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Analysis and Development Characterisation of Automotive Wheels

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ABSTRACT:

The Rim is the "outer edge of a wheel, holding the tire". The importance of wheels and tires in the automobile is obvious. Without the engine the car may be towed but even that is not possible without wheels. The wheel along with tire has to take the vehicle load, provide a cushioning effect and cope up with the steering control.Materials are playing increasingly important role in automotive, aircraft, defense and electronic consumer products because of light weight and associated attractive engineering properties. Magnesium alloys wheels in automobiles reduce the weight of vehicle and offer improved safety by shortening braking distances and deliver higher acceleration rates as well as improving mileage.

The requirements of the automobile wheel include strength, ductility, toughness, fatigue strength and corrosion resistance. The main objective of this work is to determine the finite element simulation of SAE wheel impact test and also essential to shorten the design time and enhance mechanical performance and lower development cost .This thesis, the CAD model of the wheel is prepared using CATIA V5 and Finite element modelling will be done using HYPERMESH. The Simulation will be carried out using ANSYS. The wheel rim should pass the following tests, in order to use it for the intended purpose. Structural analysis of automotive wheel of development magnesium alloy through FEM and finite element simulation of SAE standard vehicle wheel impact test are conducted to validate the suitability of the material for the application. The results of the structural analysis by considering the above mentioned load cases will be presented. Also alternative designs to reduce the weight of the wheel rim without hindering its structural integrity will be checked.

INTRODUCTION:

Today, the transportation sector is responsible for major part of total petroleum consumption and carbon emissions in the environment. The lavishness and safety features of recent cars have witnessed an increase in vehicle weight, which enhances the fuel consumption and CO_2 emission. The weight of the vehicles has increased by an average of over 20% in the two decades. Most of the increased weight constituents increased the engine size along with the addition of safety features. A general rule of thumb is that for every 10% reduction in vehicle weight, the fuel consumption of vehicles is reduced by 5-7%.

LITERATURE SURVEY:

Automobile wheels have in the time period spanning the last five decades progressively evolved from the early spoke design of wood and steel the carryovers from wagon and bicycle technology, flat steel discs, and more recently stamped metal configurations. The three basic elements of a wheel are the hub, the spokes and the rim. Sometimes these components will be one piece, sometimes two or three.Steel wheels are usually pressed from sheet metal and then welded together. They are still found on many cars since they are inexpensive, durable and flexible, but also heavy.Aluminum wheels were introduced for styling reasons, to give upper class or flagships models a distinctive personal touch. In addition, its low weight and thus the resulting reduction in the unsprung mass ensured also a superior ride quality.In the design phase of an aluminum wheel, the following characteristics must be considered:

1. Stiffness- The structural stiffness is the basic engineering parameter to be examined when designing an aluminum wheel which offers at least the same vehicle performance as an equivalent steel wheel.

2. Static performance (strength)- In order to avoid any deformation under maximal axial (accelerations and braking) and radial stresses (turning), the yield strength of the material must be considered.
3. Fatigue behavior- The fatigue performance is the most important parameter for wheel dimensioning.
4. Crash worthiness- Numerical simulation methods are more and more used for the design of wheels for crashworthiness.

AUTOMOTIVE ALLOY WHEEL STRUCTURAL ANALYSIS:

Static analysis structural 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.

FINITE ELEMENT SIMULATION OF WHEEL IMPACT TEST:

Wheels used in passenger cars should essentially pass three types of tests before selling in the market, such as dynamic cornering fatigue test, dynamic radial fatigue test, and impact test.

CURRENT AND POTENTIAL APPLICATIONS OF MAGNESIUM:

The automotive application of Mg alloy is currently drawing much attention of motor vehicle industries because legislation limiting emission has triggered the serious requirement of weight reduction.

Magnesium alloys show a great potential and a number of challenges to successful use in automotive structures due to its main benefit of extra weight reduction.

