ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Design & Structural Analysis of 4-Wheeler Rim by Material Optimization

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ABSTRACT
This project deals with the design and structural analysis of a 4 wheeler rim of a Maruti Suzuki Alto car by material optimization. The materials such as structural steel, aluminium& magnesium alloys. The main motive of our project is to analyze the traditionalwheel rim of a Maruti Suzuki Alto car by the optimization of above materials. The design of the wheel rim is done over CATIA software. And further the Static and dynamic structural analysis was carried out to test the Total deformation, Directional deformation & Equivalent Stresses in the Rim using Finite Element Analysis software named ANSYS.

INTRODUCTION:
The Invention of wheel falls in the late Neolithic era in 2200-3300 BCE. This invention was one of the most groundbreaking event that took place in the human history. The first wheel was made from wood carved into a circular shape with a hole at the center to attach the axle. These axle with the wheels were attached to a wagon and was used for transportation purpose. After a few years the domestic animals were used to draw the wagon. As the years went by the use and the design of the wheel progressed. During the Industrial revolution the wheels became the important elements which shaped and advanced the Automobile industries. Decades after decades went by the wheels were covered by different type of materials for better grip. These grips were further known as tires. The materials used to make tires were Nylon, Cord and Rubber etc. The discovery of different metals like Steel, Iron, Aluminium and variation of different metals mixed together led to the designing of rims. These rims were designed for weight reduction and aesthetic purpose. Types of Rims included one piece rim, two piece rim, rim with nave plate and rim with spokes. Nowadays the rims are made of alloy. Alloy is a material which is a mixture of two different metals [2].

The wheel is a part that enables efficient movement of an object across a surface where there is a force pressing the object to the surface. The spoke wheel rim assembly contributes the major weight addition in motorcycle after engine. To overcome this disadvantage alloy wheels are invented. While comparing all alloy materials aluminium alloy is the best of other alloy materials. The automotive industry faces increasing pressure to maximize performance while minimizing weight and cost to produce more fuel efficient vehicles [1].

Figure 1. Wheel modle.

They generally provide a lot of strength than pure metals. Alloys of Aluminium and magnesium are fairly light in weight and provide the same strength in comparison with other alloys. Alloy wheels are nonferrous alloys which mean they don't have any iron content in them. The alloys which are low at cost don't have an oxide layer. These oxide layers provide

Cite this article as: Bugatha Varun Kumar & Sk.Hidayatulla Sharief, "Design & Structural Analysis of 4-Wheeler Rim by Material Optimization", International Journal & Magazine of Engineering, Technology, Management and Research, Volume 6 Issue 12, 2019, Page 23-30.

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protection against corrosion. Alloys also come in different types of designs for aesthetic purpose and allow the use of attractive bare metal finishes. These alloy rims are covered under a coat of paint to prevent corrosion. The protection of oxide layer or paint only lasts for 3-5 years after that the alloy wheel starts corroding. The refurbishing or strengthening of these alloy wheels is done. Intricate shaped rims are manufactured along with the normal rim designs. So alloy rims are widely used because they are well optimized [3].

Wheels:

Wheels must be strong enough to support the vehicle and withstand the forces caused by normal operation. At the same time, they must be as light as possible, to help keep un-sprung weight to a minimum. Wheels can be made from cast aluminium alloy or magnesium alloy. Alloy wheels are popular because of their appearance and because they are lighter than similar steel wheels. Aluminium is a better conductor of heat, so alloy wheels can dissipate heat from brakes and tyres more effectively than steel ones. Most wheels have ventilation holes in the flange, so air can circulate to the brakes. Most passenger car wheels are of well, or drop-centre design. This design allows for tyre removal and fitting. The removal and fitting of tyres should be carried out according to manufactures instructions [4].

Figure 2. Wheel modle.

TYPES OF WHEELS:

There are only a few types of wheels still in use in the automotive industry today. They vary significantly in size, shape, and materials used, but all follow the same basic principles.

