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Multi-Spoke Car Alloy Wheel Design and Performance Evaluation

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Abstract. Steel wheels often have a greater mass than aluminium or magnesium alloy wheels, which reduces their speed and steering responsiveness compared to steel wheels. In comparison to steel wheels, alloy wheels may reduce overall vehicle weight. Composite materials are being used in the automobile sector in order to decrease weight without affecting vehicle quality or reliability. Using less petrol and steering better is a well-established fact in the automobile industry. Aluminum alloy A356 and magnesium alloys AZ91E and AM60A will be proposed for use in the structure study of alloy wheels with 4, 5, or 6 spokes, respectively, as part of the project. The ANSYS software will be used to carry out the structural analysis. Existing data and reverse engineering methods are used to generate a four-wheel Alloy wheel model. IGES files are exported from Catia V5 software and imported into ANSYS Workbench for study of alloy wheel models. After that, the best-performing spokes and materials will be evaluated side by side.

Keywords: Car Wheels, CATIA, ANSYS;

INTRODUCTION TO WHEELS

The invention of the wheel was a watershed moment in human history. From an enormous bearing to a vital feature of every modern transportation vehicle, the wheel has evolved. The vehicle suspension system relies heavily on its wheels to handle the static and dynamic stresses which come with driving. It is a circular device capable of spinning on its axis, aiding movement or transit while supporting a weight (mass). Transport applications are a common source of examples. Friction is reduced to a minimum when a wheel and axle is used to facilitate rolling motion. An external force, such as gravity, or the application of another force, is required in order for wheels to revolve around their axes [1-2].

Many other circular rotating or turning things are also known as "wheels," including ship's wheels, automobile steering wheels and flywheels [3]. When building a mechanical structure, safety and economy are of the utmost importance so that people can utilise them safely and affordably. The aesthetics, weight, manufacturability, and performance of a new wheel are the four most essential components of its design and/or optimization. A combination of cast and forged aluminium alloys and steel are utilized to build the wheels. Titanium has also been used in alloy wheels in the recent past. When there are so many wheel possibilities, how can we decide which one is better? We arrived at this result by applying a generic scenario (loading conditions) to three random designs [4-5].

As a circular device, the wheels' primary principle is to produce rotational movement. Regardless of whether the moment is generated by an internal or external force, it is required for a wheel to spin around its axis. The axle receives power from the rotating wheel, and the wheel's rolling motion reduces friction. Static and dynamic loads will affect on the vehicle while it is in motion, hence the suspension support is critical. Flywheels and steering wheels are common examples of other circular items that make use of this design [6]. The most important considerations while designing a new wheel are weight, manufacturing, and performance. Steel wheels, rally wheels, and alloy wheels are just a few of the many types of wheels available. Steel wheels were the most common kind of

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wheel in the early years, and they were the first type of wheel. Steel wheels are made by welding together multiple sheets of steel and shaping them into a well-defined form. These wheels are substantial and well-built. It's heavier than alloy wheels like aluminium wheels or magnesium wheels, which are lighter. There are two types of steel wheels: Rally wheels and stock wheels. It is stronger and more durable than steel wheels. The inner piece of the steel rim is completely soldered to the rim of the wheel [7-8].

Alloy wheels are widely used production material for automobiles and trucks. Aluminum and magnesium metal alloys are merged to form these rims. Alloy wheels provide a number of benefits over steel or cast wheels, including being lighter while maintaining the same strength, being better heat conductors, having a more attractive look, and having better tire-to-road contact [9].

Having lighter wheels improves the vehicle's handling and reduces the vehicle's unsprung mass. As a result, the suspension is more tightly aligned with the road surface, resulting in increased grip. When compared to steel wheels, it will also cut fuel consumption. Reduced heat loss at the brakes owing to unrestricted air flow is one benefit of good heat conduction, which also helps the braking system under driving circumstances. Aluminum Alloy Wheels and Magnesium Alloy Wheels are two examples of alloy wheels based on the composition of the parent element. Alloy wheels are often made using aluminium, which is a typical alloying material. Heat reduction, low weight, corrosion resistance, and fuel savings are just a few of the benefits of this material [10-11]. The key advantages of using these metals are weight reduction, excellent precision, and a variety of wheel design options. Magnesium alloy wheels have good corrosion resistance and forging and 30% lighter than aluminium. As opposed to aluminium alloys, magnesium alloys have desirable qualities such as low density, high specific strength, and excellent castability. There are several advantages to using magnesium alloy material, including reduced oil consumption as well as a high level of impact resistance and sturdiness in size. Vibrations and noise emissions may be absorbed by the Mg Alloy Wheel since it is light in weight, low in density, and can withstand [12].

