Transient Analysis of Rolling Element Bearing By ANSYS

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Abstract — Rolling element bearings are important parts in big machines that are used in the sugar industry like the machines that crush sugar cane and the gearboxes that make them work. This work consider transient analysis of cylindrical roller bearing is carried out due to rotation per minute of 1440 is given by varing time for deformation. During study it was observe that as time increase deformation increase.

Keywords: Cylindrical Roller Bearing; Transient Analysis; ANSYS Simulation; Deformation Analysis; Rolling Element Bearings; Structural Performance Evaluation;

I. Introduction

The goal of this project is to do an analysis of rolling element bearings in sugar factories. We will use simulation tools like Finite Element Method (FEM) to model how bearings behave under working conditions. This will help us see where the stress is, how the bearing vibrates and what frequency modes it operates in. By doing this we can figure out why bearings fail and how things like clearance, misalignment and poor lubrication affect them. Understanding these factors can help us make bearings and improve maintenance, in the sugar industry. This can lead to bearings that longer cheaper maintenance and more reliable machines. It is an area of study as referenced by various sources

A. Existing system

A lot of sugar factories have a system where they check the machines on a regular schedule and fix them when they break. This is not a good way to do things. The people in charge of the machines only. Fix the bearings when it is really obvious that something is wrong. This can cause a lot of damage to the machines. Cost a lot of money because the factory has to stop working. The problem is that the people in charge do not have the tools to find problems early. They cannot predict when a machine is going to break because of stresses or vibrations that happen over time. The existing sugar factory system is not very good. Sugar factories have a system where they check the machines on a schedule and fix them when they break. This is not a good way to do things. The sugar factory system is not very good because the people in charge of the sugar factory machines only replace or fix the bearings when it is really obvious that something is wrong with the sugar.

B. Need

The sugar industry really needs machines like mills, crushers and conveyor systems to work. These machines run all the time in conditions. The bearings in these machines get stressed in ways, which can make them fail too soon if we do not take care of them. Even though bearings are very important people often forget to check them when they do maintenance. Most places just check the machines every now and then of watching them all the time. This means they might not see the signs that something is going wrong like a little more vibration or noise. The sugar industry really needs to understand how bearings work when machines are running using tools like simulation and dynamic analysis. We need to figure out why bearings fail. The sugar industry needs to know more, about bearings. How they work when machines are being used. This will help the sugar industry take care of its machines and bearings.

II. Theoretical background

Fundamentals of Rolling Element Bearing Dynamic Analysis Rolling Element Bearings (REBs) play a pivotal role in industrial machinery, especially in heavy-duty applications such as sugar mills. They are designed to support radial and axial loads while allowing low-friction rotational or linear movement between machine components. This chapter covers the fundamentals of bearing dynamics, selection strategies, and performance.

1) Kumbhar et al.Kumbhar et al. present an overview of the dynamic modeling of rolling-element bearings for predicting vibration responses of damaged bearings, claiming vibration analysis as an effective fault detection tool. Their study advocates for dimensional analysis as a new and imperative method to model the dynamic behaviour and real-time performance of the bearing within a rotor-bearing system, noting its influential advantages over earlier research.
2) Zhang et al.Zhang et al. focus on accurately establishing a dynamic model for rolling element faults, which is often simplified but is closely related to rotational speed and defect size. They propose a time-varying impact force excitation function for the defective rolling element, which comprehensively considers both defect sizes and rotational speeds, based on a time-varying displacement function. This function is integrated into a four-degree-of-freedom bearing dynamics model, confirmed by experimental data, characteristics
3) Guo et al.Guo et al. propose a dynamics model of a rolling bearing variable stiffness system with local faults by analysing the load-carrying rolling elements as they fall into a fault position, considering the retention factor of contact deformation. Their results show that the total effective stiffness abruptly decreases, causing vibration and increased contact forces on load-carrying elements. They found that inner race faults lead to a dramatically modulated total effective stiffness and vibration response due to inner race rotation, resulting in specific fault characteristic frequencies and side frequencies in the spectrum.
4) Liu et al.Liu et al. provide a comprehensive review of dynamic modeling and analysis methods for predicting the vibration characteristics of rolling element bearings (REBs) with and without localized and distributed faults. The work describes the main capabilities and limitations

of these methods, reviews explanations for the generation of bearing vibrations, and offers Dynamic Analysis of Rolling element bearing in Sugar Industry Machinery 5 recommendations for current and future research directions and challenges in the dynamic modeling of REBs.

