Bearing Design Analysis Using Two Materials and Simulated Vibration Testing Using Solidworks Software

Aan Candra Ajis[1], Dewi Amalia Agustina[1], Mochammad Mashud Okta kusuma[1], Muhammad Zainur Ridlo[1]

[1]Universitas Muhammadiyah Jember, Jember, Indonesia

Corresponding author: muhammadzainurridlo@unmuhjember.ac.id

Article Information: submission received XXX; revision: XXX; accepted XXX; first published online XXX

Abstract
Bearing vibration testing is an important technique in predictive or preventive maintenance. Abnormal bearing vibrations can indicate problems such as bearing wear or damaged lubrication processes. This bearing study aims to determine the vibration strength of bearings using a specified frequency of 310 hertz on two different bearings (Aluminum Alloys 1100 H12 and Alloys Steels). The method used is a 3D design using Solidworks software to create bearing designs from the two selected materials. After creating the design, a simulation analysis was performed using the vibration analysis available in SolidWorks to determine the vibration response of each bearing. The simulation results showed a comparison between material 1 and material 2. This evaluation included an analysis of the vibration frequency and amplitude. The results of the study showed that the aluminum alloys 1100-H12 material had a lower frequency than the alloy steels.

Keywords: Bearing; Aluminum alloys 1100-H12; Vibration; Simulation; Solidworks

1. INTRODUCTION

Rolling element bearings are a critical component in a rotating machine because they function to support the load and maintain rotational stability between the rotating and the stationary parts. In high-speed and loaded operating conditions, bearings are prone to pitting, wear, cracking, and spalling which leads to decreased performance, downtime, and even catastrophic failures (Suherman et al., 2022). The literature reports that the portion of interference in mechanical equipment related to bearing failure can be very dominant, so early detection strategies are important to reduce maintenance costs and the risk of shutdown (Y. Liu et al., 2026).

Vibration based condition monitoring is the most widely applied approach to the diagnosis of bearing damage because vibration contains spectral information that is directly related to the defect mechanism. Various studies (reviews) show the rapid development of diagnosis methods based on signal processing, machine learning, and deep learning to extract damage characteristics from vibration signals (Pandiyan & Babu, 2024). Classically, defects in bearing elements give rise to characteristic frequencies such as FTF (cage), BSF (rolling element), BPFO (outer trajectory), and BPFI (inner trajectory). A study in a nationally accredited journal also confirms that the identification of bearing defects can be done through mapping of these typical frequencies in the frequency domain or FFT (Riva'i & Pranandita, 2018).

In addition to the diagnostic aspect, another challenge that is no less important is designing components to be more resistant to dynamic excitation (Laine et al., 2024). Material differences (e.g. aluminum vs. alloy steel) have implications for stiffness, density, and vibration response (e.g. deviation and resonance tendencies), so material selection can affect the reliability and lifespan of components (Bhaumik et al., 2023; Yan et al., 2024). Studies of vibration engineering applications in engine components (e.g. engine mounting damper elements) show that material characteristics and structural configuration can alter the measured vibration amplitude and vibration isolation ability (Triswandi et al., 2023). On the other hand, the study of fault modeling and dynamic modeling emphasizes the importance of analytical or computational models to explain and predict vibration behavior due to defects and the influence of operating conditions (Y. Liu et al., 2026).

Based on this background, this article focuses on the evaluation of the vibration response of bearings through simulation or computational approaches (e.g. CAD/FEA modeling) by comparing the performance of two materials (Aluminum 1100-H12 and Alloy Steel) under specific vibration excitation. This approach is expected to make a practical contribution to material selection to minimize dynamic responses (e.g. deviations) and improve bearing design reliability in rotary engine applications (Chourasia & Joladarashi, 2022).

