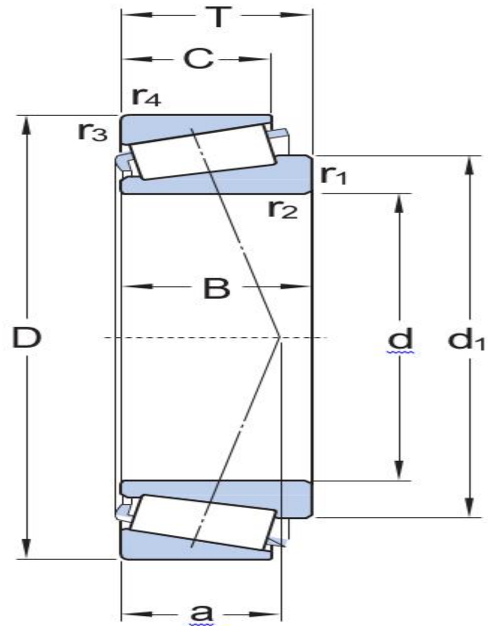


FIGURE 5. Parameters of bearing

Dimensions

Table 1. Bearing Dimension

Bore diameter	25mm
Outside diameter	52mm
Width, total	16.25mm
Width, innerring	15mm
Width, outerring	13mm
Contact angle	14.036 °

Properties

Table 2. Bearing Properties

Bearing part	**Complete bearing**
Number of rows	1
Locating feature, bearing outer ring	None
Bore type	Cylindrical
Cage	Sheet metal
Arrangement of contact angle (double-row bearing)	Not applicable
Matched arrangement	No
Coating	Without
Sealing	Without
Lubricant	None
Relubrication feature	Without
Unit system	Metric

V. ANALYSIS

Meshing of element

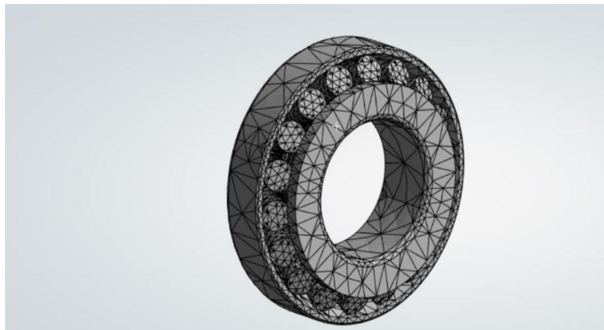


FIGURE 6. Bearing Meshing in Ansys

Material Selection

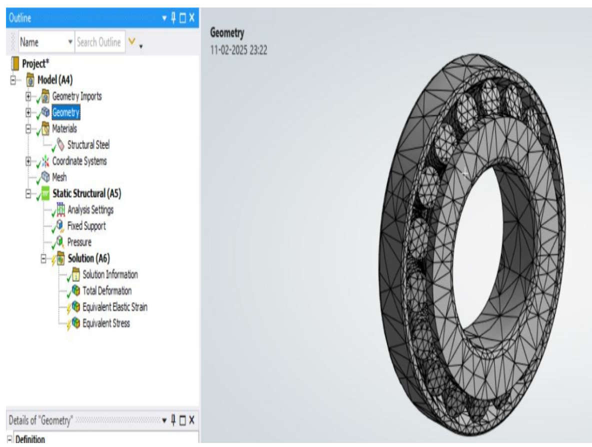
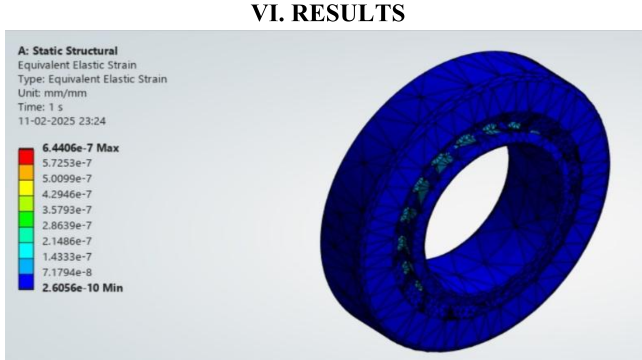