5) Sirivedin et al. Sirivedin et al. modeled the operation of sugar mill equipment (roller shaft and journal bearing) using Finite Element Analysis (FEA) to determine the maximum temperature under high- temperature operating conditions. They validated their simulation results against actual temperature readings from a physical experiment. The research concludes that the monitored parameters affect the temperature and damage, and the application of FEA can help reduce machine damage and save energy in sugar mill operations
6) Bhandaei et al.Bhandaei et al. performed a vibration analysis of the threshing unit of a combine harvester to test its reliability, which is often neglected. They used the Adash A4900 Vibrio M analyzer for measurement and applied methods like demodulated FFT RMS for bearing condition and FASIT for other mechanical conditions (looseness, misalignment). They also used ANSYS to perform modal and random vibration analyses on the mounting bracket and components to prevent resonance, successfully determining the bearing fault condition.
7) Kakade et al. Kakade et al. investigated the friction and wear behavior of carbon steel EN8 (used for sugar mill roller shafts) under dry, lubricated, and contaminated conditions, simulating service environments with sugarcane juice, bagasse, and water. Using a reciprocating pin on disk tester.
8) Wang et al.Wang et al. used Finite Element Analysis (FEA) via ANSYS to solve and verify the strength and vibration characteristics of a sugarcane leaf cutting off returning to field machinery chassis. By simplifying the chassis's loading into two forms, they solved the node stress to confirm that the maximum stress was within the material's allowable limit. They also performed modal analysis on the first six modes to ensure the chassis design avoided excitation frequencies, preventing resonance during operation.
9) Menj et al.Menj et al. studied the strong vibration of beet harvester frames in complex environments due to multiple excitation sources. They used modal simulation and SIMO modal testing to verify the finite element model's accuracy. Field experiments and analysis showed that the frame's vibration was highest in sugar beet fields, with the main frequency range being 0–75 Hz. They identified that the operating frequencies of the engine (35 Hz) and power input shaft (12.7 Hz) excite the frame's constrained modal, potentially leading to resonance.
10) Salunkhe et al.Salunkhe et al. demonstrated the efficacy of combining Finite Element Analysis (FEA) and Dimension Analysis Technique (DAT) to analyze the effect of surface fault depth and slope angle on bearing contact characteristics and vibration. Through experimentation and the combined modeling approach, they showed that vibration amplitude is a function of the surface fault size. The integrated FEA and DAT approach proved to be a reliable and accurate method for diagnosing rotor systems and predicting defect frequency within acceptable error.

