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Title: **4SCOPES, 5SCOPES AND 6SCIPES ALLOY WHEELS DESIGN AND IMPACT AND FATIGUE SIMULATION OF ALLOY WHEELS**

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4SCOPES, 5SCOPES AND 6SCIPES ALLOY WHEELS DESIGN AND IMPACT AND FATIGUE SIMULATION OF ALLOY WHEELS

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ABSTRACT

Alloy wheels are automobile wheels which are made from an alloy of aluminium or magnesium metals or sometimes a mixture of both. Alloy wheels differ from normal steel wheels because of their lighter weight, which improves the steering and the speed of the car. Alloy wheels will reduce the unstrung weight of a vehicle compared to one fitted with standard steel wheels.In the automobile sector, the industries are going to explore the composite material to achieve reduction of weight without significant decrease in vehicle quality and reliability. It is fact that reduction of unstrung weight leads to more precise handling and minimizing the fuel consumption.Composites are the only materials that cater to the never ending demand of the material technology. The aim of the project is to suggest a new composite material Magnesium AZ91E-2%Al_2O_3 to the alloy wheels and evaluate its performance by performing the static & impact analysis in ANSYS.A parametric model is designed for Alloy wheel used in four -wheeler by collecting data from reverse engineering process from existing model.Alloy wheel models are designed in Autodesk Inventor14.0 software, then converted into IGES format and imported into ANSYS Workbench for analysis.Geometry of alloy wheel was optimized to get reduction in weight by performing the shape optimization.

Key Words: Alloy wheel, magnesium composite material, Autodesk Inventor, ANSYS, impact analysis, optimization.

1. Introduction to Wheels

1.1 Wheel

A wheel is a circular device that is capable of rotating on its axis, facilitating movement or transportation while supporting a load (mass), or performing labour in machines. Common examples are found in transport applications [1]. Road wheel is an important structural member of the vehicle suspension system that supports the static & dynamic load encountered during vehicle operation [2].

A wheel, together with an axle overcomes friction by facilitating motion by rolling. In order for wheels to rotate, a moment needs to be applied to the wheel about its axis, either by way of gravity, or by application of another external force [3]. More generally the term is also used for other circular objects that rotate or turn, such as a ship's wheel, steering wheel and flywheel. Style, weight, manufacturability and performance are the four major issues related to the design of a new wheel [4].

1.2 Types of Wheels

- *Steel Wheel*

Steel wheels are the first kind of wheels and also the most commonly used wheels. This wheel comprises of many sheets of steel, moulded into shape and welded typically together. These are strong and heavy wheels. These are commonly found on all types of vehicles. But, its having more weight when compare to alloy wheels such as aluminium wheel, magnesium wheel.

- *Rally Wheel*

Rally wheels are second kind of wheels. These wheels are also steel wheels. But, higher steel gauge for higher strength. The inner section of a steel wheel is usually welded to the rim along its entire circumference.

- *Alloy Wheel*

Now a day an alloy wheels are mostly used in modern car, motorcycle and trucks. These wheels are made from a combination of alloy of aluminium and magnesium metals.

Advantages of an alloy wheels:
1. Lighter weight but similar strength.
2. Good conductors of heat.
3. Trendy appearance.
4.To improve vehicle handling/performance.
5. Good road to tire contact.

As the wheels are lighter the handling can be improved with the help of reducing un-sprung mass. This makes the suspension to follow the ground more closely and it provides more grip. It will also reduce fuel consumption when compare to steel wheels. Good heat conduction can facilitate the heat dissipation from the brakes. So, it improves braking performance in driving conditions [14].

- *Aluminium Alloy Wheels*

Aluminium is the material commonly used for making alloy wheels. It is the metal with features of excellent lightness, thermal conductivity, corrosion resistance, characteristics of casting, low temperature, machine processing and recycling, etc. This metals main advantage is reduced weight, high accuracy and design choice of wheel.

- *Magnesium Alloy Wheel*

Magnesium wheel is about 30% lighter than aluminium and also, excellent for size stability and impact resistance. Recently the technology for casting and forging is improved and the corrosion resistance of magnesium is also improving. Magnesium alloys are considered as the most promising material in 21st century, which possesses attractive properties com-pared to aluminium alloys such as low density, high specific strength and good cast ability. When used as wheel material magnesium alloy are not only able to reduce wheel mass and oil consumption, but also facilitate absorbing vibration and damping the noise emission.

Main properties of magnesium alloy wheels:
1. Light weight
2. High corrosion resistance
3. Low density (1.8 g/cm³)
4. High performance.