The first type of wheel worth mentioning, and by far the most-used wheel, is the steel wheel. This kind of wheel consists of several sheets of steel, stamped into shape and typically welded together. This type of wheel is strong, but heavy. They are found on every kind of vehicle from sports cars to the larger pickup trucks; the wheels look different but are essentially the same device.

The second type of wheel to be mentioned is the rally wheel. These are essentially steel wheels but they are made somewhat differently, and tend to consist of a heavier gauge of steel. While the inner portion of a steel wheel is generally welded to the rim along its entire circumference, a steel wheel's inner portion is cut to resemble the spokes of a mag wheel, and is welded accordingly [6].

Mag wheels are cast and/or milled wheels typically made from aluminum or an alloy thereof. They used to be made of magnesium for their light weight and strength, but magnesium catches fire somewhat easily and is very difficult to put out. This is unfortunate, because it is superior to aluminum in every other way. This tendency also makes it a dangerous metal to work with, because piles of shavings tend to burst into flame and burn through concrete surfaces when they get too hot.

As previously mentioned, spoke wheels (sometimes with more than 100 spokes) are still in use today and are popular on roadsters and low-riders. They tend to be fairly low in weight, and are reasonably strong. They have an "old school" appearance and style which is often highly sought after.

Various combinations of these technologies can be used to produce other, more unusual wheels. Large earth-moving vehicles such as the more gargantuan dump trucks often have some degree of the vehicle's suspension actually built into the wheel itself, lying

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between the hub and rim in place of spokes. Also, various companies make wheels which are designed like steel wheels but are made of aluminum. The most famous of these are made by centerline, and the style is actually called the centerline wheel [7].

Requirements:

Car producers ask from their wheel suppliers a high quality product that meets all the requirements of standard driving conditions, but is also able to withstand severe misuse. The most important characteristics of aluminium wheels are styling flexibility and cosmetic appearance, even after long term use. Another important factor is the generally reduced weight and thus the related low rotary moment of inertia, although there are specific aluminium wheel styles which are not significantly lighter than steel wheels. Lighter wheels improve car handling and riding comfort through the reduction of the unsprung mass, allowing the suspension to follow the terrain more closely and thus improve grip. The reduction of the overall vehicle mass also helps to reduce fuel consumption. Furthermore, the better heat conduction of aluminium leads to a faster dissipation of the heat from the brakes, which improves braking performance in highly demanding driving conditions and reduces the chance of brake failure due to overheating.

In the design phase of an aluminium wheel, the following characteristics must be considered:

Stiffness

The structural stiffness is the basic engineering parameter to be examined when designing an aluminium wheel which offers at least the same vehicle performance as an equivalent steel wheel. The structural stiffness is determined by the final shape of the wheel; the material stiffness (Young's modulus) is more or less given and little depending on alloy and temper.

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. Misuse cases have to be evaluated in relation to the tensile strength. Yield tests under pressure are also conducted to check this behaviour. An additional, important factor is the temperature resistance, i.e. the wheel must be able to tolerate.temporarily 200°C due to the proximity of the brakes and temperatures around 100°C over longer periods [8].

Cast aluminium wheels

Competition cast wheel
Source: Speedline Spa

Figure 3. Aluminium Wheels

MODELLING:

The various car rim geometry for the exiting car rim and certain variation of them in regards to cross section of arm and rim geometry is modeled and the suitable constrained and loading condition will imposed.

Further the variation in the geometry and the arm shape are provide different possible approach for design of rim. The optimization is provide the comparison between the variety of design existing and proposed [9].

