

Design And Structural Analysis of Automotive Wheel Rim Using Aluminum Bronze

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Abstract— This research focuses on the design, material selection, and structural analysis of an automobile wheel rim using aluminum bronze. Aluminum bronze is a copper-based alloy known for its strength, corrosion resistance, and wear resistance. In the automotive industry, choosing the right material for wheel rims is important because it affects the vehicle's weight, fuel efficiency, handling, and durability. Traditional materials like aluminum alloys and steel have some drawbacks, such as fatigue wear and corrosion in harsh conditions. To overcome these issues, this project explores aluminum bronze as an alternative. The wheel rim was designed using CATIA software and analyzed in ANSYS Workbench. Finite Element Analysis (FEA) was used to study how the rim behaves under different loads like radial and cornering forces, and dynamic stresses during driving. The analysis looked at deformation, stress, strain, fatigue life, and safety. Mechanical tests were also done to check how well aluminum bronze performs. The results showed it has high tensile strength, good impact resistance, strong fatigue performance, good hardness, and excellent ductility. It also performed well when exposed to temperature changes. When compared to aluminum alloy, aluminum bronze had slightly more deformation but performed much better in terms of fatigue life, impact strength, and stress handling. Even though it is more expensive, its longer lifespan, strength, and recyclability make it a good choice for car wheel rims. This project shows that aluminum bronze can be a reliable and durable material for modern vehicles.

Keywords – Aluminum Bronze, Automobile Wheel Rim, Finite Element Analysis, ANSYS Workbench, CATIA, Structural Analysis, Fatigue Analysis, Tensile Test, Impact Test, Hardness Test, Bending Test, Thermal Expansion, Material Selection, Corrosion Resistance, Wear Resistance, Fatigue Life, Mechanical Properties, Safety Factor, Equivalent Stress, Automotive Engineering.

I. INTRODUCTION

In the automotive industry, choosing the right material for wheel rims is important because it affects

safety, performance, and fuel efficiency. Traditional materials like steel and aluminum alloys are commonly used, but they have some drawbacks like corrosion and lower fatigue strength.

Aluminum bronze is a strong copper-based alloy that offers high strength, good wear resistance, and excellent corrosion resistance. These properties make it a good alternative for making wheel rims, especially in vehicles that need to carry heavy loads or operate in harsh conditions.

This project focuses on designing a wheel rim using aluminum bronze and checking how it performs under different loads. The design was created in CATIA software and tested using ANSYS simulation. Tests like tensile, impact, hardness, and fatigue were also done to compare aluminum bronze with aluminum alloy. The aim is to see if aluminum bronze is a better and more reliable material for modern vehicles.

II. MATERIALS

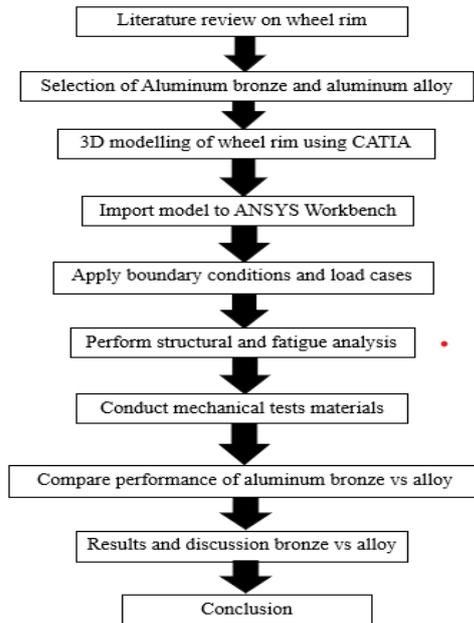
2.1 Aluminum alloy is lightweight, easy to shape, and commonly used in cars. It helps improve fuel efficiency but has lower strength and wear resistance, especially under heavy loads or in harsh environments.

2.2 Aluminum bronze is a copper-based alloy that contains aluminum and other elements. It is much stronger than aluminum alloy and offers better resistance to wear, corrosion, and fatigue. It is used in marine and industrial applications where durability is important.

Even though aluminum bronze is heavier and more expensive, it performs better in terms of strength, safety, and long-term durability. That makes it a good

option for car wheel rims that need to handle stress, heat, and rough conditions.

