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Design And Analysis Of A Car Wheel Rim

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Abstract
The primary goals of this study are to design, model, and analyze the structural characteristics of automobile wheel rims made of various materials, such as magnesium alloy (AM60B) and aluminium alloys (Al-7068, AlSi7Mg0.3). The primary objective is to evaluate and compare the structural performance of three different wheel rims under identical stress and boundary conditions using ANSYS 2025 R1Workbench. Each design is tested for total deformation and equivalent (Von-Mises) stresses under radial loads, internal pressure, and rotational velocities comparable to a vehicle speed of 160 km/h. The 3D CAD models were made with SpaceClaim, and the strength and durability characteristics of the materials were assessed using finite element analysis (FEA). Simulation results showed that Design 3 with AlSi7Mg0.3 outperformed the other analyzed configurations, exhibiting the least amount of total deformation (0.153 mm) and Von-Mises stress (13.49 MPa). Al-7068 followed closely behind, but AM60B, while being lighter, deformed more under stress. The project's conclusions indicate that aluminium alloys, namely AlSi7Mg0.3, provide the ideal balance of strength, weight, and deformation resistance for car wheel rims, which qualifies them for enhanced performance and fuel efficiency. This study provides valuable insights into material selection and design optimization for safer and more efficient automotive components.

I. INTRODUCTION

Today's historians and archaeologists believe that the invention of the wheel was the true beginning of any ancient civilization. The most important invention of antiquity is the wheel. From an enlarged bearing, the wheel has evolved into a crucial component of all contemporary vehicles. To guarantee passenger safety, contemporary motor vehicles are manufactured in accordance with extremely stringent regulations. The materials used to make these wheels have advanced in sophistication, and they can be made of steel or nonferrous alloys like aluminium and magnesium. Over the years, automobile wheels have changed from their first spoke designs made of steel and wood. The rims of contemporary cars are made of cast and forged aluminium alloys and are stamped metal. Numerous cutting-edge techniques for testing that are compatible with experimental stress measurement have been developed since the 1970s.

Over the last ten years, the vehicle wheel has been subjected to reliability and durability study (fatigue life prediction) to address the inherent variances in engineering structure. The size, weight, design, and materials of the wheel rims are all impacted by braking performance. The distance between the wheel rim and brake rotor is determined by the rim's size. Better cooling will result from increased air flow around the brakes due to a larger wheel rim diameter. Another crucial factor is the wheel rim's weight. Light weighting a vehicle always improves its handling.

Wheel flex will be lessened with a more stiff wheel. This is crucial for high-performance tires with low aspect ratios that can produce strong cornering forces.

Figure 1.1 : Wheel Rim

Steel Disc Wheel

This type of rim is commonly seen on passenger vehicles, particularly OEM tires, and it is constructed by welding the wheel and rim together.

Figure 1.2 : Aluminium Disc Wheel

Magnesium alloy Wheel

When compared to aluminium, magnesium is almost 30% lighter and has far better size stability and impact resistance. Nevertheless, its primary application is in the realm of racing, where the characteristics of weightlessness and exceptional strength are paramount. Its surface area is much larger than that of aluminium.

Figure 1.3 : Alloy Wheel made of magnesium

Titanium alloy wheel

Titanium has superior corrosion resistance and strength (approximately 2.5 times that of aluminium), but it is less practical owing to its higher cost, more complicated design, and more labour-intensive production. It has not yet been fully developed.

Figure 1.4 : Titanium alloy wheel

II. LITERATURE SURVEY

They were once constructed from magnesium due to its lightweight and strong properties; nevertheless, magnesium is prone to catching fires and is notoriously difficult to extinguish. This is a shame because, in every other respect, it is far better than aluminium. As a result of this quality, working with heaps of shavings might be risky since they have a potential to catch fire and melt concrete.1 The addition of heavier steel wheels makes a vehicle feel more like a tank when driving, reduces its acceleration and agility, and lowers its centre of gravity compared to an aluminium wheeled vehicle. While this may not be ideal for use during the summer, it may have a profoundly positive impact on one's physical and mental well-being throughout the winter. A car with slow acceleration and agility, a low centre of gravity, and an understanding of strength and weight may be quite beneficial when driving in the snow. Snow tires bite harder with heavier wheels. Steel wheels are more durable than alloy wheels; they are also harder to break and need more energy to bend. Damage that is just cosmetic is typically not a huge deal because of how familiar they seem and how well they work.