PROBLEM DEFINITION AND OBJECTIVE

In today's cars, aluminium alloy wheels are the most common because of their superior heat conductivity. Corrosion resistance, fuel consumption and the weight of the offspring are some of its downsides. Fuel consumption may be lowered by employing magnesium alloy instead of aluminium alloy, and the weight of the wheel is reduced as a result. The major goal of this research is to compare alloy wheels with four, five, and six spokes using new composite materials (magnesium alloy AZ91E, magnesium alloy AM60A, and aluminum alloy A356) [13-15].

LITERATURE SURVEY

Aluminum matrix composites: issues and prospects [16] The merits and downsides, limitations, and possible uses of aluminium matrix composites are all thoroughly studied. The supplies have been used up. S The alloy wheel modelling and analysis for four-wheelers. A parametric model of the aluminium alloy used in four-wheelers is part of this study. A comparison of the model and the aluminium alloy is used to assess the design. Sourav Das is the name of this person [17], Wheels made of lightweight aluminium alloy. The design of automobile aluminium alloy wheels is the subject of this essay. It has created lightweight aluminium and magnesium alloys that transmit heat well. It provided. Magnesium alloys are less ductile than aluminium alloys. This article will examine the material attributes required for automotive applications, the best material for automotive uses, and the welding processes required to attach it [18] Aluminum alloys are the most preferred new low weight material available, according to this survey. Weight reduction in disc wheel rims has been achieved. When comparing static and dynamic stresses and strains in aluminium and magnesium alloys, it was revealed that the aluminium alloy stresses act less and have a greater FOS [19].

MODELLING OF ALLOY

The wheel rim is modelled in two and three dimensions using CATIA V5 commands. A 2D rim profile may be constructed by beginning with the XY plane's origin and rotating the drawing 3600 degrees. The circular pattern feature is used to design the number of spokes in symmetrical sequence. Sharp edges are smoothed using the fillet command, and holes for nuts & bolts are created by taking the surface to be holed and using the fillet command [20].