III.METHODOLOGY



IV.SELECTION OF ALUMINUM

Aluminum (symbol: Al) is a silvery-white metal known for being lightweight, corrosion-resistant, and highly versatile. It is the third most abundant element in the Earth's crust (after oxygen and silicon) and the most abundant metallic element. Its combination of desirable physical and mechanical properties has made it one of the most widely used metals across numerous industries, including transportation, construction, aerospace, packaging, and electronics. Aluminum's unique characteristics, such as low density, high corrosion resistance, and excellent workability, make it an ideal choice for a variety of applications where weight, strength, and sustainability are critical factors.

4.1 ALUMINUM ALLOY

Aluminum alloys are combinations of aluminum with other elements (such as copper, magnesium, manganese, silicon, and zinc) designed to improve its mechanical, thermal, and corrosion resistance properties. While pure aluminum has excellent corrosion resistance, low density, and good workability, it lacks the necessary strength for some engineering applications. Alloying aluminum with other elements enhances its strength, durability, and versatility for a wide range of industrial uses.

Aluminum alloys are commonly used across industries such as aerospace, automotive, construction, marine, electronics, packaging, and transportation because of their lightweight properties, strength, corrosion resistance, and ease of fabrication. critical temperatures, and high refrigerating effect to ensure energy efficiency.

4.2 Comparison of Material Properties

Property	Aluminum Bronze	Aluminum Alloy
Density	7.4 to 8.3 g/cm ³	~2.7 g/cm ³ (lighter than steel)
Tensile Strength	550 MPa to 900 MPa	High strength
Hardness	200 to 250 HB	Good toughness
Fatigue Resistance	Excellent	Excellent
Melting Point	900°C to 1,000°C	550°C to 660°C depending on alloy composition
Thermal Conductivity	110 W/m·K	205 - 235 W/m·K depending on the alloy
Corrosion Resistance	Excellent in seawater & harsh environments	Excellent, especially in non-aggressive settings
Machinability	Good (can be machined easily)	Easy to machine, extrude, and fabricate

V.FINITE ELEMENT SIMULATION

ANSYS Workbench plays a crucial role in this project by enabling the structural and fatigue analysis of the automobile wheel rim designed using aluminum bronze material. As a powerful Finite Element Analysis (FEA) tool, ANSYS helps simulate real-world mechanical conditions to predict how the wheel rim will behave under various loads such as radial forces, impact shocks, and cyclic fatigue.

The wheel rim model was first created in CATIA software and exported in IGES format. This geometry was then imported into ANSYS Workbench, where material properties for both aluminum bronze and aluminum alloy were assigned. Boundary conditions such as fixed supports at lug holes and external pressure loads on the rim barrel were applied to replicate actual driving scenarios.

The analysis in ANSYS involved the following modules and techniques:

Static Structural Analysis: Used to determine total deformation, shear stress, and strain distribution. This analysis revealed that aluminum bronze has higher strength and load-bearing capacity but slightly more deformation than aluminum alloy.

Fatigue Analysis: Performed using the Fatigue Tool in ANSYS, based on stress-life (S-N curve) methods.

Aluminum bronze showed a significantly higher fatigue life and a much lower fatigue damage index compared to aluminum alloy.

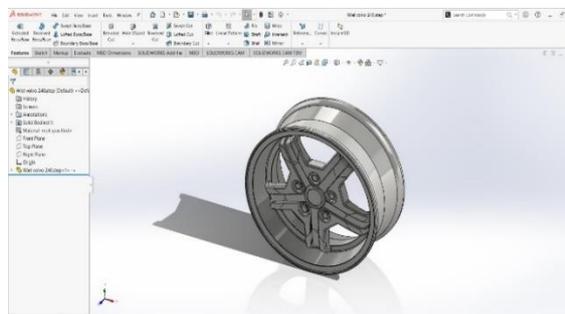
Impact Resistance Simulation: Although simplified, impact conditions were approximated by applying shock loads and analyzing stress concentrations around the V-notch area. This confirmed that aluminum bronze exhibits better energy absorption capability under sudden impact conditions.

Safety Factor Evaluation: ANSYS provided visual mapping of the safety factor distribution, indicating critical zones and confirming the structural reliability of the rim design.

Comparative Material Study: By changing only the material properties in ANSYS while keeping geometry and load conditions constant, a direct comparison between aluminum alloy and aluminum bronze was achieved. The software automatically calculated stress responses, deformations, and fatigue behavior for both cases.

