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Design, FEM Analysis and of Alloy Wheel Rim of a Four Wheeler

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Abstract: Wheel is a main mechanical term of the vehicular suspension system that supports the static and dynamic loads encountered during vehicle action. Since cars carry heavy loads of occupants as well as self-weight, the alloy wheel rim should be strong enough to withstand this load. Thus, their design should be done very cautiously. While designing such main kind of automotive component taking care of protection and cost are very important concerns so that user can use it safely. Major five technical considerations while modelling any new alloy wheel rim are styling, aesthetic, mass, manufacturability and capability. While analysing stress and displacement distribution in vehicle wheels subjected to increase pressure and radial load .essential efforts have been taken to discover the Finite Element Techniques. Alloy wheel rim has been designed using Creo software, after that static structural analysis is done with different materials, load and boundary conditions using ANSYS Software. At last the results of total deformation and equivalent stresses are obtained for different wheel rim materials and compared with each other. Thus, the best material can be selected for manufacturing of the wheel rim.

Keywords: Wheel rim, creo, ANSYS workbench, solid model, finite element technique, static analysis, static loading

I. INTRODUCTION

Alloy wheel rims are automobile wheels which are made from an alloy of aluminum or magnesium metals or sometimes a mixture of both. Difference between Alloy wheels rim sand normal steel wheel rim is due to their low weight, which improves the routing and the velocity of the car. Initially light-alloy wheel rims were made of magnesium alloys. Although they miss approval on regular vehicles, they remained famous in 1960s,

Different types of Wheel –

1. Alloy wheel
2. Steel Wheel
3. Mag Wheel
4. Ralley Wheel
5. Spoke Wheel

Fig 1. Alloy wheel rim

At present four wheeler wheels are made of Aluminum Alloys. In this theory AL is replaced with ZA due to its less cost and its density is less compared with that with AL. Due to less density, the wheel weight also get reduced due to zinc alloys. Static analysis is done on the wheel rim. Design is optimized by analyzing the model in ANSYS. Steel and light alloy are the foremost materials used in a wheel rim however some special wheels composite materials are being used together with glass-fiber.

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a) Wire Spoke Wheel - This is a needed where the exterior edge part of the wheel (rim) and the axle mounting part are linked by numerous wires called spokes. Currently automobiles with their high horsepower have made this type of wheel manufacture obsolete. In classic vehicles this type of wheel is used. Low weight alloy wheels have evolving in latest years, a design to give importance to this spoke effect to fulfill user's style requirements.
b) Steel Disc Wheel - This is a rim which follows the steel-made rim and the wheel into one by welding, and it is mainly used for passenger vehicles.

c) Light Alloy Wheel –With use of light metals these type wheels are developed, These wheels speedily become usual for the OEM in Europe in 1960's and for the replacement tire in US in 1970's.

1. Aluminium Alloy Wheel- Aluminium is a metal with properties of good lightness, corrosion confrontation, thermal conductivity, physical characteristics of casting, low heat, machine handling, etc. Its main advantage is high precision and design choices of the wheel. This metal is useful for energy preservation because we can easily recycle it.
2. Magnesium alloy wheel- Magnesium alloy wheel used because of its low weight than aluminium and also worthy as for solidity and impact fight. However, it is restricted to use in racing only, which needs the features of weightlessness and high strength at the cost of weathering resistance and design choice, etc compared with aluminium.
3. Titanium alloy wheel- Titanium is an admirable metal for corrosion resistance and strength (about 2.5 times) compared with aluminium, but it is poorer due to machine processing, designing and it is very costly. It is still in the development stage even though it is used in racing.
4. Composite material wheel –There is difference between the composite material wheel and light alloy wheel, and it is developed mainly for low weight. However this wheel has poor heat consistency and having good strength.

II. MANUFACTURING METHODS

Alloy wheel rims are mass-produced by using below methods -

Forging - Wheel rims produced by this method are usually of higher toughness and ductility than aluminium wheels, although it is very costly.