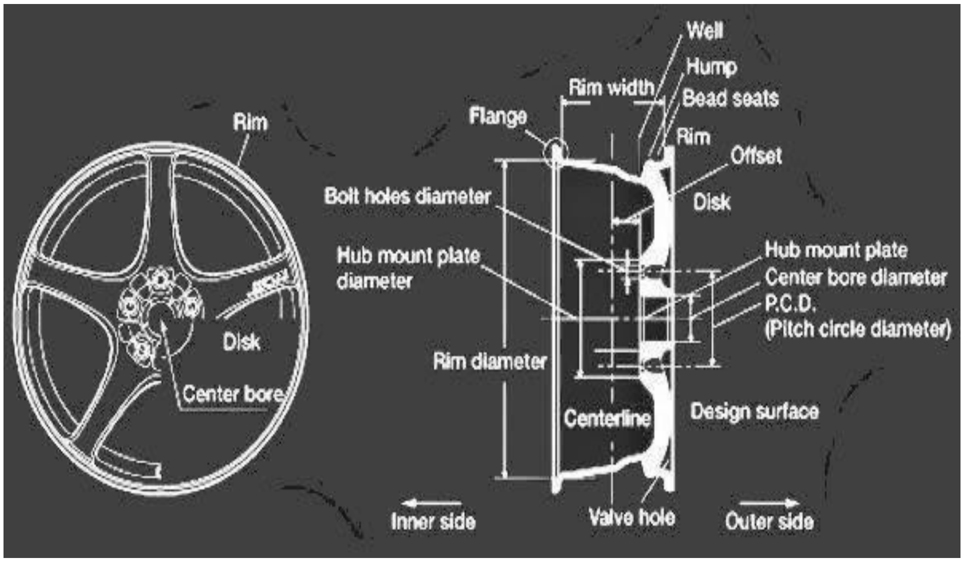

Figure 1. Wheel Specifications

Figure 2. 4 Spokes model of car wheel

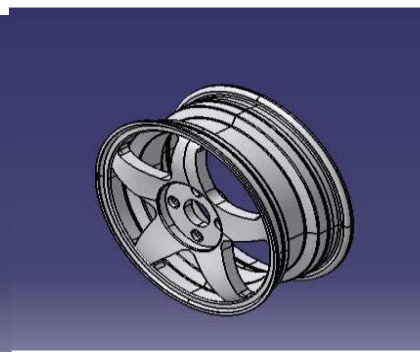

Figure 3. 5 Spokes model of car wheel

Figure 4. 6 Spokes model of car wheel

Table 1: Specifications of alloy wheel

Rim Diameter	14"
Rim width	5.5"
Offset	43mm
PCD	4×100
Centre Bore	54.1mm

ANALYSIS OF ALLOY WHEEL

Static structural analysis is performed using IGES-formatted spokes imported into ANSYS 16. "Static Structural" on ANSYS's workbench is chosen. Geometry and mesh is imported into the model, and then materials are assigned using engineering data. Total deformation, equivalent elastic strain, equivalent strain, and strain energy are calculated.

For complicated systems, Finite Element Analysis (FEA) is a sophisticated approach. Structure and continuous analysis are numerical. When the issue is too complicated for more typical analytical techniques. The Finite Element technique is used to build and solve several simultaneous algebraic problems. The Finite Element Method began with stress analysis. Aside from heat transfer and fluid movement, finite element techniques are used to study lubrication, electric and magnetic fields. Buildings, electric motors, heat engines, ships, airframes, and spacecraft all use finite element techniques. Engineers, physicists, and economists instinctively disassemble complicated systems into smaller, more readily understood elements, and then reassemble the whole to assess its overall behaviour. The Finite Element Method typically portrays a structure as a collection of microscopic components. Individual pieces are easier to comprehend than the system as a whole due to their simpler geometry. In many circumstances, a good model may be built with a few well-defined components. Discrete issues. In other circumstances, the problem can only be stated mathematically as an infinitesimal since the subdivision is infinite. Differential equations or related formulations might imply infinity of components. They're termed continuous systems. FEA can easily predict failures due to unknown stresses by highlighting weak areas in materials and letting engineers comprehend all possible stresses. The production costs would be far lower if each sample was manufactured and evaluated individually. In FEA, many materials may be employed, such as isotropic (same throughout) or orthotropic (same at 90 degrees). The anisotropy is distinct.

FEM is a computer-based simulation that stresses and analyses a material or design in order to provide precise findings. Existing products may be improved as well as new ones are designed using this method. Prior to manufacture or installation, a corporation may verify that a suggested design will meet the client's requirements. Existing products and structures may be repurposed for new use by being modified. It is possible to employ FEA to assist in determining design adjustments in the event of a structural collapse. To perform FEA calculations, a grid of points known as nodes is compiled into a structure known as a mesh. The material and structural qualities of the mesh are programmed to determine how the structure will respond to various loading circumstances. Depending on the expected stress levels in a given place, nodes are distributed throughout the material at a certain density. In general, regions that are subjected to a lot of stress have a greater node density than those that don't. Fracture points of previously tested materials, fillets, corners, intricate details, and high stress locations are examples of potential study targets. The mesh functions like a spider web, with a mesh element extending from each node to each of its neighboring nodes. The material properties of the object are conveyed to the object via a web of vectors.

Aluminum (Al) is the primary metal component in this A356 alloy. Copper, magnesium, manganese, silicon, and zinc are among the alloying element A356 alloys have excellent strength-weight ratio due to which it has wide applications in automobiles. Its material's composition and properties lead to high specific stiffness and tensile strength than other aluminum alloys. It will reduce the weight of the plane and improves fuel efficiency. To create A356 alloys, researchers looked at how these properties may be improved upon. A356 alloys are employed in lightweight and corrosion-resistant engineering components and constructions. There are 7 percent Si, 0.3% Mg alloys with 0.2% Fe (max) and 0.10 percent Zn in the chemical composition of A356 aluminium alloy (max).