The use of ANSYS Workbench made it possible to simulate complex real-time behavior of the wheel rim without physical prototypes, saving time and cost. Its advanced solver capabilities and intuitive post-processing tools provided detailed insights into material performance, ensuring that aluminum bronze is a feasible and high-performance option for automotive wheel rims.

5.2 CAR WHEEL RIM DESIGN



VI. MATERIAL TESTING



6.1 Comparison of Mechanical Properties

The above graph illustrates the comparative mechanical performance of Aluminum Alloy and Aluminum Bronze based on average values from tensile, impact, and fatigue tests. Aluminum Bronze exhibits significantly higher tensile strength and greater fatigue life, indicating better load-bearing capacity and long-term durability under cyclic loading. On the other hand, Aluminum Alloy demonstrates superior impact energy absorption, highlighting its higher toughness under sudden or dynamic loading conditions. This comprehensive comparison helps in selecting the suitable material based on application-specific mechanical demands.

Fig 5.1

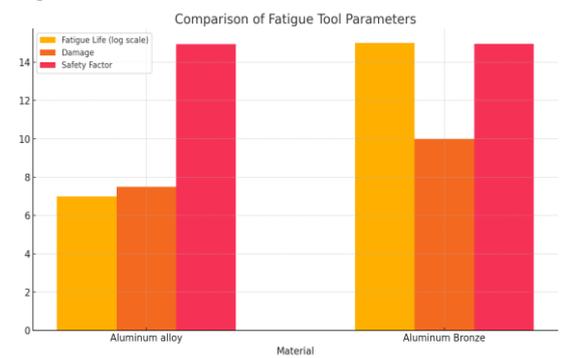


Fig.6.1 Comparison of Mechanical Properties – Aluminum Alloy vs Aluminum Bronze

6.2 COMPARISON OF FATIGUE TOOL

The above graph provides a comprehensive comparison of fatigue tool parameters average fatigue life (log scale), damage, and safety factor for Aluminum Alloy and Aluminum Bronze. It is evident that Aluminum Bronze exhibits significantly higher fatigue life compared to Aluminum Alloy, as shown on a logarithmic scale. However, Aluminum Bronze also incurs higher damage values, suggesting greater stress accumulation or wear during usage. Despite this, the safety factor for Aluminum Bronze remains

slightly higher than that of Aluminum Alloy, indicating better reliability under fatigue loading conditions. Overall, the data suggest that Aluminum Bronze, while more durable in terms of fatigue life, may require more careful consideration in design due to its higher damage values. Fig 6.2

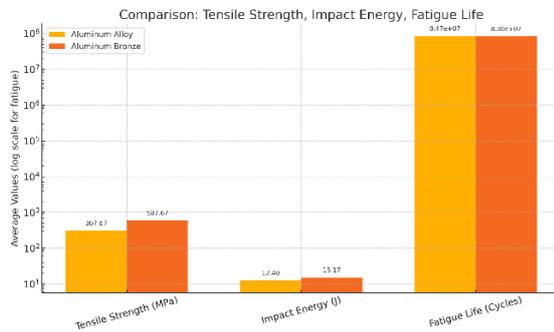


Fig6.2 COMPARISON OF FATIGUE TOOL

VII. CONCLUSION

In this Research, the design and structural analysis of an automobile wheel rim using aluminum bronze was carried out to evaluate its performance under real-world conditions. The rim was modeled using CATIA software and analyzed using ANSYS Workbench for various parameters such as total deformation, shear stress, fatigue life, and safety factor. The results from the static and fatigue analyses, along with mechanical testing—including tensile, impact (Charpy V-notch), hardness, bending, and thermal expansion—were used to compare aluminum bronze with a standard aluminum alloy. The findings clearly indicate that aluminum bronze has higher tensile strength, better fatigue life, improved safety factor, and excellent resistance to wear and corrosion. Although the deformation was slightly higher than aluminum alloy and the cost per kilogram is more, aluminum bronze proved to be more durable and reliable for long-term applications. Its ability to absorb impact energy, withstand repeated loading, and resist failure under high stress makes it a suitable and advanced material for automotive wheel rims, especially for heavy-load and performance vehicles. Overall, aluminum bronze shows great potential as a high-performance, sustainable material alternative for wheel rim applications. Its use can improve vehicle safety, extend component life, and support innovation in the automotive industry. This project highlights the importance of material selection and simulation tools like ANSYS in designing components that meet both performance and safety standards.

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