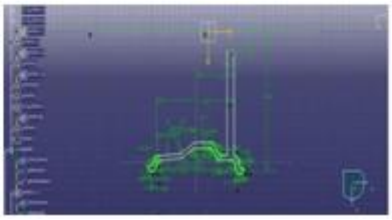

Figure.4Modeling of Wheel Rim with J Contour

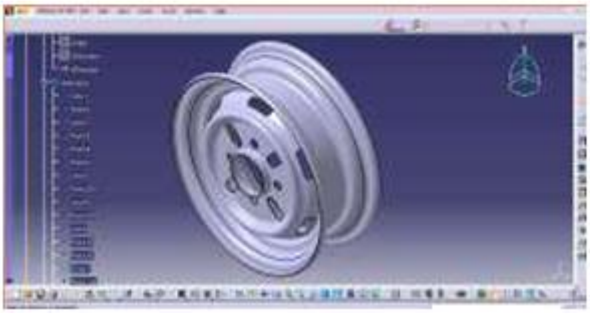

Figure 5: Complete model of car rim.

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ANALYSIS OF WHEEL RIM BY USING ANSYS:

Static and Dynamic analysis is carried out by using analysis software so called Ansys 15.0. There will be many modules in the software and each has its own importance in the field of engineering.

In the design fields the industries were increasing with a large number of models or designs. For this the simulation process will be very hard to bring the results. At this time, analysis software replaced the problem by ease of simulation. This structural software's are incorporated with a parallel algorithm for their rapid work processing.

Structural analysis was most commonly used application of the finite element method. Here the term structural term is used not only for the civil engineering components like buildings and bridges. They were also used for the mechanical structures, aeronautical and also naval applications such as aircraft bodies, ship hull, and also mechanical components like machine parts, pistons etc…

Meshing:

Fig 4. Meshing of car rim

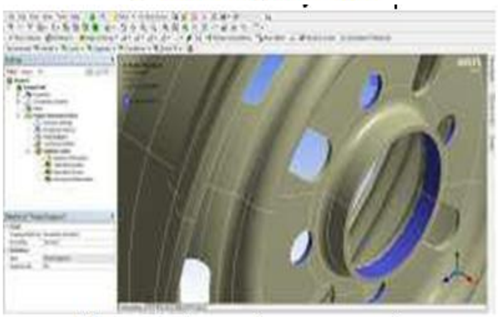

Figure 6 : Constraints on a car rim

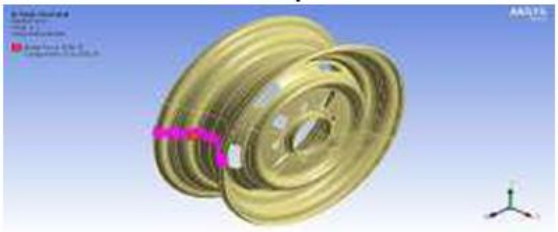

Figure 7 Nodal force

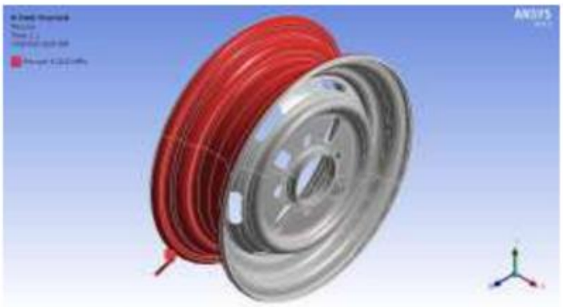

Figure 8 :Pressure along the circumference

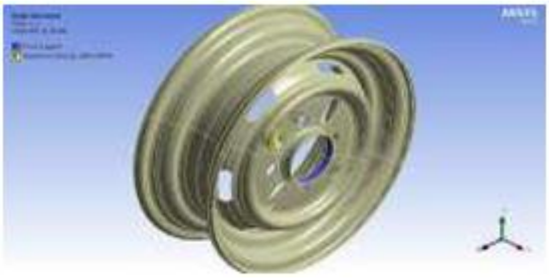

Figure 9: Rotational velocity along the X-axis

All the loading condition (i),(ii),(iii) are applied in combine manner on a car rim . the combine position of loading as shown in figure when the vehicle running on the road it exert relational force, pressure force and centrifugal force on it.