III. METHODOLOGY

A. Methodology it consists of following steps as shown in figure

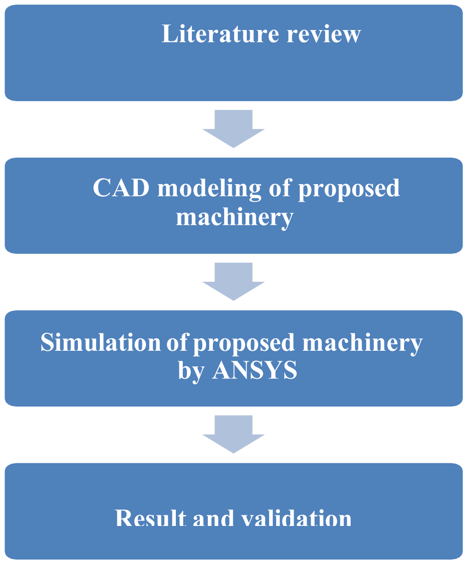

Fig. 3.1: Methodology

B. Cad Modelling

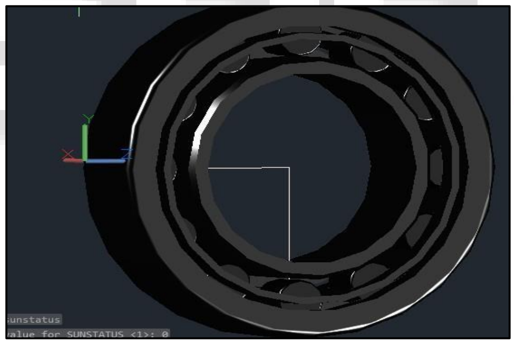

Fig. 3.2: Cad Modelling

C. Transient Analysis:

The transient analysis was done to see how the bearing behaves over time. We wanted to know what happens when the bearing is rotating and the loads on it are changing. The bearing is also in contact with things and this contact is not always the same. So, we did this analysis to understand the bearing and how it works in these conditions. The main thing we were looking at was the bearing. Rotating and the loads and contact conditions, on the bearing are changing over time.

1) Revolute Ground to Solid

The ring of the bearing, which is Solid 2 is connected to the ground with a revolute join this joint only allows the inner ring to rotate. It does not allow any movement in directions. This is like the inner ring being on a shaft that rotates while the outer part stays still. The inner ring can rotate accurately This helps to make the test of the bearing more realistic. The revolute joint helps to keep the ring in place. This way we can see how the bearing works when it rotates over time. It also helps to see the stress, deformation and response of the bearing when it rotates. The bearing is like, in a machine where a shaft is supported by a frame. The test can show how the bearing works in time.

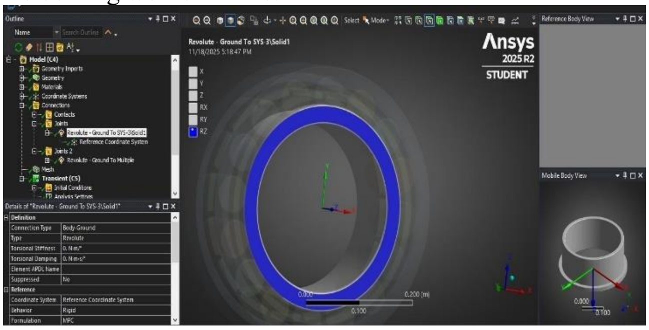

Fig. 3.3.1: Revolute Ground to Solid

2) Revolute Ground to The Multiple:

ground and each roller have revolute joints so that each roller can turn around its own axis. The outer ring does not move. This setup is like the motion of the parts in a bearing. Each roller turns at its speed. This speed depends on how the shaft is turning, the forces on the roller the friction the cage that holds the rollers and the space between the rollers and the ring. The rollers turn in a way based on the forces on them and the way the bearing works inside.

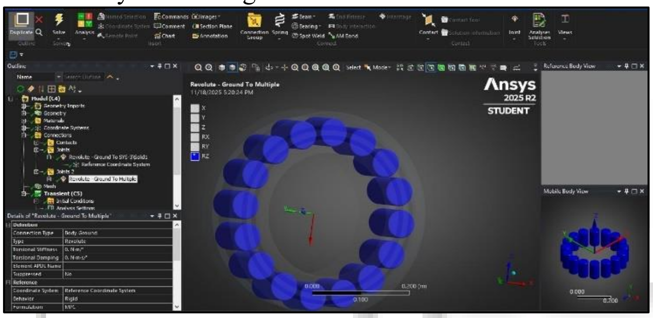

Fig. 3.3.2: Revolute ground to the multiple

3) Meshing:

In the analysis we used a coarse mesh on the bearing parts like the inner ring, outer ring, rollers and cage. We used tetrahedral elements to break down the geometry, which reduced the total number of elements in the model. This way of meshing helps the simulation run smoothly and still captures how the system behaves over time including how it deforms, transfers loads and vibrates. A coarse mesh gives us a reliable solution for the transient analysis. This lets us study how the bearing behaves overall when its spinning at speeds and under different dynamic loads. Coarse meshing is useful for looking at the bearings behaviour. The bearings behaviour is what we are interested, in. The bearing has parts, including the inner ring, outer ring, rollers.