2. LITERATURE REVIEW

Bearings on a rotating machine and their relation to vibration

Rolling element bearings (rolling bearings) play a role in maintaining shaft stability, reducing friction, and channeling radial or axial loads (Evalina et al., 2024). In operating practice, bearings are one of the components that most often degrade due to contact wear, misalignment, dynamic loads, and inadequate lubrication, which then manifests as an increase in vibration levels (Gultom, 2022). Therefore, testing or monitoring bearing vibration is an important part of a predictive or preventive maintenance strategy (*Xu et al.*, 2023). This article also puts the vibration test as the main context, which is to compare the vibration response of the bearings on two different materials with a specific frequency excitation (310 Hz) through a SolidWorks simulation.

Vibration based condition monitoring for early detection of bearing damage

Broadly speaking, the diagnosis of bearing damage is carried out by analyzing vibration signals in the time domain and frequency domain. The Scopus literature shows that bearing defects often appear as harmonics at frequencies characteristic defects, including sideband modulation in the vibration spectrum, so spectral analysis remains a robust approach to detecting and identifying faults(Mika et al., 2025). Some studies have also emphasized the use of FFT transformations to convert vibration signals from time domains to frequency domains to aid in the diagnosis and classification of bearing conditions, including linking an increase in amplitude at a given frequency to indications of fault (Dinwasiba et al., 2021).

Dynamic modeling and vibration characteristics of bearings

Understanding the vibration characteristics of bearings both in healthy conditions and when there are local or distributed defects is crucial for reliability diagnosis and evaluation. The review in Nonlinear Dynamics summarizes the various dynamic modeling approaches to predict the bearing vibration characteristics and the limitations of each method (J. Liu & Shao, 2018). A relevant outline for this study is that the vibration response of bearings is influenced not only by the defect condition, but also by the configuration of the system (shaft; housing; bearing), dynamic excitation, as well as material parameters that affect the effective mass and rigidity of the structure.

Influence of materials on vibration response (stiffness, mass, resonance)

In structural vibration analysis, the natural frequency and shape mode depend on the geometry, material properties (e.g. modulus of elasticity, density), and the conditions of the support and constraint. SolidWorks itself affirms this dependency in the context of frequency or modal analysis (*Kumar et al., 2021*). Because aluminum and alloy steel have different density, stiffness, and damping characteristics, material choices have the potential to alter dynamic responses such as displacement, dominant frequency, and proximity to resonance (Koubova, 2024). This is the basis of the research logic in this article: comparing the vibration response of two materials (Aluminum Alloys 1100 H12 vs Alloy Steels) at 310 Hz excitation to see the difference in frequency and amplitude produced.

Influence of materials on vibration response (stiffness, mass, resonance)

CAE/FEA is commonly used to estimate vibration response prior to prototyping, especially to: (i) identify natural frequency and shape modes, (ii) avoid close resonance operations (Berthold et al., 2024), and (iii) lowering the amplitude of vibration through changes in design or material (Gao et al., 2024). The use of SolidWorks for the natural frequency analysis of components (e.g. engine mounting) as a measure of resonance prevention in the design. Correspondingly, this article uses the 3D design and vibration analysis stages in SolidWorks to evaluate the response of two materials at the same excitation frequency (310 Hz) and multiple amplitude scenarios.

3. METHOD

This study is a vibration simulation-based comparative study to evaluate the dynamic response of two bearing designs (Bearing 1 and Bearing 2) at an excitation frequency of 310 Hz with five amplitude levels (Amplitude 1-5), using two different materials: Alloys Steels and Aluminum Alloys 1100-H12. The main outputs were evaluated using the AMPRES (mode and risk influence analysis) indicators reported as Hertz, Max, Min, Node Max, and Node Min.