2. Problem definition and objective

Problem Definition

Now a day an aluminium alloy wheels are mostly used in vehicles because of excellent thermal conductivity. But, the

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problems in using aluminium alloy wheels are galvanic corrosion, increased fuel consumption and unsprung mass. Using magnesium alloy the unsprung mass of wheel can be reduced compared to aluminium alloy wheel. Therefore, fuel consumption will be reduced, but these alloy wheels are not giving good life at the larger run. In this work, magnesium composite material alloy wheel of a car is modelled and analyzed to overcome the above said problems.

Objective

- New composite material (Magnesium AZ91E-2%Al_2O_3) as an alloy wheel material
- Impact Analysis

3. Modelling of Alloy

CATIA (Computer Aided Three-dimensionalInteractive Application) (in English typicallyarticulated/) is a multi-stage CAD/CAM/CAEbusiness programming suite created by the Frenchorganization Dassault Systems coordinated byBernard Charles. Written in the C++ programmingdialect, CATIA is the foundation of the DassaultSystems programming suite.

Table 1: Specifications of alloy wheel

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

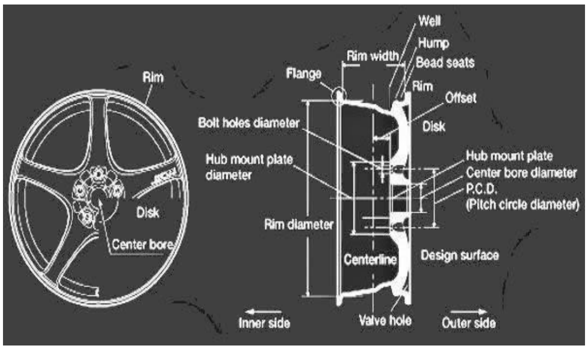

Fig.1: Wheel specifications

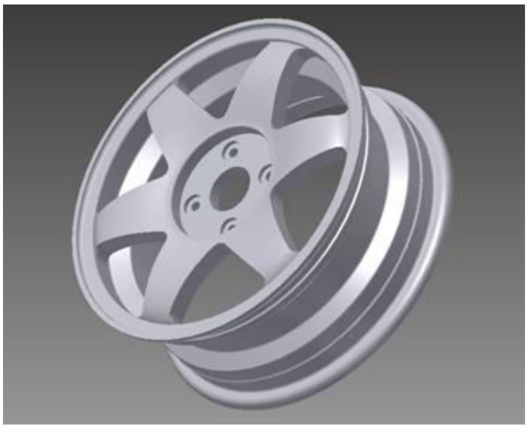

Fig.2: Alloy wheel 3D model

4. Analysis of alloy Wheel

4.1 Static Analysis

Static analysis calculates the effects of steady loading conditions on a structure, while ignoring inertia and damping effects [13], such as those caused by time-varying loads. Static analysis is used to determine the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects [14]. Steady loading and response conditions are assumed; that is, the loads and the structure's response are assumed to vary slowly with respect to time.

I. Material compositions and properties

The AZ91 magnesium alloy is the mostpopular commercially available magnesium alloy. This alloy shows perfect

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cast ability and goodmechanical properties combined with good corrosionresistance for the high purity version of the alloys

<u>Magnesium composite AZ91E-Al_2O_3 :</u>

Base metal- Al 9%

ZN 1% and remaining Mg [17].

Reinforcement - nano particles of Al_2o_3 2% (50µm).

Table 2: Material Properties

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

II. Loading & boundary conditions for static Analysis

- Fixed Supports: The pitch circle holes are constrained in all degrees of freedom [19].
- Pressure Load: Consider 30 psi of air pressure load acting on the outer surface of the wheel [20]. Therefore

  30 = 30x0.4535x9.81/(25.4) 2 = 0.207 N/mm2
- Load: the load of 3800N is applied throughout the inner surface of the hub diameter by taking one middle node.

  Gross weight= kerb weight + passenger weight+ luggage weight =1138+ (5x65) +85 =1548Kgs

  Each wheel carries = 1568/4=387Kgs

  Each wheel load = 387x9.81 = 3796.47 ≈ 3800 N.