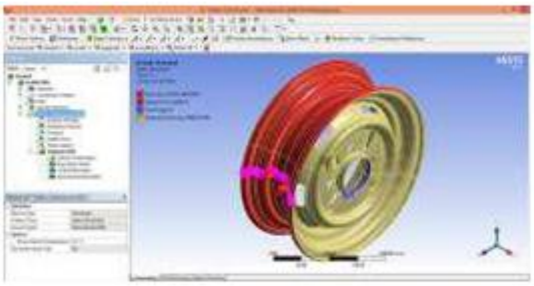

Figure 10 : Combination of all the loading condition.

The first loading condition Nodal force second loading condition Pressure last loading condition is rotation

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International Journal & Magazine of Engineering, Technology, Management and Research
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velocity all these applied on the car rim and find out the total deformation, directional deformation and equivalent stresses for different materials .

Total Deformation of Car rim

Result by using rotational velocity. Material aluminum alloy.

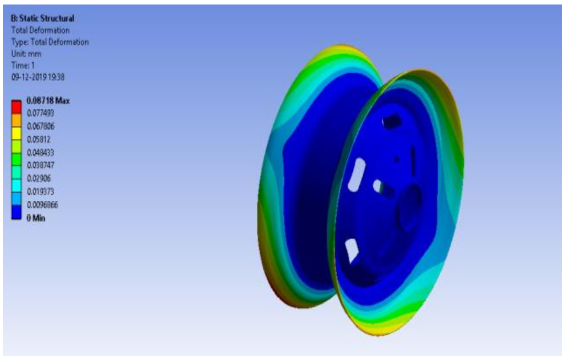


Figure11:-Total Deformation (Al)

Material magnesium alloy.

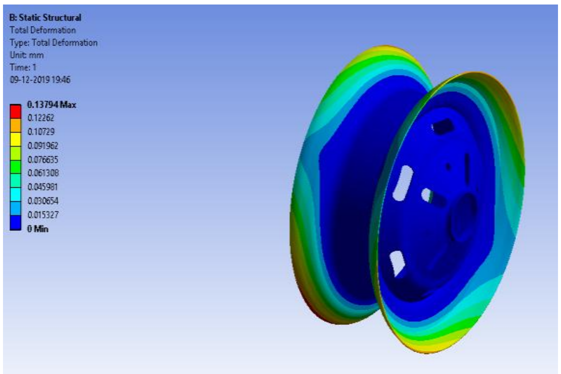


Figure 12 :-Total Deformation (Mg)

Material structural steel.

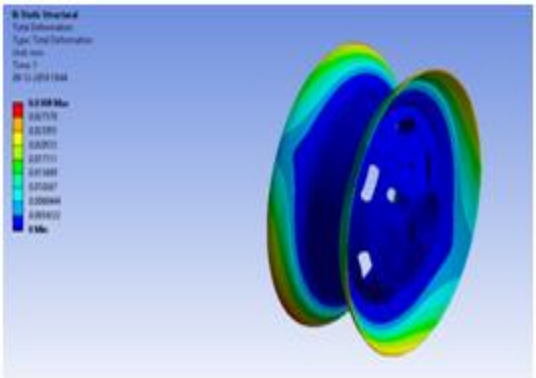


Figure 13:-Total Deformation (STEEL)

Result by using rotational velocity.
Material aluminum alloy.

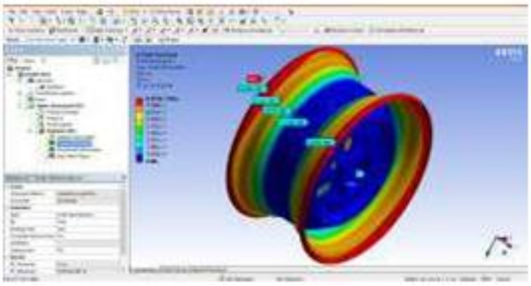


Figure 14:-Total Deformation (Al)

Material magnesium alloy.