Pemodelan geometri (CAD) dan parameter desain

The geometry of the bearings is made in the form of a 3D model (assembly) using SOLIDWORKS software, including outer rings, inner rings, cages (gotri rings), and ball bearings as listed in the table below:

Table 1. Bearing Part Size

Name	Bearing 1	Bearing 2
	Ukuran	
Outer Diameter	65 mm	62 mm
Inner Diameter	37 mm	30 mm
Gotri Diameter	24 mm	9,52 mm
Outer Ring Thickness	31 mm	16 mm

Outer Ring Height	6 mm	5,2 mm
Inner ring thickness	31 mm	16 mm
Inner Ring Height	6 mm	5 mm
Amount of Gotri	8 Pcs	9 Pcs

Material dan properti mekanik

Material selection is the most important part of the simulation stage to determine the material. The specifications of the materials used in the following table. Alloy steels are a type of steel to which elements other than carbon are added to improve their mechanical, physical, and chemical properties. While aluminum alloys 1100-H12 are a type of aluminum alloy of the 1000 series with an aluminum purity of about 99%. This alloy is in a tempered condition of H12, which signifies that this material has undergone partial cold working to increase its strength. The material specifications are in the table below:

Table 2.Spesifikasi Alloys Steels dan alumunium alloys 110 H12

Property	**Value**	**Units**
Elastic Modulus	210000	N/mm^2
Poisson's Ratio	0.28	N/A
Shear Modulus	79000	N/mm^2
Mass Density	7700	Kg/m^3
Tensile Strength	723.8256	N/mm^2
Compressive Strength		N/mm^2
Yield Strength	620.422	N/mm^2
Thermal Expansion Coefficient	1.3e-05	$/K$
Thermal Conductivity	50	$W/(m:k)$
Specific Heat	460	$J/(Kg.K)$
Material Damping Ratio		N/A

The basic harmonic vibration is represented as a sinusoidal deviation:

$$y(t) = A\sin(\omega t) \quad (1)$$

with deviation, amplitude, ωangular velocity (rad/s), and ttime.

Frequency period relationship:

$$f = \frac{n}{t}, T = \frac{t}{n}, \omega = 2\pi f \quad (2)$$

which is used to attribute 310 Hz excitation to the ω angular domain. For FEM (linear)-based dynamic analysis, structural systems are generally stated:

$$\mathrm{M}\ddot{u} + \mathrm{C}\dot{u} + \mathrm{K}u = \mathrm{F}_0\sin(\omega t) \quad (3)$$

Harmonic steady state response is sought at a specified frequency step range.

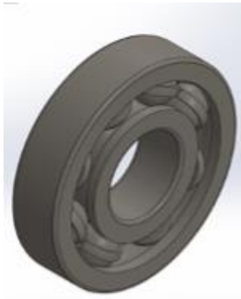

Figure 1. Bearing design

Figure 2. Ball ring design

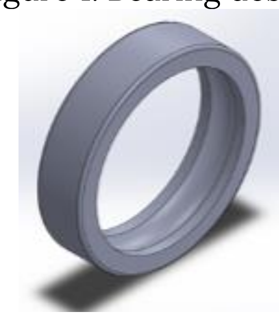

Figure 3. Ring out design

Figure 4. Ring gotri design

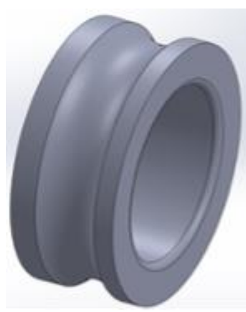

Figure 5. Ring design

Bearings are mechanical components that function to drive the rotating system, ball bearings are elements that rotate between the inner and outer rings. This type of element can be in the form of a ball, the outer ring is the part of the bearing that moves away from the shaft and is usually stationary and the In Ring is the part of the bearing that is adjacent to the shaft or a moving part.