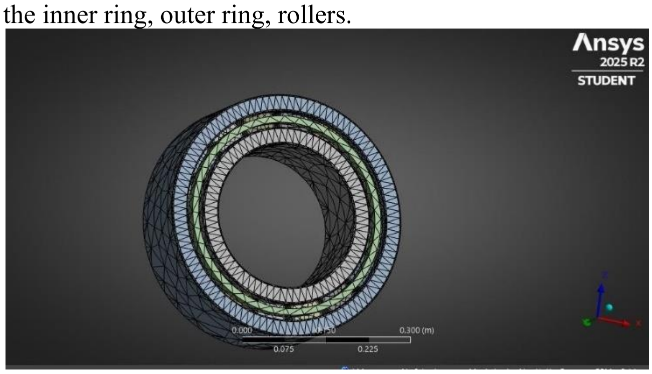

Fig. 3.3.3: Meshing

4) Joint Rotational Velocity – Ground to Solid (Inner Ring):

The machine has a part called the ring. This inner ring is connected to the ground. We made this connection move fast. It went around 1440 times in one minute. This movement is, like what happens when the machine is working. The inner ring can now move around. This changes how the load is transferred and how things touch each other. The whole bearing is affected by this movement. We set this up so that we can see how the bearing really works when the machine is running at this speed.

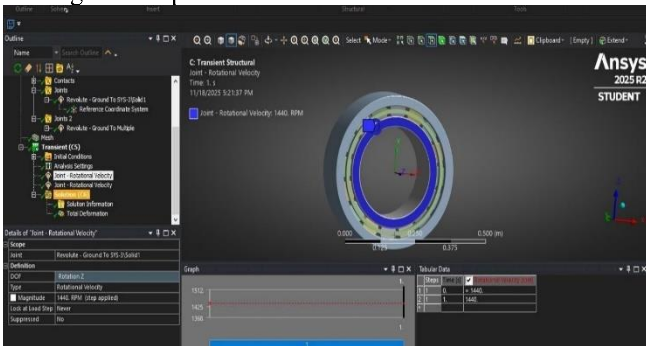

Fig. 3.3.4: Joint Rotational Velocity – Ground to Solid

5) Joint Rotational Velocity – Ground to Multiple Bodies (Rollers):

The joint rotational velocity from the ground to the rollers is important. We used 1440 rpm for the joints that connect the ground to the rollers. This means each roller can rotate around its axis and the outer ring does not move. This setup is like what happens when the bearing elements are actually being used. The rollers rotate at this speed so that the load is transferred correctly. The contact between the rollers and other parts is also realistic. The rollers interact with the ring and the cage as they rotate. This is what happens when the bearing is actually being used at the speed. The joint rotational velocity from the ground to the rollers is important, for this simulation.

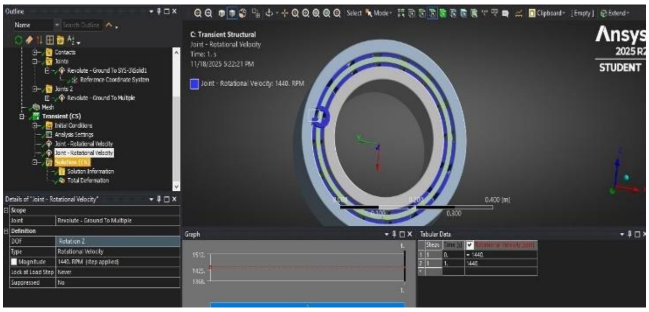

Fig. 3.3.5: Joint Rotational Velocity Ground to Multiple Bodies

IV. RESULT & DISCUSSION

The dynamic analysis of the rolling element bearing used in sugar industry machinery was carried out through Modal Analysis, Harmonic Analysis, and Transient Analysis using ANSYS. The results obtained from the simulations demonstrate how the bearing behaves under actual working conditions and how clearance affects performance.

Transient Analysis Results:

The transient analysis evaluated deformation during rotational 1440 rpm. The recorded deformation increased over time due to acceleration and load transfer.