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Table 2. Material properties of A356 alloy

Property	**Yield strength**	**Elastic modulus**	**Mass density**	**Poisson's ratio**
Value	195 N/mm^2	72000 N/mm^2	2.7gm/CC	0.33

Other than Magnesium Composite Alloy AZ91E, the most important component of metal is despite its low density, magnesium is a strong metal. It's a low-emissions method that makes use of recyclable materials. However, because to its weak characteristics and high reactivation, pure magnesium is no longer widely utilized. Magnesium's flaw will be remedied by the addition of zinc and aluminium. At room temperature, AZ91E possesses excellent casting and a broad variety of materials characteristics. Magnesium Composite's chemical composition includes 9 percent aluminium, 1 percent zinc, and the rest magnesium.

Table 3. Material properties of Magnesium Composite Alloy AZ91E

Property	Yield strength	Elastic modulus	Mass density	Poisson's ratio
Value	146N/mm2	49913N/mm2	1.85gm/CC	0.35

MESH MODEL

After importing in the geometry, create for mesh

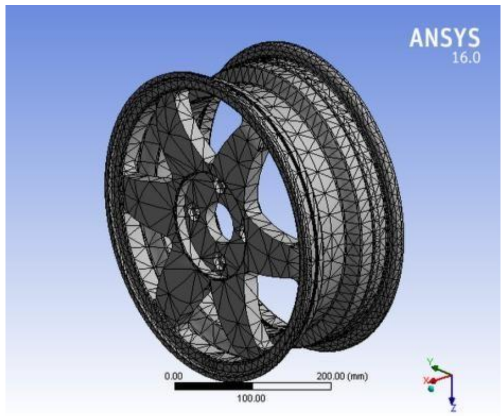

Figure 5. Meshed model

LOADING & BOUNDARY CONDITIONS FOR STATICANALYSIS

The model is subjected to a variety of boundary conditions and loads. Pitch circular holes are restricted for support. The outside surface of the wheel is subjected to a pressure of 0.207 N/mm2 while the inner surface is subjected to force load of 4500N.

- Maximum weight of car is 1462kg to 1825kgConsider in this Mass = 1825 kg
- We have F = M * A (A=9.81 N / KG)F = 1825 * 9.81 F =17908 N
- Total Force of 4 wheels in a car is17908 N
- For 1 wheel in a car is 17908/4 = 4500N