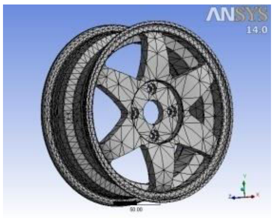

Fig.3: Meshed body

Fig.4: Fixed Supports

Fig.5: Remote Force

Fig.6: Pressure

III. Results for Static Analysis

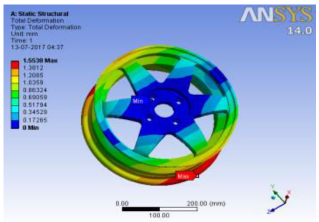

Fig. 7: Total Deformation

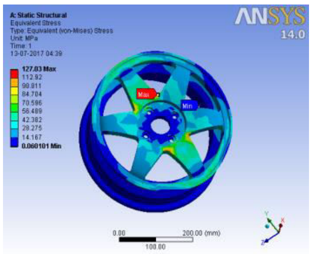

Fig. 8: Von-misses Stress

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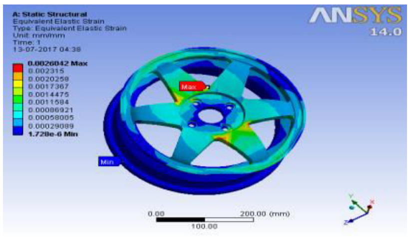

Fig.9: Von-misses Strain

From the above analysis, the results such as displacement, von-misses stress and equivalent elastic strain are obtained. Total deformation of magnesium composite material alloy wheels was shown in above fig.7. Total deformation was maximum at rim flanges and minimum at hub portion because hub area and bolts are fixed. The minimum and maximum deformation is shown in fig.7. Von-misses stress is shown in fig.8, the minimum stress at wheel width and spokes middle area and maximum stress at spokes intersection shown in above von-misses stress fig.8. Fig.9 shows the von-misses strain and it also shows the regions where maximum and minimum strain obtained.

4.2 Impact Analysis

ANSYS Workbench engineering software is used to do the impact analysis. In the impact analysis, the scale of the initial time step is very important. The assignment of the initial time step in the analysis has to catch up completely the dynamic behaviour of the structure.Due to the test standard, the contact area between impactor and wheel rim cannot be smaller than 375 mm X 125 mm. The mass of the impactor must be adjusted to match with the size of the wheel rim. In this analysis, the size of the impactor in the finite element model shown in Figure 23 is similar to that used in the standard test. The contact area in the Figure 3 is 400mm X 150mm, the length of the impactor is 1223 mm, and the mass is 576Kg. The material of the impactor is the following: Young's modulus is 2X10^5 Mpa, Poisson's ratio is 0.3, the density is 7.85X10^-6 kg/mm^3, Yielding strength is 250 Mpa and Ultimate strength is 460 Mpa.Based on the test standard, the height of the impactor above the wheel rim must be 230 mm, but in the simulation the distance between them is adjusted to be 0 mm for saving the computer time, therefore, the potential energy is transferred to be a kinematic energy that the initial velocity of 2124.29 mm/s is assigned on the impactor.

$v = 2gH = 2 \times 9810 \times 230 = 2124.29mm / s$

Pressure of 30psi was applied on the wheel upper surface and fixed supports at the bolts and hub.