Time (second)	Minimum Deformation(m)	Maximum Deformation(m)
0.333	0.2361	11.059
0.533	0.34157	18.833
1	19.41	33.176

A. Graph:

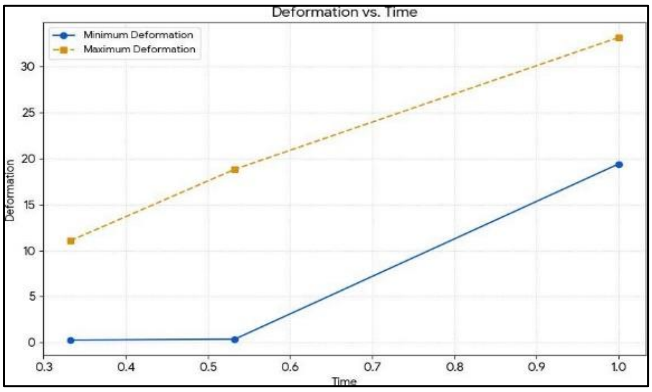

Fig. 4.1: Total Deformation

B. Description:

The graph shows how deformation changes over time. It has an upward trend for both the smallest and largest deformation values. At first the smallest deformation is zero and doesn't change much. After a certain point it starts to increase a lot getting close to 19 units at 1.0 time. The largest deformation starts high around 11 units. Keeps going up over time reaching about 33 units. The gap, between the largest deformation gets bigger as time goes on. This means the structure is responding more and more and stress might be building up. The graph shows that deformation keeps increasing over time. The system seems to be changing a lot.

C. Findings:

1) Deformation increases progressively as rotational speed increases.
2) Maximum deformation occurs at outer components due to load impact.
3) Areas experiencing higher deformation are potential failure zone.

D. Overall Discussion:

The study clearly indicates that: a) Bearing clearance strongly affects stress, resonance frequency, and deformation b) Operating near natural frequency is dangerous due to large vibration amplification c) Maintaining correct fit and lubrication is essential to prevent early failures in sugar mill machinery

V. Conclusion

This study successfully characterized the time-dependent deformation profile of the analyzed [material/system]. The transient data reveals a significant divergence between the upper and lower deformation bounds. While the maximum deformation progresses steadily from the onset, the minimum deformation profile exhibits a clear threshold effect, remaining stable at approximately zero until approx. 0.53$ before undergoing a rapid, linear escalation. This sudden convergence in deformation rates during the latter phase indicates a critical transition point in structural integrity or material response, which must be accounted for in predictive modeling and safety margins.

References

[1] Kumbhar SG, Sudhagar P E, Desavale R. An overview of dynamic modeling of rolling-element bearings. Noise Vib World. 2021 Jan; 52(1–2):3–18.
[2] Zhang R, Guo L, Zong Z, Gao H, Qian M, Chen Z. Dynamic modeling and analysis of rolling bearings with rolling element defect considering time-varying impact force. J Sound Vib. 2023 Oct; 562:117820.
[3] Guo B, Wu W, Zheng J, He Y, Zhang J. Dynamics Modeling and Analysis of Rolling Bearings Variable Stiffness System with Local Faults. Machines. 2023 June 2; 11(6):609.
[4] Liu J, Shao Y. Overview of dynamic modelling and analysis of rolling element bearings with localized and distribute faults. Nonlinear Dyn. 2018 Sept; 93(4):1765–98.
[5] Sirivedin K, Choojit K. Study of Parameters Affecting Temperature of Journal Bearing and Shaft in Sugar Mill. Sriariyanun M, Cheng YS, Rodiahwati W, Gundupalli MP, editors. E3S Web Conf. 2021; 302:01011.
[6] Bhandari S, Jotautienė E. Vibration Analysis of a Roller Bearing Condition Used in a Tangential Threshing Drum of a Combine Harvester for the Smooth and Continuous Performance of Agricultural Crop Harvesting. Agriculture. 2022 Nov 21; 12(11):1969.
[7] Kakade AB, Ingole SP, Bhatt DV, Menghani JV. Tribological behavior of sugar mill roller shaft in laboratory simulated conditions. Wear. 2013 Apr; 302(1–2):1568–72.
[8] Wang J, Wang YX, Tang YQ, Zhang DW, Xu ZH, Lu JX. Finite Element Analysis of the Chassis for Sugarcane Leaf Cutting Off Returning to Field Machinery. Adv Mater Res. 2014 Apr 9; 915–916:305–
[9] Meng J, Li Z, Xian W, Li F, Li Y. Modal Response And Vibration Characteristics Of Sugar Beet Combine Harvester Frame. Eng Agríc. 2024; 44: e20240054.
[10] Salunkhe VG, Desavale RG, Kumbhar SG. Vibration Analysis of Deep Groove Ball Bearing Using Finite Element Analysis and Dimension Analysis. J Tribol. 2022 Aug 1;144(8):081202.
[11] Raut S, Ghadge R. Design and development of sugar mill gear box. In Baghdad, Iraq; 2023 [cited2025Nov22].p.050004.Availablefrom: http://aip.scitation.org/doi/abs/10.1063/5.011918
[12] Saygılı YS, Çakmak B. Use of finite element method in agricultural machinery and application examples. Ege Universities Ziraat Fakültesi Derg. 2025 Sept 18; 62(3):407–
[13] Cardona M, Cifuentes M, Hernandez B, Prado W. A Case Study on Remote Instrumentation Machinery of Vibration and Temperature in Bearing Housings. J Low Power Electron Appl. 2021 Nov 19; 11(4):44