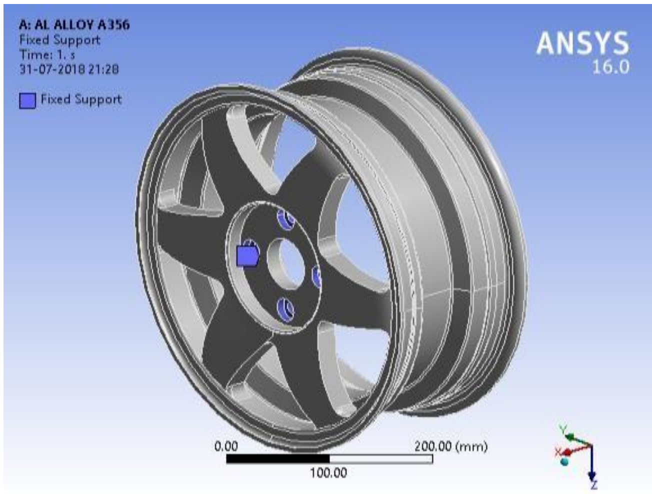

Figure 6. Fixed supports on wheel

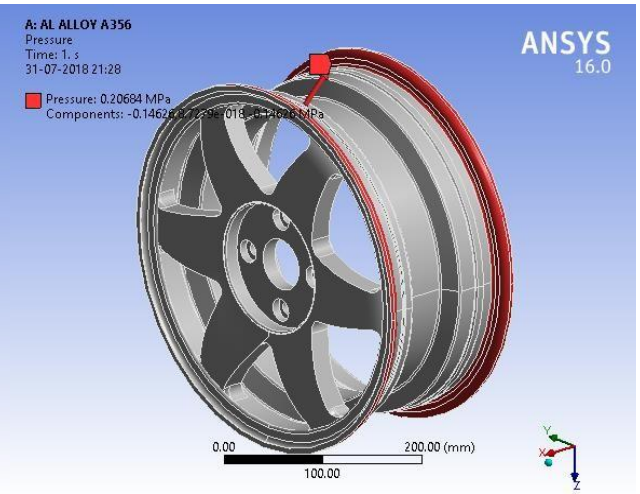

Figure 7. Pressure on wheel

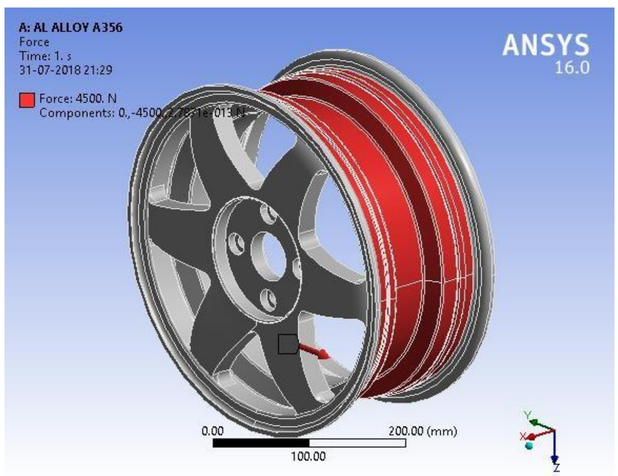

Figure 8. Force load on wheel

RESULTS FOR STRUCTURAL ANALYSIS

Results of Al Alloy A356

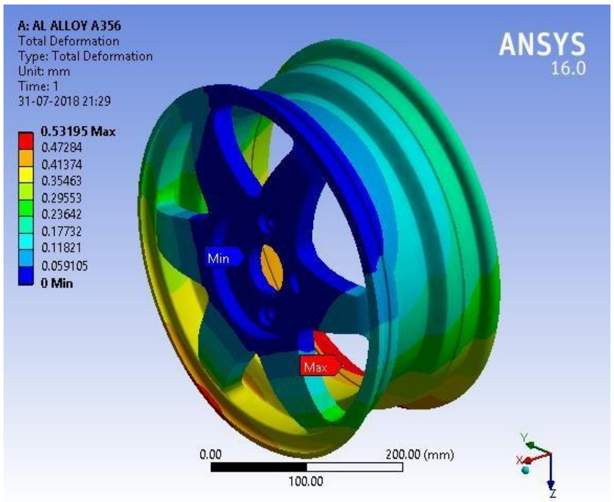

Figure 9. Total Deformation Max:0.53195mm, Min:0 mm

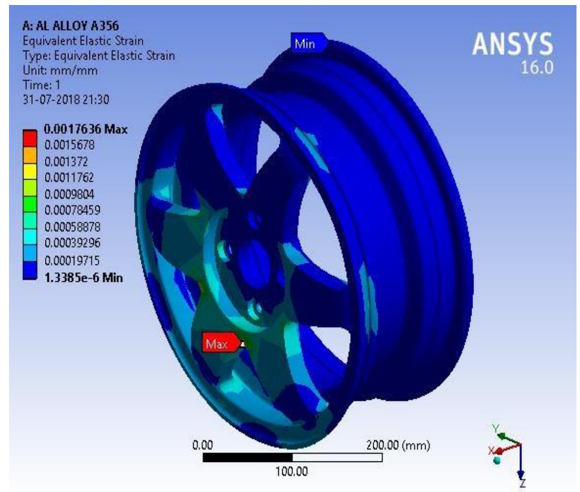

Figure 10. Equivalent Elastic Strain Max:0.0017636mm/mm Min:1.3385e-6 mm/mm

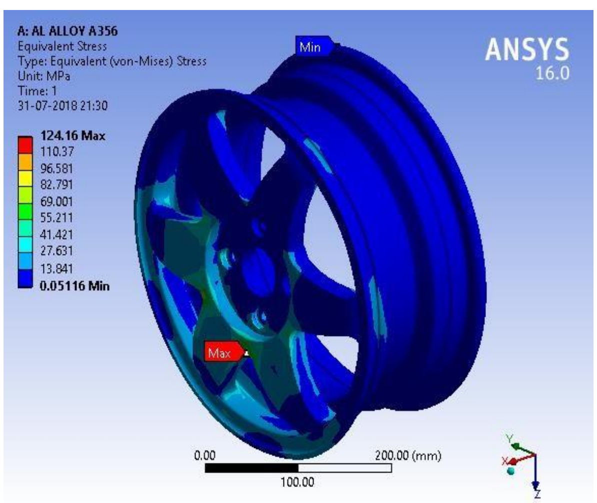

Figure 11. Equivalent Stress Max:124.16MPa Min:0.05116MPa

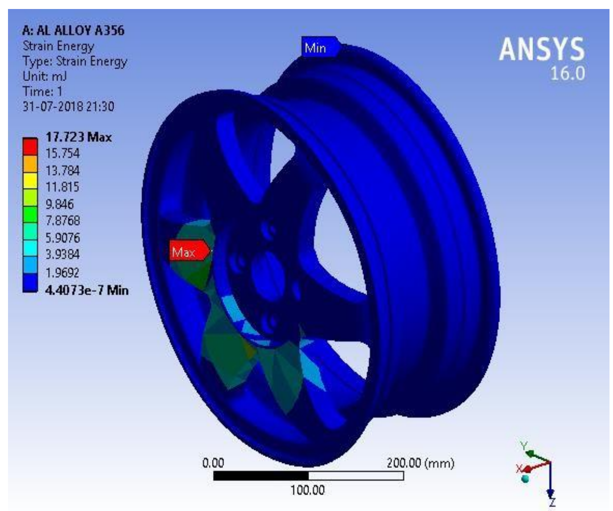

Figure 12. Strain Energy Max:17.732ml Min: 4.4073e-7ml

Results of Al Alloy A356

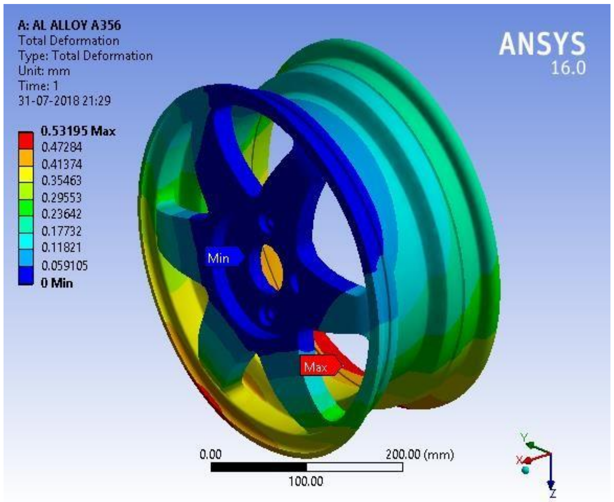

Figure 13. Total Deformation Max:0.53195mm, Min:0 mm

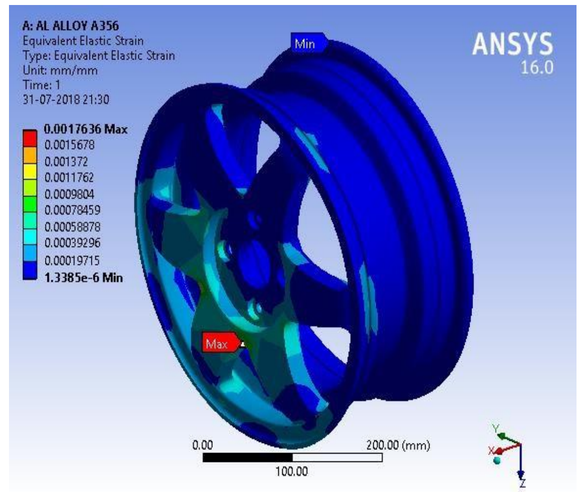

Figure 14. Equivalent Elastic Strain Max:0.0017636mm/mm Min:1.3385e-6 mm/mm

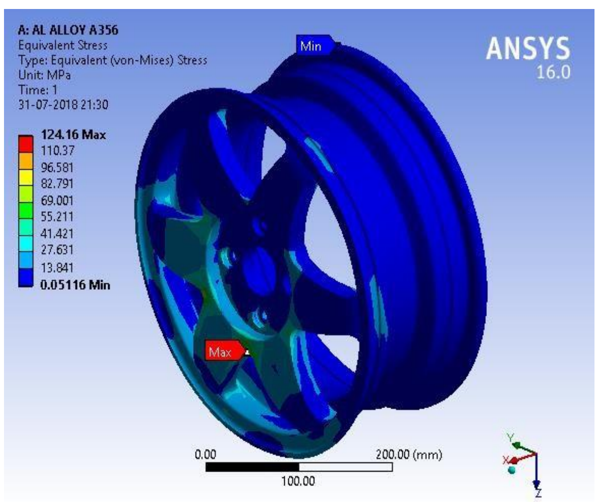

Figure 15. Equivalent Stress Max:124.16 MPa Min:0.05116 MPa

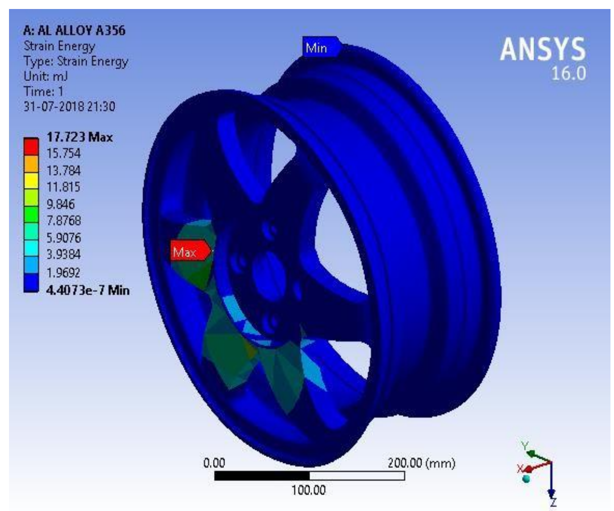

Figure 16. Strain Energy Max:17.732ml Min: 4.4073e^{-7}ml