1. One Piece Rim –In this type of method casting or forging done at the same time by one as for the rim and disc.

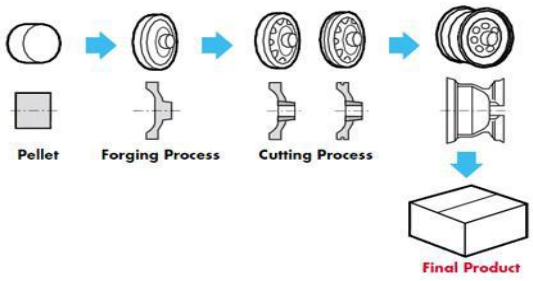

Fig 2.Forging method (for one piece rim)

2. Two Pieces Rim-This is the method which separately manufacture the rim and disc same like making of the steel wheel and these components are welded after.

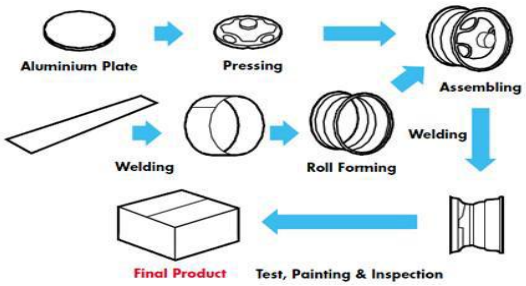

Fig 3. Forging method (for two pieces rim)

High pressure die casting -

In HPDC die placed in a big machine which carries great closing force to hold the die in close condition. The molten magnesium is pour into a filler tube. With the help high speed and pressure, piston pushes the metal into the die, the magnesium solidifies and then after opening the die wheel is released from it. Wheels formed by this method can offer

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decreases in price and excellences in corrosion resistance but they are less ductile and of lower strength due to the nature of HPDC.

Low pressure die casting -

This process usually works a steel die; it is arranged above the crucible filled with molten magnesium. Normally the vessel is sealed against the die and pressurized air gas mix is used to force the molten metal up a straw. This kind of method can advances in ductility over HPDC magnesium wheels and any cast aluminium wheels, also it is less ductile than forged magnesium.

Gravity Casting -

These are in production because of it can be drawn into thin wires so it is using since the 1921s, and relative properties above what can be made with aluminium casting. Tooling costs is cheapest for this than any other process. This has allowable small batch production, flexibility in design and short development time.

III. LITERATURE REVIEW

According to Karthik A.S. et al. (2016) [1] Finite Element Techniques are used to find out stress and displacement distribution in vehicle wheels subjected to increase pressure and radial load. The model was made using "CATIA V5" and the analysis was done through "Ansys workbench" finite element package. After comparing the results of different Material model selected like magnesium, aluminum, and titanium are used to check the capacity of the wheel.
According to Jaspreet Singh, et al. (2015) [2] they analyzed Alloy Wheel by static loading using Ansys15.0 and the summery of this Paper was, FEA was performed on aluminum alloy wheel. The results of the von-misses stress, factor of safety, and total displacement were calculated. Also using reverse engineering results obtained are fine for the design.
According to Meghashyam-et.al (2013) [3] model of the wheel rim was created with the help of CATIA software. Later this CATIA model was imported to ANSYS for analysis work. With the help of ANSYS software the different forces, pressure acting on the component and also for calculating the results. ANSYS static analysis work was done by two different materials taking into consideration like aluminium and forged steel and their relative performances have been observed respectively. Also rim was subjected to modal analysis, a part of dynamic analysis was performed and performance was observed. In this they observed the results of static and model analysis, and forged steel was suggested as best material.

