Vol. 9, No.2, Juli 2026, Halaman 190-196 | ISSN 2622-7398
DOI:https://doi.org/10.30596/rmme.v9i2.31605 | http://jurnal.umsu.ac.id/index.php/RMME
Jurnal Rekayasa Material, Manufaktur dan Energi

Design Modification and Strength Analysis of a Bearing Housing Using Finite Element Method

Mulyadi[1*], Bobby Umroh[2], Hendery Dahlan[3]
[1)]Mechanics of Material/Universitas Pembinaan Masyarakat Indonesia
[2)]Manufacturing, Universitas Medan Area
[3)]Mechanics of Material, Universitas Andalas
*Email: mulyadi@upmi.ac.id

ABSTRACT

Bearing housings are critical mechanical components in small-scale manufacturing machinery. In field operations, standard pillow block designs frequently experience premature structural failures such as material cracking and high deformation under dynamic loads.

This study aims to determine the exact structural causes of failure in standard bearing housings used within chain transmission systems and to develop an optimized, structurally superior modified design. The investigation was conducted numerically using open-source tools: FreeCAD for three-dimensional parametric modeling and PrePoMax (CalculiX solver) for Finite Element Analysis (FEA). The component was modeled using ASTM Class 35 Cast Iron with a yield strength of 170 MPa. The loading condition simulated a 1 HP motor running at 1500 rpm with a generated torque of 1.59 kg·m, where the chain tensile force was applied directly to the housing bore.

The initial simulation revealed that the baseline design suffered from high stress concentrations around the bolt hole and fillet regions due to insufficient material thickness. The maximum principal stress reached 107.4 MPa, yielding an inadequate safety factor of 1.6 and a displacement of 0.002 mm. To resolve this, structural modifications were implemented by adding reinforcing ribs and thickening the housing profile. The FEA results of the modified design showed a significant stress reduction to 55 MPa (a decrease of approximately 49%). Furthermore, the maximum displacement at the top section dropped to 0.0009 mm, demonstrating a 45% reduction in displacement and higher structural stiffness. Consequently, the safety factor increased substantially from 1.6 to 3.6 (simulated at 3.09 in direct stress ratio).

The incorporation of strengthening ribs and wall thickening successfully redistributes operational loads and minimizes material distortion. The modified design satisfies industrial safety regulations and is highly feasible for implementation in small-scale industrial chain drive applications.

***Keywords*:** Bearing Housing, Finite Element Method, Stress Concentration, Reinforcing Ribs, Safety Factor.

INTRODUCTION

Bearing housings are critical mechanical components that support rotating transmission shafts while maintaining precise alignment within industrial machinery [1]. In many small-scale manufacturing sectors, such as food processing and building material production, these housings are often subjected to challenging operational conditions that lead to frequent mechanical failures. Common failure characteristics reported in the field include excessive structural vibration, material cracking under dynamic loads, and premature bearing wear caused by housing deformation [1] [2].

Vol. 9, No.2, Juli 2026, Halaman 190-196
DOI:https://doi.org/10.30596/rmme.v9i2.31605
ISSN 2622-7398
http://jurnal.umsu.ac.id/index.php/RMME
Jurnal Rekayasa Material, Manufaktur dan Energi

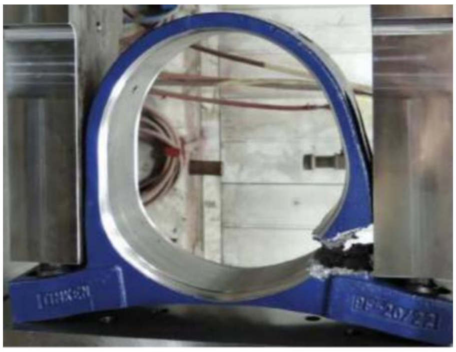

Figure 1. Failure modes of pillow block bearing housings [3].

Such failures result in significant unplanned operational downtime and high maintenance costs, which directly threaten the productivity of Small and Medium Enterprises (SMEs) [1] [3]. Investigations into broken housings, particularly those made of cast iron, reveal that damage typically originates at stress concentration areas like bolt holes, often exacerbated by improper assembly torques or manufacturing defects such as porosities. Traditional analytical calculations are often insufficient for assessing these complex geometries and failure modes, creating an urgent need for more advanced numerical approaches. Consequently, this research is rationalized by the necessity to perform detailed design modifications and strength analyses to enhance structural integrity while optimizing component weight [3]. The application of the Finite Element Method (FEM) provides a crucial rationale as it allows for a virtual, high-fidelity evaluation of design robustness before the manufacturing stage [4].