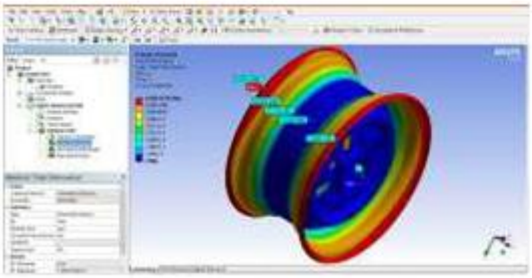


Figure 15:-Total Deformation (Mg)

Material structural steel.

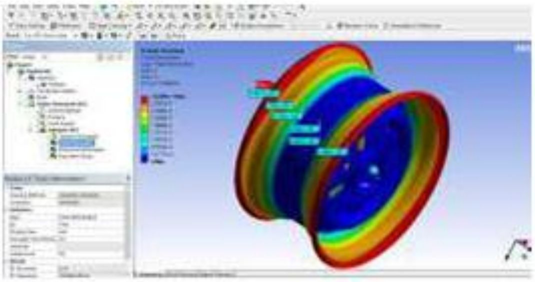


Figure 16:-Total Deformation (STEEL)

Result by using rotational velocity Vector Material aluminum alloy.

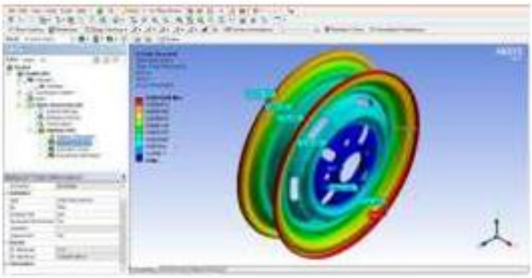


Figure 17.:- rotational velocity Vector (Al)

Material magnesium alloy.

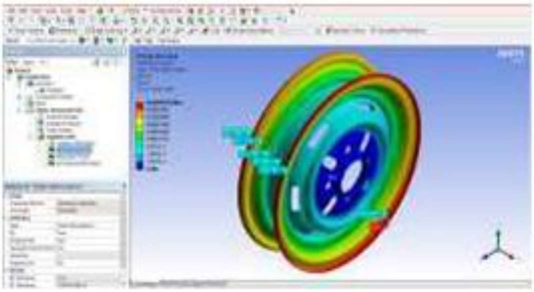


Figure 18:- rotational velocity Vector (Mg)

Material structural steel.

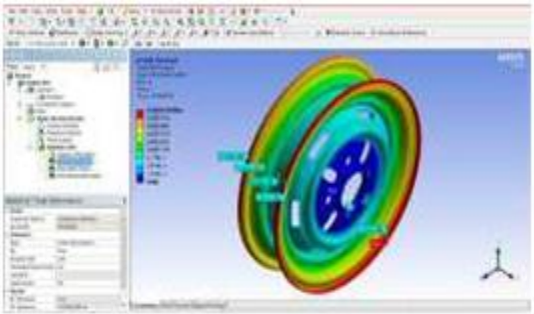


Figure 19:- rotational velocity Vector ((STEEL)

Combination of all the boundary condition Material aluminum alloy.

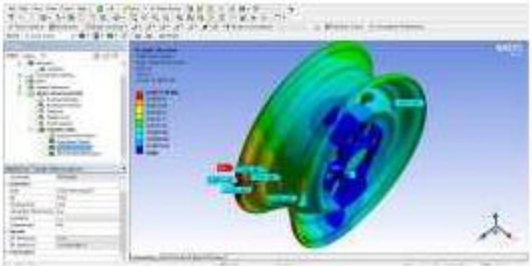


Figure 20:- boundary condition (Al)

Material magnesium alloy.