IV. PROBLEM DEFINITION

Every two wheeler and four wheeler is having Alloy wheels and Rim. There are many factors which we need to consider for Problem Statement. The stated problem here is to analyse the equivalent stress and deformation for the given on the aluminium alloy wheel. The loading conditions for finding the stress and displacement on the wheel is as stated below. In this theory a wheel is designed used in a four wheeler. Present used material for wheel is aluminium alloys, so in this aluminium alloys are replaced with zinc alloy due to its less cost and its density is less compared with that of aluminium. Due to less density, the wheel weight also gets reduced. And also the zinc alloys is more strengthen than that of aluminium alloys.

V. DESIGN CALCULATIONS

Considering the dimensions of TATA Indica vehicle alloy wheel rim.

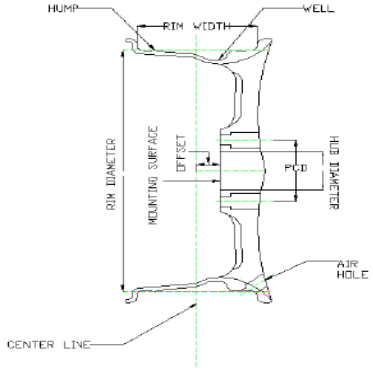

Fig 4.2D Diagram of aluminum wheel rim

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Table 1. Specifications of Alloy wheel rim of TATA Indica

Sr.No	Parameters	Value
1	Rim diameter	350mm
2	Bolt circle diameter	87mm
3	Hole circle diameter	240mm
4	Width of rim	122mm

Wheel rim is similar to Pressure vessel hence it is subjected to the following stresses.

Radial Load:
Fr = F*K
Where,
Fr = Radial load
F = 3240 N
K = 2.25 as per Industrial design
Fr = 3240*2.25
=7290 N

Angular Velocity:
ω = V/r
V= 80km/hr = 22.22m/s
r = 0.235
ω= 94.55 rad/s

Circumferential stress /Hoop stress:
σ_c = P*d/2t
= 0.5*350/8
=21.87 N/mm2

Longitudinal Stress:
σ_c = P*d/4t
= .5*350/16
= 10.9 N/mm2

VI. MODELING AND ANALYSIS OF ALLOY WHEEL RIM

Modeling of alloy wheel rim:

The 3D model of alloy wheel rim is created in Creo 2.0software using the dimension measured form actual 14 inch alloy wheel rim of TATA Indica car. It is as shown in Fig 5.

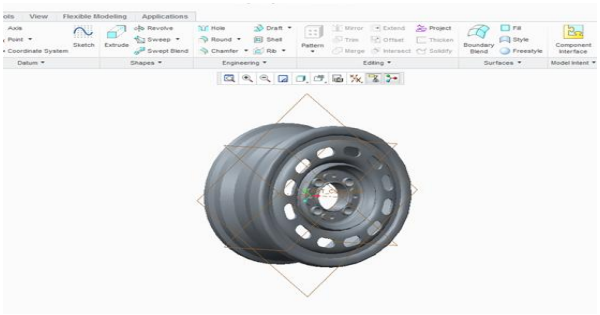

Fig 5. 3D model of alloy wheel rim in creo 2.0

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Static structural analysis of alloy wheel rim:

The 3D model alloy wheel rim created using creo software is imported in ANSYS 17.0 software. It was meshed and applied boundary conditions as shown fig 5 and 6 respectively

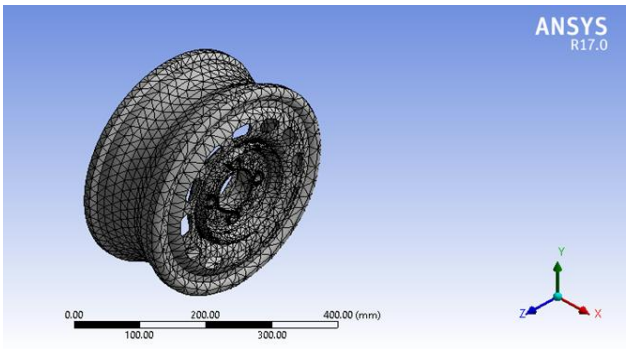

Fig 6. Meshing of Alloy wheel rim

Boundary conditions are applied to the meshed alloy wheel rim which includes force boundary conditions and restriction boundary conditions. It is as shown in fig.4