The primary objective of this study is to identify the specific causes of failure and degradation in standard bearing housing designs currently utilized in chain transmission systems. Furthermore, this research aims to generate an optimized structural modification of the housing design that balances ergonomics, manufacturability, and structural rigidity. The study also seeks to calculate and simulate the stress distribution, strain, and displacement of the proposed modified design using Finite Element Analysis (FEA). The problem-solving plan involves several distinct phases, beginning with the development of three-dimensional (3D) solid models using CAD software. These models will then be exported to FEM environments where different operational scenarios, such as varying bolt tightening torques and dynamic chain tensions, will be simulated. Based on the results of the initial simulations, areas of high stress concentration will be targeted for geometric reinforcement, such as the addition of stiffeners, while areas with low stress will be evaluated for mass reduction to achieve an efficient design. Finally, a comparative analysis between the baseline and modified designs will be conducted to verify that the proposed design can safely withstand operational loads throughout its intended service life.

FEM is a numerical technique that discretizes complex physical models into a finite number of small elements to solve displacement functions at nodal points. By calculating a stiffness matrix, the method determines the resulting strain and stress fields within the component when subjected to external loads and boundary conditions [4].

The external forces acting on the system can include the chain tensile force, which serves as the primary load received by the shaft and subsequently transmitted to the bearing housing [5]. The formula for the chain tensile force (P) is defined as [3][6]:

$$F_t = \frac{P.60}{2\pi . n . R} . C_s$$

Where:

P = Motor power (Watts).
n = Sprocket speed (rpm).
R = Effective radius of the sprocket (m).

C_s= Load correction factor (typically 1.0 – 1.5 depending on the type of load).

The concept of load being transmitted from the shaft through the bearing to the housing is a critical aspect of structural integrity analysis, as these housings must be designed to withstand both static and dynamic loads generated during operation [7]. Proper estimation of these loads is essential for determining the maximum stress concentrations, typically analyzed using the Finite Element Method (FEM) to ensure the factor of safety remains within industrial standards.

In structural strength analysis, von-Mises equivalent stress serves as the primary indicator for predicting material yield. Structural safety is confirmed if the maximum von-Mises stress remains below the material's yield strength, maintaining a factor of safety (FoS) greater than 1.0 [1] [2] [3]. The Margin of Safety (MS) for ultimate loads is calculated as [4]:

$$MS=\left(\frac{S_{tu}}{\sigma_{max}}\right)-1$$

Where S_{tu} = Ultimate tensile or yield strength of the housing material.
σ_{max}= Maximum stress obtained from numerical analysis.

Topology optimization and the strategic placement of external rib shapes (stiffeners) are proven methods for reducing the weight of transmission housings by up to 30% without sacrificing rigidity [3][5]. Because bearing housings encounter repeated loading cycles, fatigue analysis is essential to predict the endurance limit and ensure the system does not fail prematurely under cyclic stress [1] [4].

To ensure the housing material does not undergo structural failure, such as fracture or bending, the von-Mises stress criterion is utilized. This criterion is the primary indicator used in structural analysis to predict the onset of material yielding. The formula for von-Mises equivalent stress is expressed as:

$$\sigma_{vm} = \sqrt{\frac{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2}{2}}$$

Where:

$\sigma_1, \sigma_2, \sigma_3$ = Principal stresses [1]

A design is declared structurally safe if the maximum stress produced is lower than the yield strength of the material [2]. The Factor of Safety (n), also referred to as the Factor of Safety for Stress (FOSS), is determined by the ratio of the material's yield strength to the maximum working stress obtained from numerical simulations [1] [6]:

$$n = \frac{\sigma_y}{\sigma_{max}}$$

Where:

- σ_y = Yield Strength of the material (Pa).
- σ_{max} = Maximum equivalent stress resulting from analysis (Pa).

