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Design, Material Optimization and Dynamic Analysis on Automobile Wheel Rim

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ABSTRACT- Day by day the competition is increasing with new innovations and ideas in automobile sectors. With these innovations, a new path is created in the product development. In this development there is a large scope in modifying the existing materials or replacing old products by new and advanced material products. Automotive organizations are paying their major interest in the weight reduction of components because the weight of the vehicle is the most important factor to be considered as it affects the fuel economy. This weight can be reduced by introducing new materials with better properties and manufacturing process with optimization of design.

By this we can achieve more fuel efficiency in vehicles due to reduced weights. Minimizing the weight in the wheel is more effective than minimizing the weight in other components because of its rotational moment of inertia effect during its motion and also the tyre take the overall vehicle load and provides cushioning effect. This project is with the design of aluminum alloy wheel for the automobile application by paying special reference to optimization of the mass of wheel by using current opportunities and trends. By reducing the weight we can achieve the objective the reducing of unsprung mass, by which the inertia loads and overall weight are reduced with improvement of performance and fuel economy. There is large scope for reducing the mass of aluminum wheel by changing or replacing the materials with composites to increase the bearing of stresses and to decrease its mass and volume. For this achievement the composite materials are introduced to reduce the weight of the components. From the finite element calculations it is found that the mass of the wheel rim can be reduced to 50% from the existing alloy wheels. The analysis also shows that after the optimization the stresses generated from the wheel rim will be below the yield stress. This gave a new approach in the field of optimization of passenger car wheel rim. In this project we will include the modelling by using CATIA V5 R20 and analysis by using ANSYS15.0.

KEY WORDS : Optimization, Finite element method, Unsprung

1. INTRODUCTION

The escalation of automobile emissions and energy costs, technology geared up towards improving the fuel economy and reduction of emissions which includes fuel injection, transmission technologies, improved aerodynamics, engine aspiration, four wheel drives, tyres with lower progressing resistance and increased use of light weight materials in production of vehicles.

Wheels have a vital importance for the safety of the vehicle and special care is needed in order to ensure their stability. The advancement of the wheel has strongly influenced the design, material selection and the manufacturing process. They are loaded in a complex manner and further improvement in the wheel design will be possible only if their loading will be better implicit. in order to achieve an optimum design of the wheel, the accurate knowledge of the loading, the mechanical properties and allowable stresses of the material is required.

The use of light weight materials for body and wheels in an area of automobiles will significantly improve the fuel economy and gas emission. Alternative materials such as alloys of aluminum and magnesium, polymer matrix composites (pmc's) instead of steel in the manufacturing of wheel reduce the weight of the vehicle. it is done without compromise in performance, comfort and safety of the passengers.

Now the revolution is started in automobile industry to manufacture the wheel rim by using carbon as it plenty available in nature with low cost. There is a lot of pressure in automobile industries due to competition to manufacture the components with optimized design and low cost. the components should have more efficiency with less consumption of fuels. hence there is a need of product development. this can be achieved by reducing the mass of the vehicle. the wheel along the tire plays an important role in passengers comfort. to reduce this mass the materials are changed from the existing materials without compromising the strength of the wheel.

By using the lighter wheels the handling can be improved because of the reduced unsprung mass and allowing the suspension to follow closely along the path and thus improving the grip.

2. LITERATURE REVIEW

The main requirements of an automobile wheel are

1. It should be as light as possible so that unsprung weight is least
2. It should be strong enough to perform the above functions.
3. It should be balanced statically as well as dynamically.
4. It should be possible to remove or mount the wheel easily.
5. The material should not deteriorate with weathering and age .In case, the material is suspected to corrosion, it must be given suitable protective treatment.

Automobile wheels which are made from an alloy of aluminum or magnesium. Alloy wheels differ from steel wheels because of their lighter weight, which improves the driving and handling of the vehicle. Alloy wheels made up of composite materials will reduce the unsprung weight of a vehicle compared to one fitted with standard aluminum alloy wheels. The benefit of reduced unsprung weight is more precise handling and reduction in fuel consumption. Alloy is an excellent conductor of heat, improving heat dissipation from the Brakes, reducing the risk of brake failure.

Lot of research is carried in the field of automobile, mainly in the passenger car wheel rim. So far, the research is done to know the stress failures of the wheel rim and the forces acting on the wheel rim. The various tests like bending test, cornering test, impact test, and dynamic stiffness test were also carried so far. A brief literature survey has been carried out on alloy wheels.