4. RESULTS and DISCUSSION

In the results of the bearing simulation 1 using solidworks software with the material used is alloys steels and the test was carried out at 310 hertz with five levels (amplitude). The results of the simulation in the image below:

J-STEM: Journal of Science, Technology, Engineering, and Mathematics (2025), Vol. 1 Issue. 2 pp. 71-83
doi: 10.63232/j-stem.v1i2.30

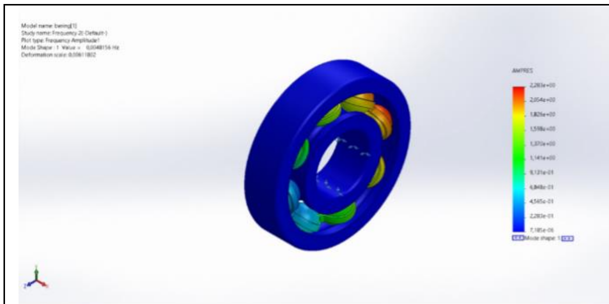

Figure 6. Amplitudo 1

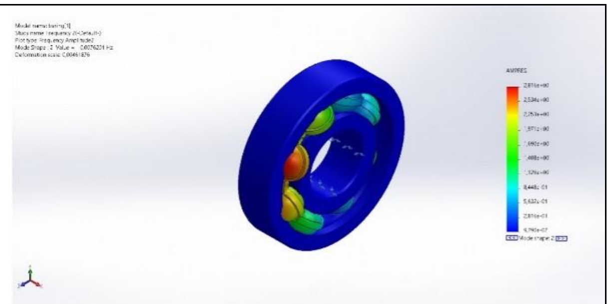

Figure 7. Amplitudo 2

In figure 6 and figure 7 above, there is a difference in the simulation process that is carried out. The analysis of the modes and the influence of risk obtained from amplitudes one and two has very different data, the data generated includes: Herzt (Hz) is indicating how often the vibration cycle occurs per second, Max (Maximum amplitude) is indicating the point where the strongest vibrations occur and often occur at resonance frequencies, Min (Minimum amplitude) is indicating the point where vibrations are weakest or almost non-existent, The max node (strain and voltage deformation) is the structure experiencing the greatest vibration at resonant frequencies, the min node (deformation and voltage) is the structure where the vibration amplitude reaches a minimum or even zero value during a given vibration mode. The following is the data from the simulation results that have been carried out in the table below:

Table 3. AMPRES data for amplitudo 1 and amplitudo 2

Data	**Amplitudo 1**	**Amplitudo 2**
Hertz	0,00481561	0,00762007
Max	2,283e+00	2,816e+00
Min	7,185e-06	9,790e-07
Node max	9160	7566
Node min	9864	9769

Table 3 shows the results of the simulation Figure 6 and Figure 7 have different data. Figure 6 has Hertz 0.00481561 while Figure 7 has 0.00762007 where the hertz result from the table above, Figure 7 has a higher hertz, Figure 6 has a max (maximum) of 2.283e+00, min (minimum) 7.185e-06, Node max 9160, Node min 9864, while in Figure 7 has max (maximum) of 2.816e+00, min (minimum) 9.790e-07, Node max 7566, Node min 9769.

J-STEM: Journal of Science, Technology, Engineering, and Mathematics (2025), Vol. 1 Issue. 2 pp. 71-83
doi: 10.63232/j-stem.v1i2.30