Displacement, equivalent elastic strain, equivalent stress, and strain energy may be derived from the aforementioned two answers via the process of analysis. Because the bolts are fixed, the rim flanges and hub region exhibit the most deformation in the tables above, whereas the table box 1 shows the smallest deformation. As can be seen in the tables above, the corresponding elastic strain is greatest in the centre and lowest near the spokes (box2). Box 3 contains data illustrating the equivalent stress (von misses), which reaches its highest in the centre and to its lowest at the spokes. The maximum and lowest strain energy are shown in the box4 tables.

CONCLUSION

Rim modelling and analysis has been completed to a high standard of accuracy. To conduct a Radial endurance test, the wheel is examined. Radial endurance is tested under three conditions: pressure, centrifugal, and vertical loads. The wheel is properly restricted, and the loads are computed and applied to the relevant nodes in accordance with the requirements. The stress plot is generated when the wheel is examined under the estimated loading condition. A solid Von Mises stress is generated when the wheel is subjected to pressure loading and radial load, revealing the wheel's maximum stress under pressure as well as the progressive transition from compression to tension around the rim. The graphic illustrates that the design is safe in the situation of centrifugal loading, based on stress distribution and total distribution at various speeds.

The progressive change from tension to compression may be seen in a section plot. The alloy wheel displacement is within 7.5 mm of the experimental measurements. Finally, it can be deduced from the research that speed rises Stress and dislocation are on the rise, while the quality of life is deteriorating.

- The corresponding elastic strain is 1.3385e-6 mm/mm and 0.0017636mm/mm, the equivalent stress is 124.16MPa and 0.05116MPa, and the equivalent strain energy is 17.732ml and 4.4073e-7ml.
- AZ91E Magnesium composite alloy AZ91E material has a maximum deformation of 0.76236mm and a minimum of 0mm, 0.0025396mm/mm equivalent elastic strain, 124.03MPa equivalent stress, and 5.4711e-7ml equivalent strain energy for the six AZ91E spokes, respectively.
- The stress, strain, and deformation in the Magnesium composite alloy AZ91E material for the 6 spokes were within the yield strength, so the alloy wheel material and design are safe, and the load distribution is more at the intersection of the spokes, as compared to each other in the static analysis of alloy wheels.

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