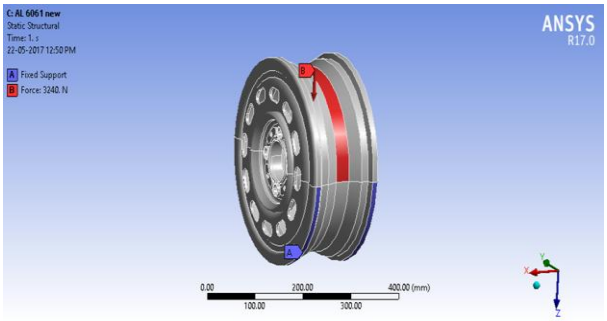

Fig 7. Boundary condition for Alloy Wheel rim

The static structural analysis was done by applying the material Mg result obtained are as shown in Fig 8.

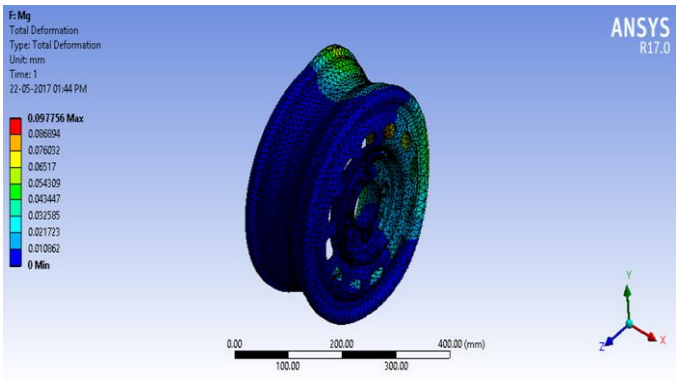

Fig 8. Total deformations in Mg

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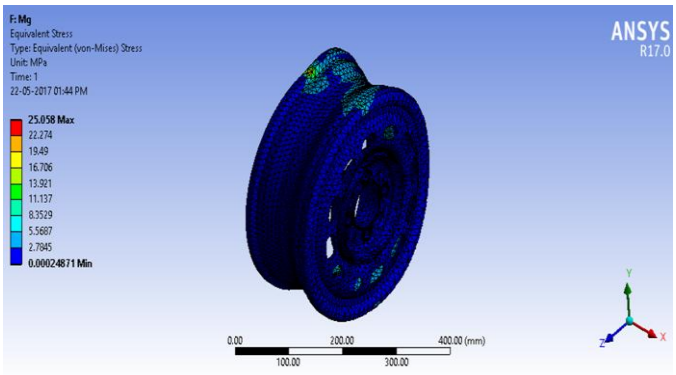

Fig 9. Equivalent stresses in Mg

The static structural analysis was done by applying the materials namely Aluminium 6061 and ZA 21.Results were obtained for total deformation and equivalent (Von-misses) stress for the material as shown in fig 10, Fig 11, Fig 12, Fig 13 respectively.