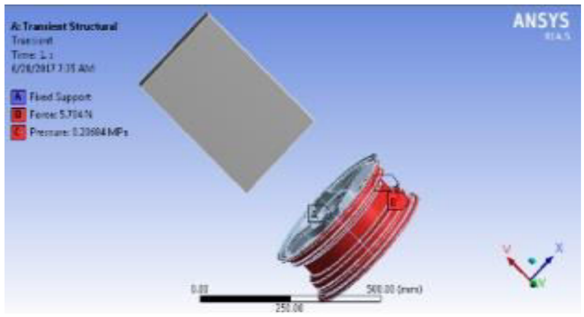

Fig .10: Impact Loading

4.3 Impact Analysis Results

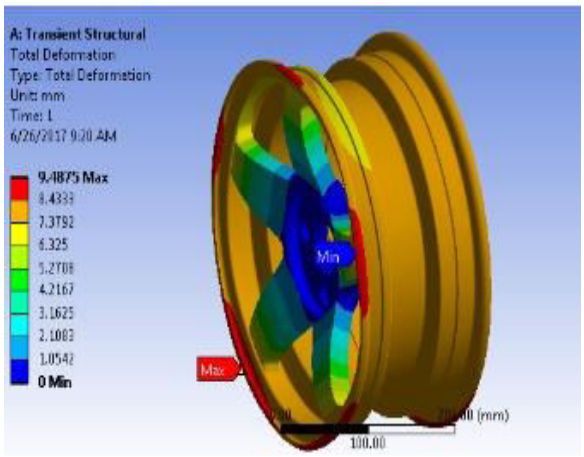

Fig. 11: Total Deformatin

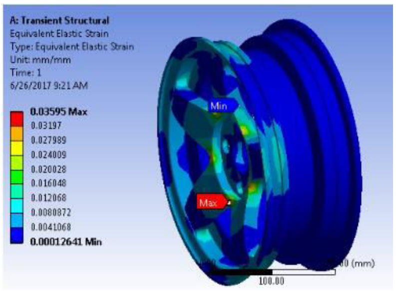

Fig. 12: Equivalent strain

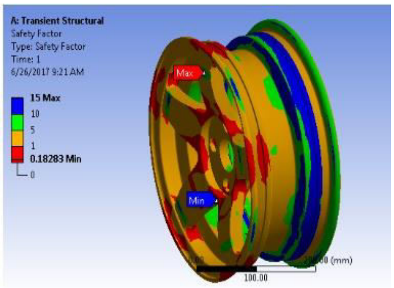

Fig. 13: Safety factor

By performin the above analysis the results such as total deformation, strain and safety factor. By the effect of impactor the total deformation shown in fig.11 was maximum at front flange portion and minimum at hub area and spokes. The equivalent strain was maximum at width and minimum at spokes intersection as shown in fig.12 and the locations where safety factor maximum and minimum was shown in fig.13.

5.1 Analysis for optimized Alloy Wheel

Static Analysis was carried out for the optimized design of magnesium composite material. Boundary, loading conditions and procedure were same as before optimization.

5.2 Analysis Results after Optimization

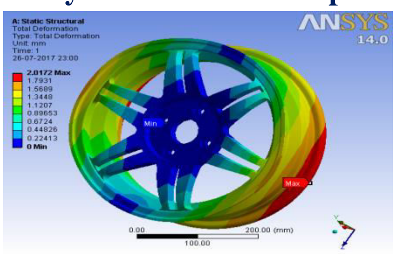

Fig.18: Total deformation

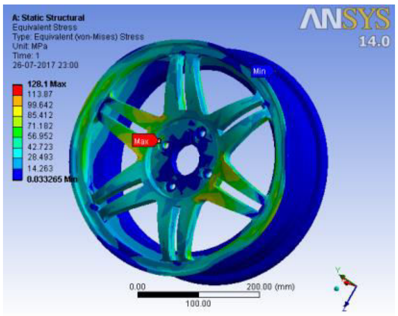

Fig.19: Von-misses stress

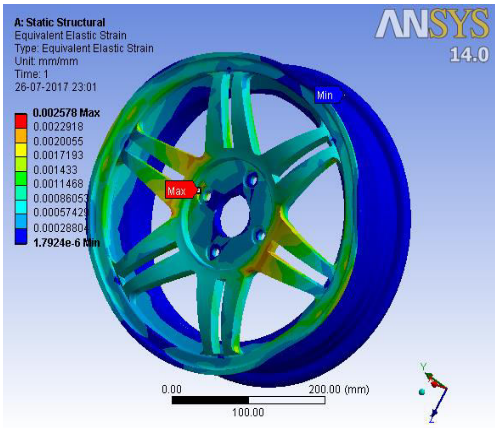

Fig.20: Von-misses strain

5. Results and Discussions

From the static analysis minimum deformation of Magnesium AZ91E-2%Al_2O_3composite material alloy wheel was 0mm and maximum deformation of 1.5538mm, minimum von-misses stress of 6.0101e-002Mpa and maximum of 127.03Mpa, minimum &maximum von – misses strain of 1.728e-006&2.6042e-003 were obtained. Stresses obtained in the wheel were within the yield stress so the design and material were safe.From the impact analysis total deformation, stress, strain and safety factor were obtained. Total deformation of 0mm minimum and 9.4875mm maximum, minimum von-misses strain of 0.0001264 and maximum strain of 0.03595, and safety factor of 0.18283 was minimum & 15 was maximum. Stress concentration was maximum at front flange portion.

6. Conclusion

The results such as stress, strain and deformation obtained in static analysis for the alloy wheel of Magnesium AZ91E-2%Al_2O_3 composite were within in the yield strength so the material and design for the alloy were safe. Stress concentration was higSn at spokes intersection.For the impact analysis also the material withstands the applied loads and stresses produced are within in the limit of safety. Stresses are concentrated at flange portion in impact analysis.

For all analysis the material performance was good. So, the new Magnesium AZ91E-2%Al_2O_3composite material to be successfully used as an alternative material for the alloy wheels of four-wheelers.

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