Rim production techniques, mechanical characteristics of materials, aluminium sheet metal rims, and fundamental rim requirements are all covered in the Aluminium Automotive Manual (2011), which also examines the many varieties of wheel rim materials and their pros and cons. However, the research has solely focused on aluminium and has failed to address any of the other materials. Strength, structural stiffness, fatigue behaviour, crashworthiness, etc. are fundamental requirements according to this document [1].

Using finite element analysis (FEA) techniques, M. Sabari et.al. (2015) compared the deformation of several materials used to make automobile wheel rims. Carbon steel and aluminium alloy were the two materials he studied. After the Solid Works program was used to develop the CAD model of the two materials, the CATIA software was used for analysis. Two variables, the applied load and the wheel rim speed, were varied in this study. A graph showing the relationship between maximum displacement and speed was also generated by rims, who adjusted the load and cruising speed. The results showed that the displacement of both materials increased with increasing speed. Alloy wheel rims have a larger displacement than steel ones. [2]

T. Siva Prasad et.al. (2014) analyzed the pros and cons of different wheel rim materials, including aluminium, magnesium, carbon fiber, steel, and more. In terms of static displacement, von Mises stress, and dynamical displacement, he compared forged steel with aluminium. Compared to forged steel, researchers discovered that aluminium wheel rims experience higher levels of stress induced displacement. According to the research, forged steel is the superior material for a wheel rim [3].

The fatigue behaviour under continual stress of an overcast aluminium alloy (Al.356.2) wheel rim was investigated by N. Satyanarayana et.al. (2012). No one in the research team thought to compare Al.356.2 to other materials.

Using AlSi7Mg0.3 aluminium alloy wheels, Sourav Das (2014) investigated how to optimize the design and weight of sport utility vehicle rims. Researchers and wheel rim material guides agree that magnesium alloys and aluminium alloys are the best of all worlds: lightweight, highly conductive, and aesthetically pleasing. In comparison to aluminium alloys, magnesium alloys have extremely low ductility. One more thing: bent magnesium rims can't be fixed [5].

S. Ganesh et.al. (2014) examined the Al 356.2 aluminium alloy wheel for spiral wheel rims utilized in four-wheel drives, outlining the benefits and downsides of different rim materials. According to the paper, Mercedes-G models employ magnesium rims, which are sturdy enough for regular cars but unsuitable for off-road vehicles. The inability to fix bent rims is the one major drawback of magnesium, which means that they end up in the trash [6].

III. RESULTS AND DISCUSSION

Solution:

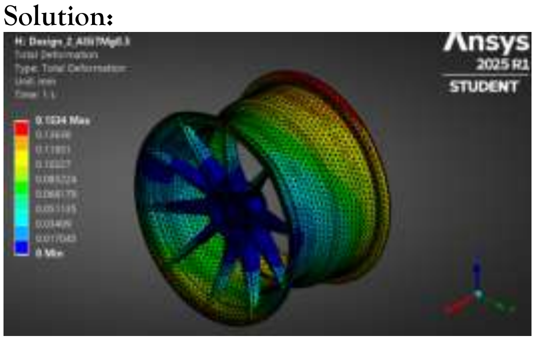

Fig 3.1 : Total Deformation of an aluminum alloy (AlSi7Mg0.3)

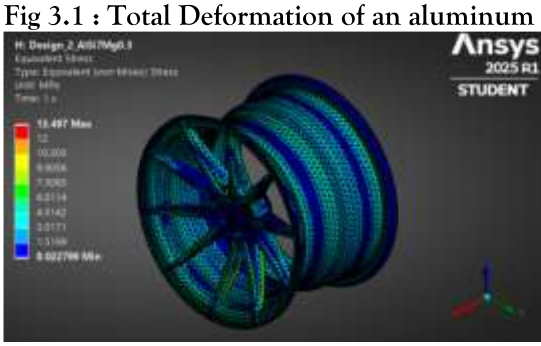

Fig 3.2 Equivalent (von-misses) stresses of an aluminum alloy (AlSi7Mg0.3)

The research of alloy wheels employing various materials and software designs has been the focus of this work. To determine which material is best, comparisons between several materials are carried out.Three distinct material types were the subject of the study: magnesium alloy (AM60B), aluminium alloy (Al 7068), and AlSi5Mg0.3. Since wheels are often made of materials with great strength, this material was selected. To get findings, such as total deformation and equivalent (Von Mises) stress, further analysis was conducted.