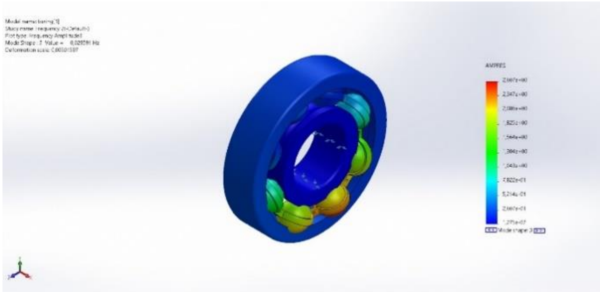

Figure 9. Amplitudo 3

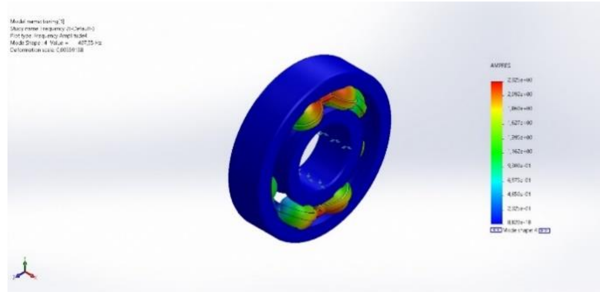

Figure 8. Amplitudo 4

Amplitude 3 and amplitude 4 have differences that can be seen from the results of the simulation conducted. The analysis of the modes and risk influences obtained from amplitudes one and two has very different data, the data produced includes: Herzt (Hz) is indicating how often the vibration cycle occurs per second, Max (Maximum amplitude) is indicating the point where the strongest vibrations occur and often occur at resonant frequencies, Min (Minimum amplitude) is indicating the point where vibrations are weakest or almost non-existent, The max node (strain and voltage deformation) is the structure experiencing the greatest vibration at resonant frequencies, the min node (deformation and voltage) is the structure where the vibration amplitude reaches a minimum or even zero value during a given vibration mode. The following is the data from the simulation results that have been carried out in the table below:

Table 4. Ampres data for amplitudo 3 and 4

DATA	Amplitudo 3	Amplitudo 4
Hertz	0,0295905	407,549
Max	2,607e+00	2,325e+00
Min	1,275e-07	8,820e-18
Node Max	8368	398
Node Min	9742	9741

The table above shows the results of simulations 3 and 4 have different data. Figure 8 has Hertz 0.0295905 while Figure 9 has 407.549 Herzt where the hertz result from the table above, Figure 9 has higher hertz, Figure 8 has a max (maximum) 2.607e+00, min (minimum) 1.275e-07, Node max 8368, Node min 9742, while in Figure 9 has max (maximum) 2.325e+00, min (minimum) 8.820e-18, Node max 398, Node min 9741.

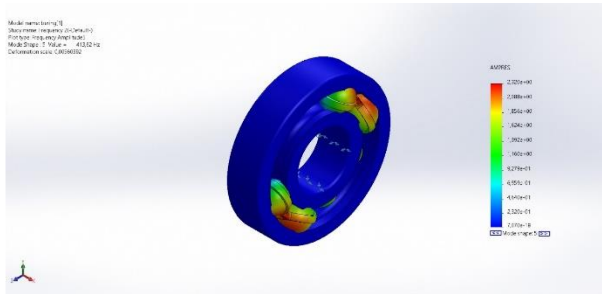

Figure 10. Amplitudo 5

Figure 10 illustrates the results of the mode analysis and the influence of risk obtained from amplitudes one and two have very different data, the data produced include: Herzt (Hz) is indicating how often the vibration cycle occurs per second, Max (Maximum amplitude) is indicating the point where the strongest vibration occurs and often occurs at resonance frequencies, Min (Minimum amplitude) is the point where vibration is weakest or almost non-existent, Node max (strain and voltage deformation) is a structure experiencing the greatest vibration at resonance frequencies, Min node (deformation and voltage) is a structure where the vibration amplitude reaches a minimum or even zero value during a given vibrating mode. The following is the data from the simulation results that have been carried out in the table below:

Table 5. Ampres data fot amplitudo 5

DATA	Amplitudo 5
Hertz	413,62
Max	2,320e+00
Min	7,070e-18
Node Max	3575
Node Min	9846

The table above is the result of the simulation of Figure 10. Figure 10 has Hertz 413.62, max (maximum) 2.320e+00, min (minimum) 7.070e-18, max node 3575, min node 9846.

Hasil simulasi *bearing* 2 (*aluminium alloys* 1100-H12)

In the results of the simulation of bearing 2 using solidworks software with the material used is aluminum alloys 1100-H12 and the test was carried out at 310 hertz with five levels (amplitude). The results of the simulation are in the image below.