Technically, a design is considered safe if n > 1 [1]. However, for industrial applications and safety-critical components, higher targets are usually required to account for

Vol. 9, No.2, Juli 2026, Halaman 190-196
ISSN 2622-7398
DOI:https://doi.org/10.30596/rmme.v9i2.31605
http://jurnal.umsu.ac.id/index.php/RMME
Jurnal Rekayasa Material, Manufaktur dan Energi

uncertainties; for example, industrial guidelines for mounted bearings often target safety factors as high as 3 to 5 to ensure long-term operational reliability [6].

RESEARCH METHODOLOGY

In this study, the geometric modeling process is performed using FreeCAD, a reliable open-source parametric CAD software for designing machine components. For structural strength analysis, PrePoMax is utilized as the pre-processor and post-processor, which is based on the CalculiX solver. The application of these open-source tools allows for accurate and efficient numerical analysis tailored for technological development within the small-scale industry sector without the burden of commercial software licensing costs.

The data required to perform the strength analysis include:

- Geometric Data: The shaft dimension is 20 mm. The distance between the fastening bolts on the machine frame is 50 mm.
- Material Data: The material used is ASTM Class 35 Cast Iron, characterized by a Young’s Modulus of 114 GPa, an ultimate strength of 252 MPa, a yield strength of 170 MPa, and a Poisson’s Ratio of 0.29.
- Operational Data: The motor power (P) is 1 HP (3-phase), the machine speed (n) is 1500 rpm, and the torque (T) generated by the motor is 1.59 kg·m. The common failure modes observed in the field are illustrated in Figure 1.

The design process is carried out using FreeCAD software. The modification stages include:

1. Existing Design Modeling: Creating a digital replica of the bearing housings that frequently experience failure.
2. Design Innovation: Enhancing structural integrity by adding stiffeners (ribs), increasing the thickness of the housing walls, or altering the profile geometry to ensure a more even load distribution.
3. Material Selection: The material remains consistent with the original design, which is cast iron.

The simulation steps are executed using FreeCAD and PrePoMax analysis software as follows:

1. Definition of Boundary Conditions:
   - Fixed Support: Defining the fastening bolt points on the frame as fixed (non-moving) supports.
   - Bearing Load: Applying the chain tensile force (F_t) to the inner surface of the bearing housing hole in the direction of the chain pull.
2. Element Creation (Meshing): The design structure is discretized into small tetrahedral elements. Mesh density and quality are refined in critical regions, such as sharp corners and bolt holes, to ensure high stress accuracy.
3. Execution & Validation: The solver calculates the stiffness matrix equations to produce visualizations of von-Mises stress distribution, displacement, and the Factor of Safety.
4. Evaluation Criteria: The modified design is considered successful and feasible if it fulfills the following requirements:
   - $\sigma_{max} < \sigma_{yield}$: The maximum equivalent stress does not exceed the material's yield point.
   - Safety Factor > 2.0: The design possesses adequate strength reserves to withstand shock or dynamic loads.
   - Minimal Displacement: The resulting deformation is minimized to ensure it does not compromise chain alignment.

Vol. 9, No.2, Juli 2026, Halaman 190-196
ISSN 2622-7398
DOI:https://doi.org/10.30596/rmme.v9i2.31605
http://jurnal.umsu.ac.id/index.php/RMME
Jurnal Rekayasa Material, Manufaktur dan Energi