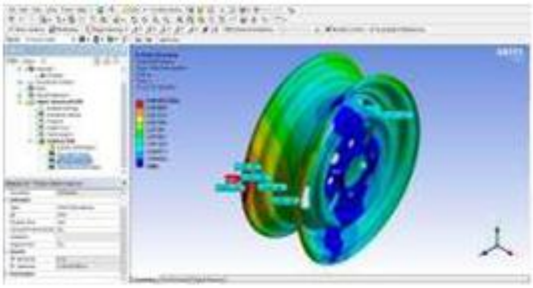


Figure 20:- boundary condition (Mg)

Material structural steel

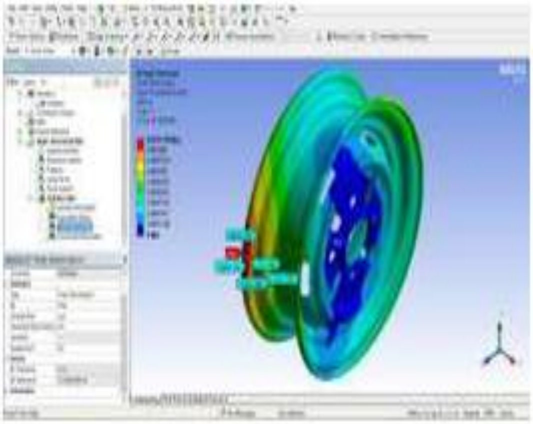
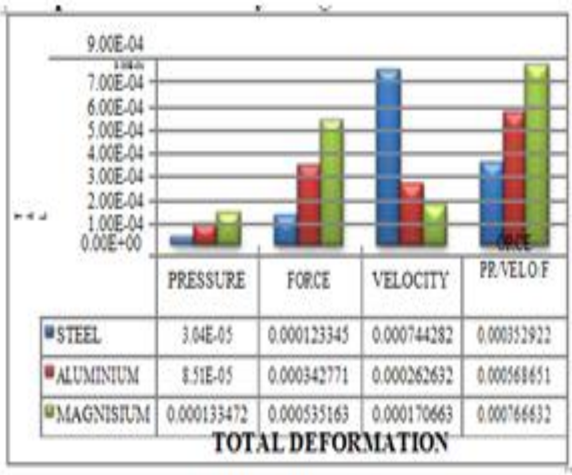


Figure 20:- boundary condition (STEEL)

Comparison of result by using chart.



Graph : Variation in Total Deformation due to change of boundary condition and Materials.

Table I: Variation in Total Deformation due to Pressure (Mpa)

SR.NO.	MATERIALS NAME	NODAL FORCE (N)	TOTAL DEFORMATION (m)
1	ALUMINUM ALLOY	6250	0.0025967
2	MAGNESIUM ALLOY	6250	0.0040543
3	STRCTURAL STEEL	6250	0.00093443

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Table II: Variation in Total Deformation due to Nodal force (N)

SR.NO.	MATERIALS NAME	ROTATIONAL VELOCITY (RPM)	TOTAL DEFORMATION (m)
1	ALUMINUM ALLOY	9806.9	0.00074428
2	MAGNESIUM ALLOY	9806.9	0.00026979
3	STRCTURAL STEEL	9806.9	0.00026338

Table III: Variation in Total Deformation due to Rotational Velocity Vector (RPM)

SR. NO	MATERIALS NAMES	PRESSURE(Mpa)	TOTAL ROTATIONAL VELOCITY VECTOR
1	ALUMINUM ALLOY	0.24132	8.5054×10^{-5}
2	MAGNESIUM ALLOY	0.24132	0.00013347
3	STRCTURAL STEEL	0.24132	3.0399×10^{-5}

CONCLUSION:

CATIA model of the wheel rim is generated in CATIA and this model is imported to ANSYS for processing work. An amount of pressure 0.24132 Mpa is applied along the circumference, Reaction force on the selected node is 6250 N in Z-direction and Rotational Velocity = 9806.9 rpm along the X-axis is applied on the wheel rims made of different materials like ALUMINIUM ALLOY,STEEL AND MAGNESIUM ALLOY and bolt circle of wheel rim is fixed.

Following are the conclusions from the results obtained:

- Steel wheel rim is subjected to more stress as compared to Aluminum and Magnesium while pressure, force and Rotational velocity apply combine.
- In all cases von-mises stresses are less than ultimate strength.
- Total and directional deformation in magnesium is more when compared to steel and aluminum.
- Weight of the magnesium rim is less as compared to other.

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