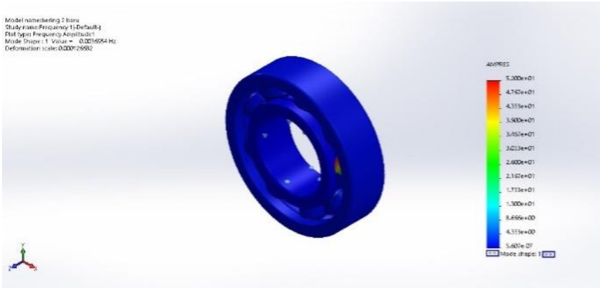

Figure 11. Amplitudo 1

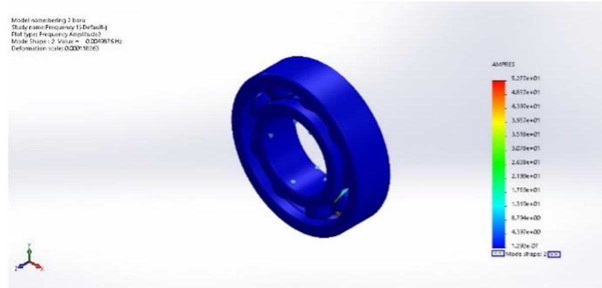

Figure 12. Amplitudo 2

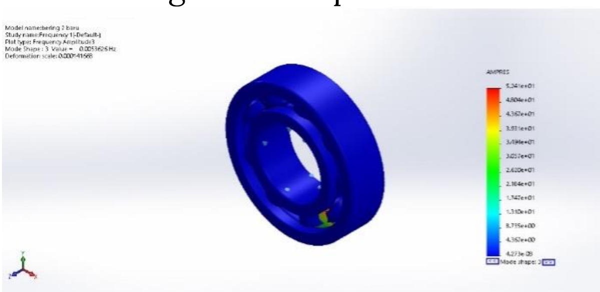

Figure 13. Amplitudo 3

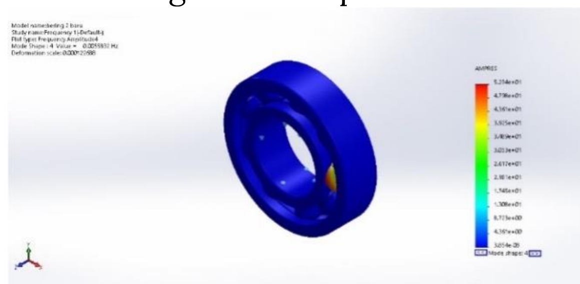

Figure 14. Amplitudo 4

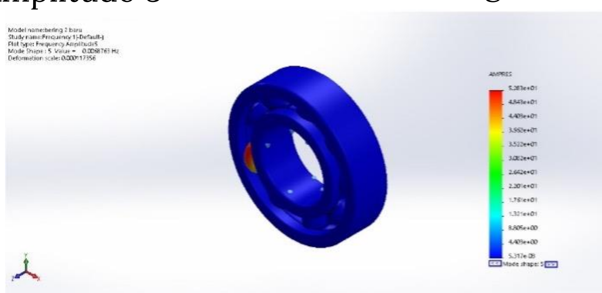

Figure 15. Amplitudo 5

The results of the mode and risk influence analysis carried out at amplitudes 1 to 5 explain that obtained from amplitudes one and two have very different data, the data produced includes: Herzt (Hz) is indicating how often the vibration cycle occurs per second, Max (Maximum amplitude) is indicating the point where the strongest vibration occurs and often occurs at resonance frequencies, Min (Minimum amplitude) is the point where vibration is weakest or almost non-existent, Node max (strain and voltage deformation) is a structure experiencing the greatest vibration at resonance frequencies, Min node (deformation and voltage) is a structure where the vibration amplitude reaches a minimum or even zero value during a given vibrating mode. The following is the data from the simulation results that have been carried out in the table below:

Table 6. Ampres data for bearing 2

DATA	Amplitudo 1	Amplitudo 2	Amplitudo 3	Amplitudo 4	Amplitudo 5
Hertz	0.00369537	0.0049876	0.00536257	0.00558316	0.0068763