MG ALLOY WHEELS IN AUTOMOBILES:

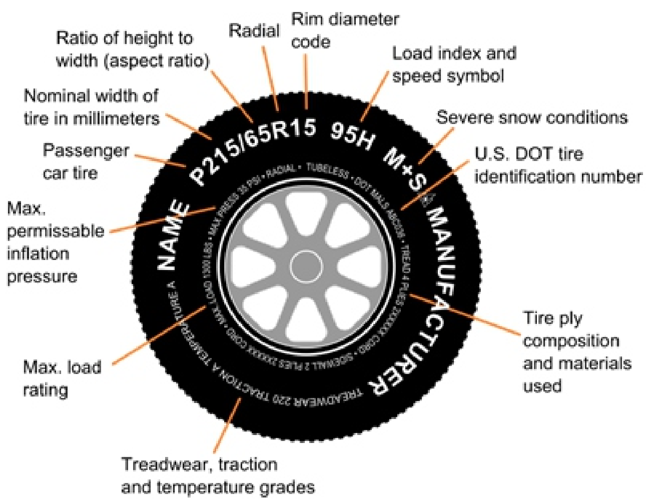
When used as wheel material, Mg alloys are not only able to reduce the wheel mass and save oil, but also facilitate absorbing vibration and damping the noise emission, enhancing accelerating and braking performance, thus improving the resultant riding comfort.

MAGNESIUM ALLOYS DESIGNATION:

Pure magnesium is rarely used in the manufacturing of aerospace and automotive parts. In order to be used in manufacturing, it is alloyed with other metals. Some of the most common alloyed elements in commercial alloys are: aluminum, zinc, cerium, silver, thorium, yttrium and zirconium.

In order to name magnesium alloys, the American Society for Testing Materials developed a method for designating the alloys.An optional letter indicating construction of the fabric carcass of the tire:

1- or 2-digit number: Diameter in inches of the wheel that the tires are designed to fit. There is the rare exception of metric-diameter tires, such as the use of the 390 size, which in this case would indicate a wheel of 390 mm in diameter. Few tires are made to this size presently. The number may be longer where a half-inch size is used, for example many heavy transport trucks now use 22.5-inch tires.



Schematic of the Representation of wheel

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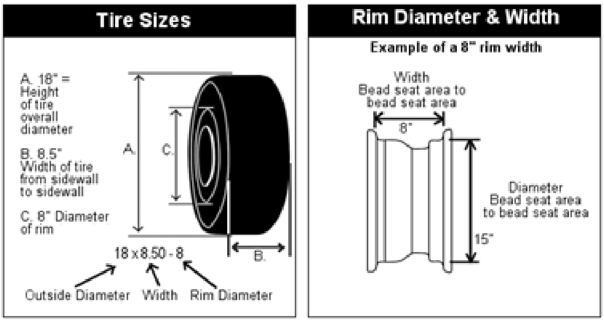
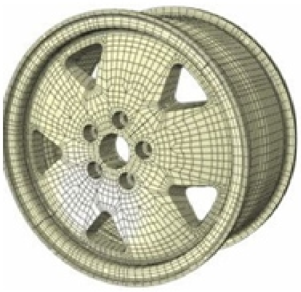
General overall dimensions and coding systems:



Overall dimension of wheel

Minimum performance standards:

In order to pass the impact test, the wheel must meet the following minimum performance standards: There will no visible fracture of the central member of the wheel assembly, no separation of the central member from the rim, no sudden loss of tire air pressure and deformation of the wheel assembly, or fracture in the area of the rim section contracted by the faceplate weight system do not constitute a failure (International standard).



Meshed geometry of Wheel rim

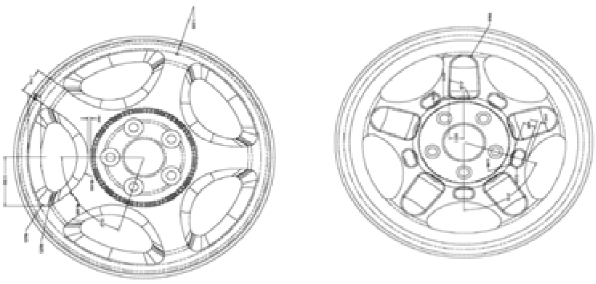
Method for validating the finite element model:

In order to validate the finite element model the structural analysis of automotive rim [5] in 2000 is taken as reference and the results are compared. He has validated his finite element model with experimental results. Ford 16" SHO style aluminum spooked wheel was modeled for this study. After validating the finite element model, it is used to conduct the structural analysis of Mg alloy wheel with the mechanical properties of the AZ80+1%Nd (T6 heat treated), i.e., the same wheel geometry and loading conditions will be used to simulate the structural analysis of Mg alloy wheel.

Test set up

Solid modeling of wheel:

Solid model of the wheel was created in Catia R19.