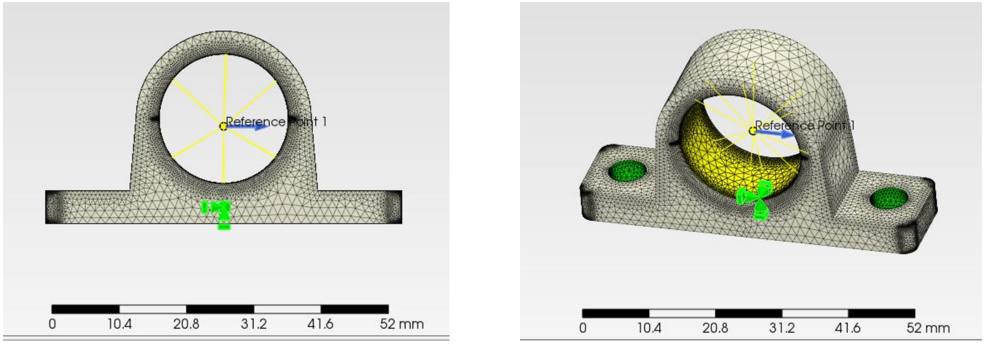

Figure 2. Mesh of the original bearing house

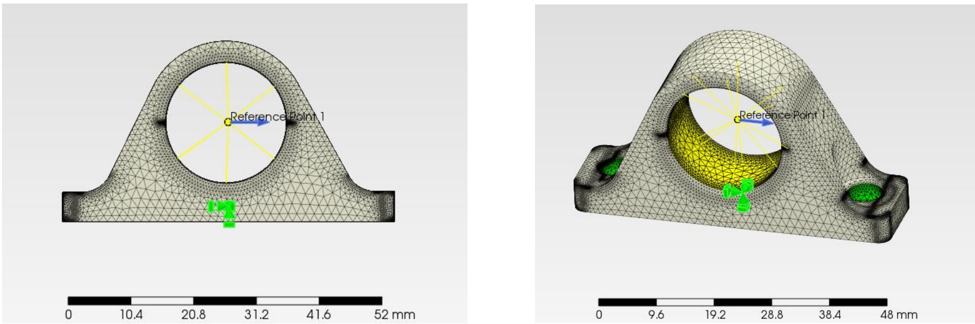

Figure 3. Mesh of the modified bearing housing

RESULTS AND DISCUSSION

The maximum stress distributions obtained from the finite element simulation results are presented in Figures 4 through 6. The simulation results indicate that the maximum principal stress for the baseline design is 107.4 MPa, whereas for the modified design, it drops to 55 MPa; both peak stresses are located at the bottom of the bolt hole. Given that the yield strength of the cast iron material is 170 MPa, these results demonstrate that the modified design is safe against material yielding. Conversely, the baseline design exhibits a lower safety margin under the applied load, as its maximum stress closely approaches the material's yield strength

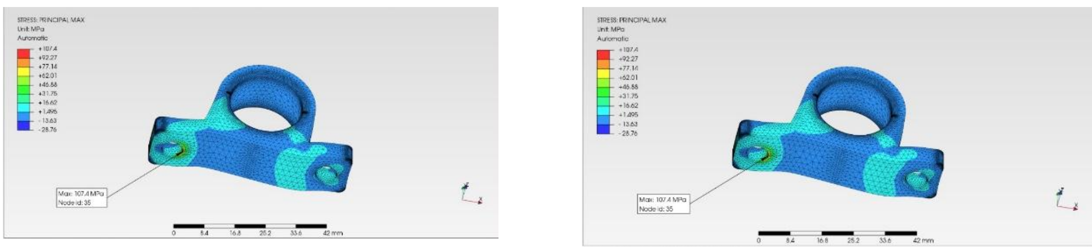

Figure 4. Maximum principals stress (left) and Von Mises Stress (right) distribution of original model

Vol. 9, No.2, Juli 2026, Halaman 190-196 | **ISSN 2622-7398**
DOI:https://doi.org/10.30596/rmme.v9i2.31605 | http://jurnal.umsu.ac.id/index.php/RMME
Jurnal Rekayasa Material, Manufaktur dan Energi

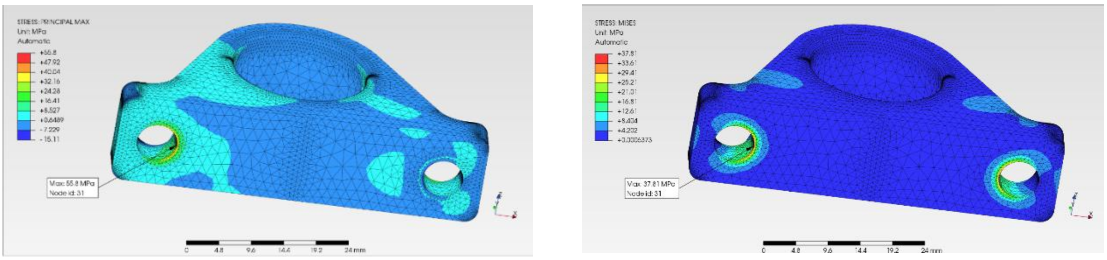

Figure 5. Maximum principals stress (left) and Von Mises Stress distribution (right) of modified model.

The displacement and deformation obtained from the modeling results are shown in Figure 6. Both the baseline and modified designs exhibit maximum displacement at the top section of the housing. However, the modified design provides a significantly lower displacement, reducing it to 45% of the maximum displacement observed in the baseline pillow block bearing. The elevated displacement and deformation at the top of the bearing housing induce high material shifting, which can trigger material damage or cracking within the housing structure. This finding aligns with the physical evidence of cracking observed in the failed bearing housing sample shown in Figure 1."