FIGURE 7. Material Selection

VI. RESULTS



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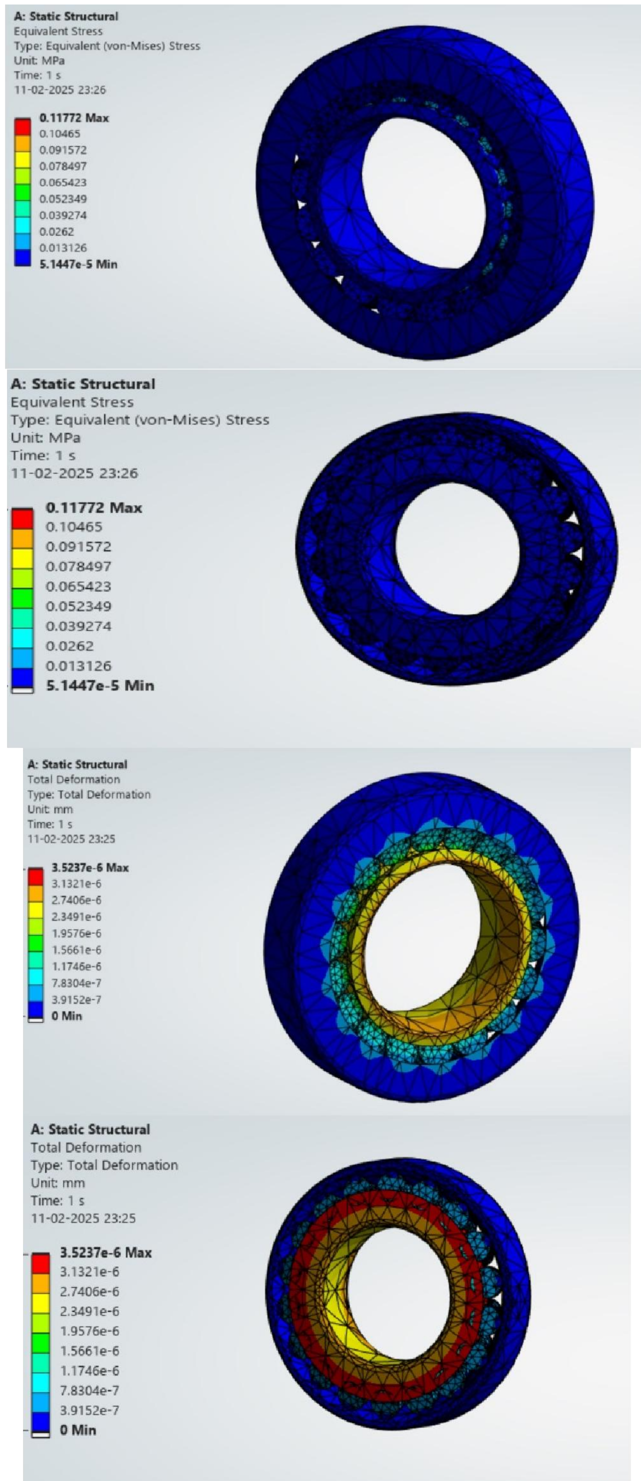

FIGURE 8. Analysis Result

VII. INTERPRETITION OF RESULTS

Equivalent Elastic Strain

Maximum strain: 6.4406×10−7 mm/mm6.4406 \times 10^{-7} \, \text{mm/mm}6.4406×10−7mm/mm.

The strain is highest in regions under concentrated load, typically where the roller and raceway interact.

Equivalent Stress (von-Mises Stress)

Maximum stress: 0.11772 MPa0.11772 \, \text{MPa}0.11772MPa.

The stress distribution indicates localized regions of high stress, likely at contact zones.

Total Deformation

Maximum deformation: 3.5237×10−6 mm3.5237 \times 10^{-6} \, \text{mm}3.5237×10−6mm.

Deformation is minimal, indicating that structural steel effectively resists applied loads.

COMPARISION WITH DIFFERENT COMPOSITE MATERIAL

Material	Equivalent Elastic Strain (mm/mm\{mm/mm}mm/mm)	Equivalent Stress (MPa\{MPa}MPa)	Total Deformation (mm\{mm}mm)
Structural Steel	6.4406×10−76.4406 \times 10^{-7}6.4406×10−7	0.117720.117720.11772	3.5237×10−63.5237 \times 10^{-6}3.5237×10−6
CFRP	1.8402×10^{-6}	0.11772	1.0068×10^{-5}
GFRP	3.2203×10^{-6}	0.11772	1.7619×10^{-5}
Kevlar	1.5520×10^{-6}	0.11772	8.4908×10^{-6}

VIII. CONCLUSION

This study concludes that material selection plays a crucial role in improving roller bearing performance, and adopting advanced composites like CFRP offers significant potential for fault reduction, weight optimization, and operational efficiency.

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[5]. Zhang & Zeng, 2020 - "Optimizing Corrective Measures for Bearing Fault Reduction"
[6]. Hoang & Kang, 2019 - "Fault Diagnosis in Spherical Roller Bearings"
[7]. Piltan et al., 2022 - "ML-based Fault Classification in Rolling Bearings"
[8]. Goyal et al., 2021 - "Artificial Intelligence in Bearing Defect Analysis"
[9]. Bhardwaj et al., 2020 - "Feature Extraction in Bearing Fault Identification"
[10]. Liang et al., 2019 - "Nonlinear Dynamics of Defective Bearings"
[11]. Zhu et al., 2024 - "Multi-source Fault Diagnosis of Roller Bearings"