Max	5.200e+01	5.277e+01	5.241e+01	5.234e+01	5.283e+01
Min	5.607e-07	1.292e-07	4.273e-08	3.854e-08	5.317e-08
Node Max	2025	644	1818	1834	904
Node Min	11165	11165	11165	11165	11165

The table above is the result of the simulation of Figure 11-15. Figure 11 has Hertz 0.00369537, Max (Maximum) 5.200e+01, Min (Minimum) 5.607e-07, Max Node 2025, Min Node 11165. Figure 12 has Hertz 0.0049876, Max (Maximum) 5.277e+01, Min (Minimum) 1.292e-07, Max Node 644, Min Node 11165. Figure 13 has Hertz 0.00536257, Max (Maximum) 5.241e+01, Min (Minimum) 4.273e-08, Max Node 1818, Min Node 11165. Figure 14 has Hertz 0.00558316, Max (Maximum) 5.234e+01, Min (Minimum) 3.854e-08, Max Node 1834, Min Node 11165. Figure 15 has Hertz 0.0068763, Max (Maximum) 5.283e+01, Min (Minimum) 5.317e-08, Max Node 904, Min Node 11165.

5. CONCLUSION

Based on research that has been conducted related to the design of 3D bearings and vibration test simulations using SolidWorks at 310 Hz excitation with five amplitude levels (1–5), evaluation based on AMPRES indicators (Hz, Max, Min, Node Max, Node Min) shows that material selection affects the dynamic response of the bearing, both in terms of response frequency and peak amplitude and critical point distribution. In general, Aluminum Alloys 1100 H12 exhibit a tendency to lower Hz values than Alloy Steels in the tested scenarios, while changes in excitation amplitude cause different Hz and Max-Min responses between materials, including the presence of certain conditions that give rise to higher responses. In addition, the Max Node tends to move at each amplitude level, indicating that the location of the vibration hotspot is not always the same and needs to be addressed in design improvements (local gain or geometry optimization) so that the risk of high vibrations can be reduced. These findings confirm that AMPRES-based simulations can be used as an initial basis for material selection and bearing design evaluation, although further research is still needed for experimental validation and refinement of modeling details to make the results more representative of real operating conditions.

References

Berthold, J., Kolouch, M., Regel, J., & Dix, M. (2024). Identification of natural frequencies of machine tools during milling: comparison of the experimental modal analysis and the operational modal analysis. *Production Engineering*, 18(5), 853–862. https://doi.org/10.1007/s11740-024-01270-6

Bhaumik, S., Anurag Krishna, B., Reddy, B. L. M., Hareesh, G., Vikram, K., Paleu, V., & Mavani, S. (2023). Investigating the Fretting Failure of Axial Thrust Steel Bearings in the Presence of Anti-Fretting Lubricating Paste. *Metals*, 13(12). https://doi.org/10.3390/met13122023

Chourasia, K., & Joladarashi, S. (2022). Modelling, static and dynamic analysis of offset bearing using ANSYS. *Materials Today: Proceedings*, 66, 2124–2132. https://doi.org/10.1016/j.matpr.2022.05.560

Dinwasiba, S. I., Widodo, A., & Haryanto, I. (2021). Diagnosis Kerusakan Bearing dengan Analisis Sinyal Getaran pada Program Matlab. In *Jurnal Teknik Mesin S-1* (Vol. 9, Issue 1).

Evalina, N., Susilo, J., & Amiruddin, A. (2024). Perancangan Sistem Monitoring Suhu dan Getaran pada Bearing dapat Motor Induksi Berbasis HMI. *RELE (Rekayasa Elektrikal Dan Energi) : Jurnal Teknik Elektro*. https://doi.org/10.30596/rele.v6i1.17197

Gao, W., Yu, X., Jiang, H., Shi, G., Dai, R., Jia, W., Wang, J., & Jiao, J. (2024). Modal and response analysis of vertical guideway of vertical lathe considering hydrostatic bearing. *Journal of Mechanical Science and Technology*, 38(12), 6563–6572. https://doi.org/10.1007/s12206-024-1112-y