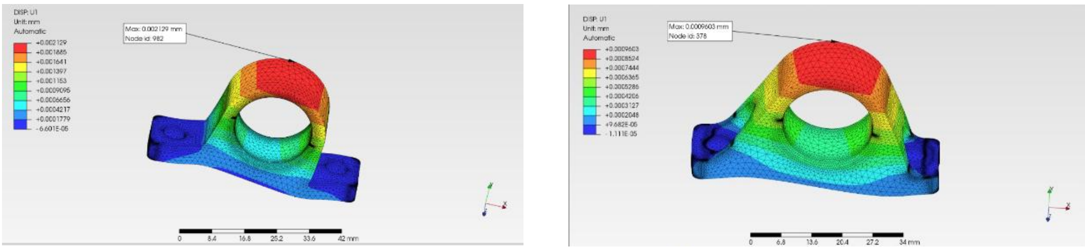

Figure 6. Displacement in the 1-direction (x) of the original (left) and modified (right) bearing housing design

Based on the maximum stress values obtained above, the factor of safety (SF) is determined as follows:

- **Baseline Design SF:** $n = \frac{\sigma_y}{\sigma_{kerja}} = \frac{170}{107} = 1{,}6$

A safety factor below 2 carries a high risk of structural failure when subjected to shock or impact loading.

- **Modified Design SF:** $n = \frac{\sigma_y}{\sigma_{kerja}} = \frac{170}{55} = 3{,}09$

A safety factor greater than 2 satisfies standard mechanical engineering safety regulations.

Table 1 below presents the comparison of the bearing housing before and after the modification.

Table 1. Characteristic Comparison of the Pillow Block Bearing Housing Before and After Modification

Parameter	Original Model	Modified Model	Remarks
Material	Cast Iron	Cast Iron	unchanged
Maximum Stress	107 MPa	55 MPa	Decreased by 42%
Displacement	0.002 mm	0.0009 mm	Higher stiffness
Safety Factor	1.6	3.6	Safe

CONCLUSION

The primary cause of failure in the baseline design is the high stress concentration at the fillet radius/bend area due to insufficient material thickness. Modifications introducing reinforcing ribs and profile thickening successfully reduced the working stress significantly. The new design achieves a Safety Factor of 2.5, demonstrating its feasibility and safety for implementation in small-scale industrial chain transmission systems.

REFERENCES

[1] M. G. Gok and M. B. Sahin, "Failure analysis of cast iron housing unit of UFC-216 type ball bearing," Internationa Advanced Researchs and Engineering Journal, vol. 08, no. 01, 2024.

[2] Pump Bearing Housing – Reverse Engineering & Fabrication, 2022.

[3] K. Kelvin, A. O. Fred and O. Bokumo JR, "Stress Analysis of Bearing Housing Components of Boogies & Review on Bearings," International Journal of Engineering and Information Systems, vol. 5, no. 11, pp. 51-57, 2021.

[4] A. F. Kopp, R. B. Hausen and M. E. S. Martins, "Automotive Technical Paper Simulational and Experimental Validation with Structural Redesign of Bearing Housing in a Formula SAE Transmission System," in SAE Brasil 2025 Congress, 2025.

[5] H. Basri, "Numerical Solution of Fatigue Stress in Journal Bearing," in nae2007 The 5th International Conference on Numerical Analysis in Engineering, Padang, West Sumatera, 2007.

[6] M. Foster, "Applying Bearing Loads In Ansys and SW Simulation," Youtube , 2016.

[7] V. Krstic, D. Milcic, M. Milcic, A. Stoic and N. Zdravkovic, "Influence of Housing Material and Geometry on Thermal Stability of Threaded Spindle," Technical Gazette, vol. 31, no. 2, pp. 604-611, 2024.

[8] TIMKEN, "Defining and Predicting Housing Strength for Mounted Bearings: Why It Matters for Optimizing Your Operation," Technical White Paper, November 2016.

[9] Y. Ogata, S. Suzuki and Y. Iljima, "nae2007 The 5th International Conference on Numerical Analysis in Engineering," Honda R&D Technical Review, pp. 103-108, October 2004.