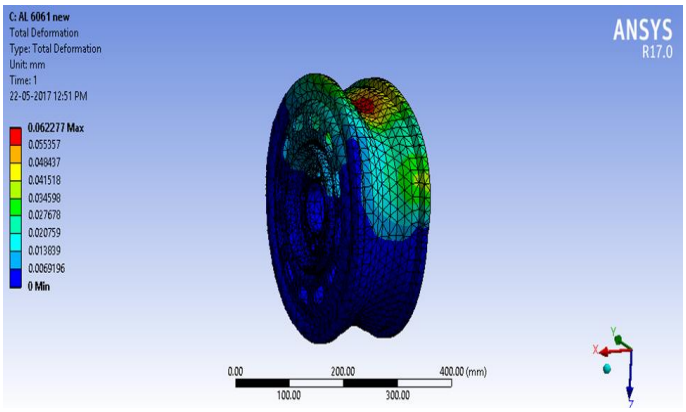

Fig 10.Total deformations in AL 6061

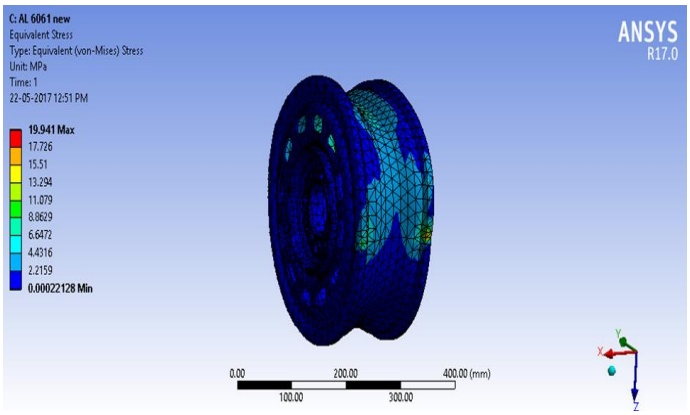

Fig 11. Equivalent stresses in AL 6061

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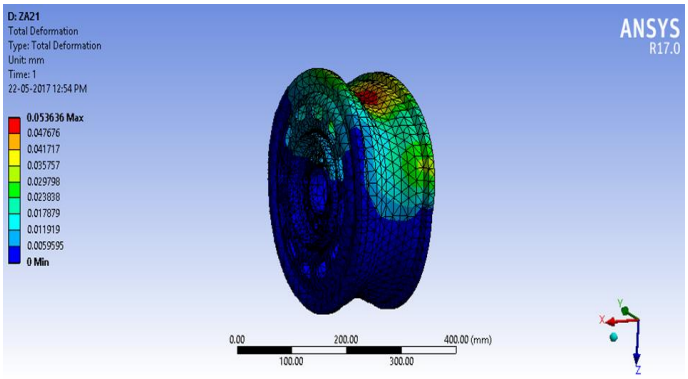

Fig 12. Total deformations ZA21

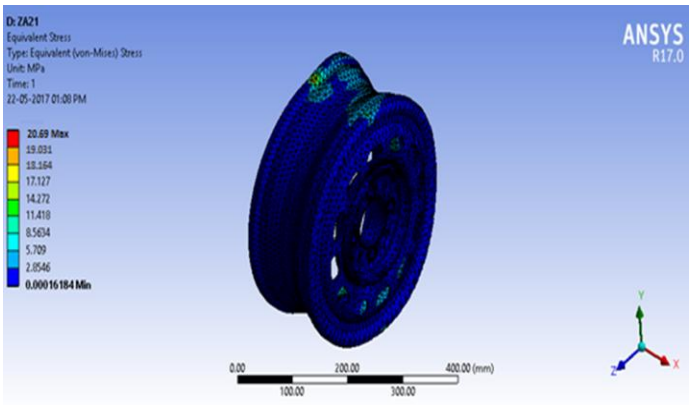

Fig 13. Equivalent stresses in ZA21

Comparison of analytical results:-

Materials	Total deformation (mm)	Equivalent Stress (Mpa)
AL 6061	0.0622	19.941
ZA 21	0.0536	20.69
Mg	0.0977	25.058

Table 2. Comparison of analytical results

VII. CONCLUSION

The maximum total deformation and Equivalent stress obtained are lowest at 0.0536 mm and 20.69 respectively for ZA21. Hence it is the best suitable material for manufacturing Alloy wheel rim. Also selection of an optimum material for alloy wheel rim (material as Zinc) can be done which will increase their strength, fatigue life (endurance limit), reliability and reduce the overall weight and cost.

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