Gultom, J. F. (2022). Analisis Metode Spektrum Fft Dan Perbaikan Terhadap Kerusakan Bearing Pada Pompa Sentrifugal SP039. *Journal of New Energies and Manufacturing* (JONEM), 1(3), 87–97. https://doi.org/10.22441/jonem.v1i3.16517

Koubova, L. (2024). Numerical Solution of Natural Frequencies and Mode Shapes. *Procedia Structural Integrity*, 63, 35–42. https://doi.org/10.1016/j.prostr.2024.09.006

Kumar, R., Jain, A., Mishra, S. K., Joshi, M., Singh, K., & Jain, R. (2021). Comparative structural analysis of CNC milling machine bed using Al-SIC/graphite, al alloy and Al-SIC composite material. *Materials Today: Proceedings*, 51, 735–741. https://doi.org/10.1016/j.matpr.2021.06.219

Laine, S., Haikonen, S., Tiainen, T., & Viitala, R. (2024). Rotor resonance avoidance by continuous adjustment of support stiffness. *International Journal of Mechanical Sciences*, 270. https://doi.org/10.1016/j.ijmecsci.2024.109092

Liu, J., & Shao, Y. (2018). Overview of dynamic modelling and analysis of rolling element bearings with localized and distributed faults. In *Nonlinear Dynamics*

(Vol. 93, Issue 4, pp. 1765–1798). Springer Netherlands. https://doi.org/10.1007/s11071-018-4314-y

Liu, Y., Cheng, Y., Yang, S., & Wu, J. (2026). Vibration signal models for fault diagnosis of rolling element bearing. *Measurement*, 264, 120303. https://doi.org/10.1016/j.measurement.2026.120303

Mika, D., Józwik, J., & Ruggiero, A. (2025). Vibration-Based Diagnostics of Rolling Element Bearings Using the Independent Component Analysis (ICA) Method. *Sensors*, 25(23). https://doi.org/10.3390/s25237371

Pandiyan, M., & Babu, T. N. (2024). Systematic Review on Fault Diagnosis on Rolling-Element Bearing. In *Journal of Vibration Engineering and Technologies* (Vol. 12, Issue 7, pp. 8249–8283). Springer. https://doi.org/10.1007/s42417-024-01358-4

Riva'i, M., & Pranandita, N. (2018). *Analisa Kerusakan Bantalan Bola (Ball Bearing) Berdasarkan Signal Getaran.*

Suherman, S., Ilmi, I., Amirsyam, A., & Syakura, A. (2022). Penambahan sr pada aluminium paduan a356 dengan metode lost foam casting (lfc). *SINTEK JURNAL: Jurnal Ilmiah Teknik Mesin*, 16(1), 18. https://doi.org/10.24853/sintek.16.1.18-22

Triswandi, R., AKurniawan, F., & Aswan Ritonga, D. A. (2023). Analisa Getaran Menggunakan Bantalan Mesin (Engine Mounting) Berbahan Dasar Kombinasi Dua Per Spiral dan Karet Alami pada Toyota Avanza. In *Cetak) Buletin Utama Teknik* (Vol. 18, Issue 3). Online.

Xu, F., Ding, N., Li, N., Liu, L., Hou, N., Xu, N., Guo, W., Tian, L., Xu, H., Lawrence Wu, C. M., Wu, X., & Chen, X. (2023). A review of bearing failure Modes, mechanisms and causes. In *Engineering Failure Analysis* (Vol. 152). Elsevier Ltd. https://doi.org/10.1016/j.engfailanal.2023.107518

Yan, C., Fan, W. J., Wang, D. M., & Zhang, W. Z. (2024). Research on the Impact of Non-Uniform and Frequency-Dependent Normal Contact Stiffness on the Vibrational Response of Plate Structures. *Applied Sciences (Switzerland)*, 14(7). https://doi.org/10.3390/app14073121

Postscript:

Similarity max 20% with Turnitin.