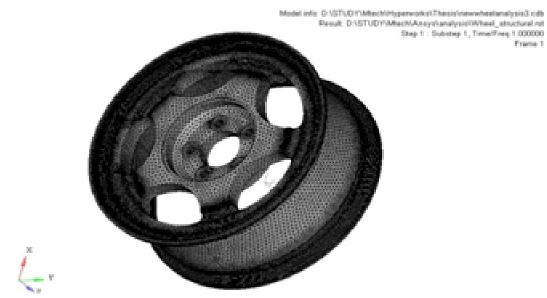


Front view profile of the rim,

Back view profile of the rim

Meshing of the wheel model

The solid model created in Catia V5 is imported to Altair Hypermesh V.11 in IGES format and is meshed using 10 noded tetrahedral elements



Loads and boundary conditions
For the wheel model shown in figure 6.9,
Radius of the bead seat, rb = 202 mm
Width of the bead seat, b = 19.8 mm
Total radial load, W = 10.4 kN (The radial load applied to the wheel in the experiment)
Angle of loading, θo = 400
Therefore, the peak value of the distributed pressure, Wo will be obtained from eqn (6.5) as

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$$W_0 = \frac{10.4\times1000\times180}{19.8\times202\times8\times40}$$

$$= 1.462 \text{ MPa}$$

The main assumptions of the finite element simulation of dynamic wheel impact test in the present study are

1.Reduction in kinetic energy of the striker to compensate for the tire absence is assumed to be 20%.

2. Friction between the striker and the wheel was neglected in the simulation, since impact test is a high-speed and short-duration event.

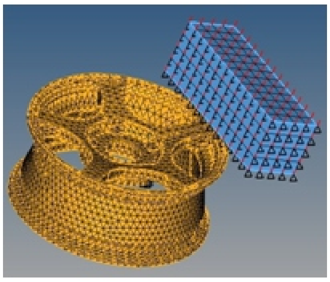

Fig 7.16 Finite element model after applying all the loads and boundary conditions for the simulation of dynamic impact test of aluminium wheel

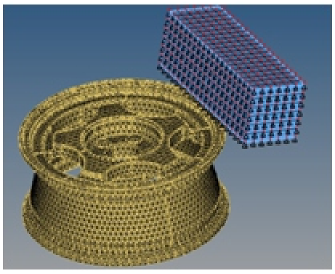

Fig7.17 Finite element model after applying all the loads and boundary conditions for the simulation of dynamic impact test of Mg AZ80+1%Nd (T6 heat treated) alloy wheel

Finite element models of the automotive wheels after applying all the loads and boundary conditions for dynamic impact test simulations of aluminium alloy wheel and Mg AZ80+1%Nd (T6 heat treated) alloy wheel.
The critical strain energy density for the aluminium wheel is
Wp = 41.21 Nmm/mm3.
For Mg AZ80+1%Nd (T6 heat treated) alloy wheel the values of σf, εf, and n are obtained from figure 5.4 as εf = 0.031, σf = 166.654 MPa, and n = 0.254549.
critical strain energy density for the Mg AZ80+1%Nd (T6 heat treated) alloy wheel is found out as
Wp = 4.118 N mm/mm3.

CONCLUSION:

Development of a suitable Magnesium alloy automotive alloy wheel is done. Magnesium alloy AZ80 is selected as the base alloy for this study since it is a medium strength alloy with good corrosion resistance, comparatively low cost and very good forging capability which offers an affordable commercial alternative to the Mg ZK60 alloy used for wheels in car racing. In order to improve the mechanical properties of permanent mould gravity cast AZ80, Considering the ultimate strength and yield strength of T6 heat treated AZ80+1% Nd alloy, which are higher than the corresponding values of all other alloys, this alloy is proposed for the automotive application as wheel material for the Ford 16" SHO style spoked wheel model used in this study. The comparison of weight of aluminium A356 alloy wheel and the AZ80+1%Nd alloy wheel showed that the total weight of the four wheels can be effectively reduced by using AZ80+1%Nd alloy wheels in the place of aluminium wheels due to the lower density of magnesium alloy.

The Finite Element structural analysis of AZ80+1%Nd (T6) alloy wheel showed that the maximum stress acting on the wheel is very much lower than the yield strength. The Finite Element simulation of dynamic wheel impact test of AZ80+1%Nd (T6) alloy wheel showed that the strain energy density and the equivalent plastic strain are lower than the critical values, thereby qualifying the alloy.This study reveals that AZ80+1%Nd (T6) alloy is a suitable material for the application of permanent mould gravity cast automotive wheel. The weight advantage gives an edge over aluminium alloy for such automotive applications in terms of better fuel saving and drivability.

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