For three distinct designs, a thorough analysis of total deformation and equivalent (Von Mises) stress was accomplished:

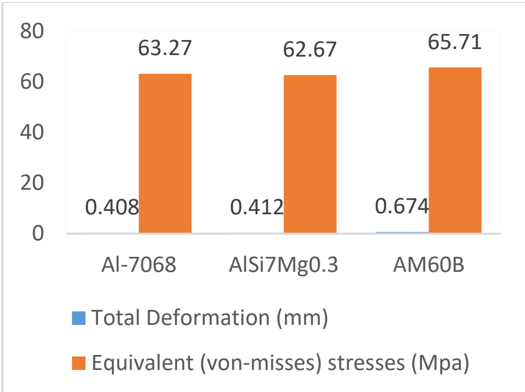

Fig: 3.3 For various materials, Design 1 shows the equivalent (von misses) stresses and total deformation.

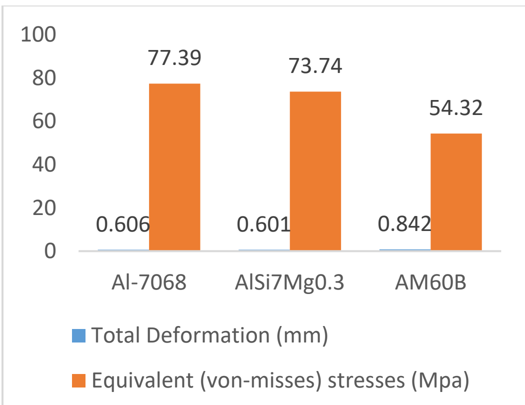

Fig: 3.4 For various materials, Design 1 shows the equivalent (von misses) stresses and total deformation.

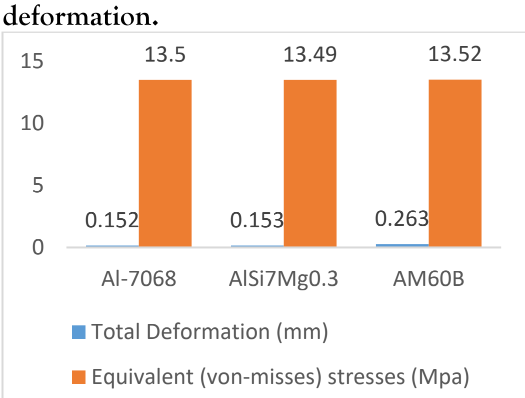

Fig: 3.5 Design 1: Equivalent (von misses) stresses and total deformation for various materials

- By examining graph 6.1, which shows the results of the study, we can observe that Design 1 Al 7068 has less deformation and von misses stresses than the other two materials. Additionally, the magnesium alloy and Alsi7mg0.3 are nearly identical.
- According to graph 6.2 for design case 2, Alsi7mg0.3 exhibits less deformation than other materials, such as magnesium alloy and Al 7068, whereas magnesium alloy exhibits smaller von Mises stresses.
- According to graph 6.3 for design case 3, Al 7068 exhibits less deformation than other materials, such as Alsi7mg0.3 and magnesium alloy, whereas Al 7068 exhibits lower von Mises stresses.

Three values are also shown by comparing the three graphs. Total Deformation and Equivalent (von-mises) Stress levels are nearly the same for all material's various designs.

IV. CONCLUSION

- When you produce alloy wheels, you combine metal with additional elements. They usually provide more strength than pure metals, which are frequently softer and more malleable.
- Alloy wheels currently are made of aluminium or magnesium, which are lighter than other materials with the same strength and provide better heat conduction.
- The spokes junction showed a significant increase in stress concentration. Based on the results of the impact test, the material is capable of withstanding loads and stresses that are considered safe. Stresses in an impact study tend to concentrate on the flange.
- Form optimization, which entailed cutting material from unstressed areas, reduced the wheel's weight by 20% after rebuilding it with optimization data. Also, the improved wheel does not do any harm when stressed. The areas with the greatest stresses were the spoke slots and intersections.
- We conducted the modelling and analysis using ANSYS. The following results are derived from the static structural investigation of many designs for different materials.
- The third design made better use of the aluminium alloy (i.e., Alsi7mg0.3), which achieved a maximum deformation of 0.153 mm and a von-mises stress of 13.52 MPa.
- To the contrary, magnesium alloy Al 7068 is determined to be the second-best material.
- According to the results of the experiment, magnesium and aluminium alloys can provide us the best results.

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