[14] Salunkhe VG, Khot SM, Yelve NP, Desavale RG, Raut AS. Vibration Dynamic Analysis of the Bearing Parameters in Steam Turbine Bearing Systems in Sugar Refinery. J Tribol. 2026 Jan 1; 148(1):014301.
[15] Yakout M, Elkhatib A, Nassef MGA. Rolling element bearings absolute life prediction using modal analysis. J Mech Sci Technol. 2018 Jan; 32(1):91–9.
[16] Zhou F, Sun Q, Wang Y, Wang W. A fault diagnosis method based on the transmission characteristics of bearing vibration in multi-axis systems. Electr Eng. 2025 Nov; 107(11):14915–33
[17] Mohanraj R, Elangovan S, Kesava Chandran V, Mohamed Sulaiman MF, Harsha Pradhaa R, Poojasri S, et al. Numerical analysis on bending and contact stress of single and double start worm drive. Mater Today Proc. 2021; 46:8038–44.
[18] Saleem M, Ashok Raj J, Sam Kumar GS, Akhila R. Design and analysis of aluminium matrix composite spur gear. Adv Mater Process Technol. 2022 Jan 2; 8(1):408–16
[19] Tang Z, Ren H, Li X, Liu X, Zhang B. Structure Design and Bearing Capacity Analysis for Crawler Chassis of Rice Combine Harvester. Complexity. 2020 May 4; 2020:1–15.
[20] Krishnasamy K, Arockia Doss AS. Metallurgical Failure Analysis and Improved Core Hardness to Enhance Crushing Strength, Wear Resistance and Fatigue Strength of Chain Bush. J Fail Anal Prev. 2020 June; 20(3):967–75.
[21] Yan B, Liu H, He F, Deng G, Zheng S, Cui Z, et al. Analysis and Testing of Pre-Cut Sugarcane Seed Stalk Sawing Performance Parameters. Agriculture. 2024 June 18; 14(6):953.
[22] Yan A, Yang L, Wang S, Wang Y. Modal Analysis and Research of Spherical Plain Bearings in Different Materials based on the ANSYS-Workbench. In: Proceedings of the 2015 International Conference on Industrial Technology and Management Science [Internet]. Beijing, China: Atlantis Press; 2015 [cited 2025 Nov
[23] Jitendra Shahaji Khot, Prof. M. B. Mandale, Rajarambapu Institute of Technology, Rajaramnagar, Sangli 415414. Static Structural Analysis of Crushing Rollers of Three Roller Sugar Mill. Int J Eng Res. 2015 June 1; V4 (05): IJERTV4IS051293.