Siva Prasad et al. [1] modeled the wheel rim using CATIA V5 R17 and static and dynamics analysis made by Ansys. The analysis is carried on two different materials forged steel and aluminum alloy. It has been observed that Aluminum alloy wheel rim is subjected to more displacement and stress compared to forged steel and suggested that forged steel is best material for design of wheel rim.

Saurabh M paropate et al. [2] taken a parametric model of two wheeler and compared the aluminum alloy material with other composite alloys. Shear stresses and critical stresses are predominant as the wheel rim undergoes fatigue and static loads as it traverses on different road conditions. In this work motorcycle wheel rim is taken from Bajaj pulsar 150cc through reverse engineering. They compared stress, displacement, total deformation, weight and cost of material for different materials and suggested that thermoplastic resin is best material for wheel rim.

Saran Theja M et al. [3] carried out analysis on a two wheeler lighter weight alloy wheel. Suziki GS 150R wheel configuration is taken for modeling. A CAD model is prepared by taking the wheel dimensions through reverse engineering and simulation is done on both pre-existing and new design. The main focus is on reducing the mass of the wheel, change in the number of spokes and modifying the fillet radius at intersection of the hub and spoke. Static analysis is performed by keeping the wheel constrained around the flange edge of the rim and loaded at end of shaft. J profile is taken and it is centered on “stiffness and deflection of complex structures” by using Ritz method.

P. Meghashyam et al. [4] made static and Modal analysis on wheel rim using ANSYS by taking two different materials aluminum alloy and forged steel. It has been observed that aluminum wheel is subjected to more stress and deflection when compared to the forged steel.

N. Satyanarayana & Ch. Sambaiah [5] did a static analysis on aluminum alloy wheel A356 by using FEA package. The 3-D model is designed by using Catia and imported into Ansys using IEGS format. They observed that the alternative stress, shear stress, total deformation and also life, damage, safety factor of alloy wheel is seen by using S-N curve which is input for A.356.2 material.

MohdZulHazml Bin MhdFauzy et al. [6] made a fatigue and static analysis of aluminum alloy wheel which is carried out using Finite Element Analysis package. The 3-D model is designed using CATIA and imported into NASTRAN using the .IGES format. The alternative stress and shear stress, total deformations are observed by using FEA software.

Liangmo Wang et al [7] suggested a new method for finding the fatigue life of aluminum alloy wheels. The ABAQUS software is used to model and analyze the static load by FEM for rotary fatigue test. The wheel life cycle is improved and indicated that the proposed method of integrating finite element analysis and nominal stress method efficient to predict the fatigue life of aluminum wheels.

Guo et al. [8] conducted many experiments and found through finite element analysis that clamp load improves the prediction of stress area and fatigue life of aluminum alloy wheel.

Grubisic and Fischer [9] examined parameters of wheels for design, durability, fatigue properties which depends on design, manufacturing technology and the material used.

Husu et al. [10] developed a probability based model for the prediction of fatigue failures of aluminum alloy wheels. This probability model is improved for the prediction of wheel fatigue life.

Kocabicak and Firat [11] used Palmgren-Miner rule and calculated the damage accumulation. This is used to estimate the fatigue life of a wheel used in passenger cars during the test of cornering fatigue.

Li, P., Maijer [12] developed a mathematical model for the prediction of residual stress distribution of aluminum alloy wheel A356.

Yang et al. [13] predicted the fatigue life of a wheel by taking the stress values from FE analysis as the basic parameters. By using this method the wheel bending test values are checked.

Liangmo wang et al. [14] it is mainly concentrated to improve the quality of aluminum wheels by introducing a new method for finding the fatigue life of aluminum wheels.

Alexandru Valentin Radulescu et al. [15] analyze the stresses in car rim by using 40 degree loading test. The static analysis is performed in order to study the static stresses and finding the high stress concentration zones. By comparing the design values with the experimental values the best design is suggested.

WU Li-hong et al. [16] replaced A365 with AM60A material. The service stress distribution in wheel becomes more uniform, the peak value of concentrated stress reduced because of low elastic modulus of Magnesium alloys. The service stress level of redesigned Magnesium wheel is low because of its optimized structure by changing the spoke configuration and increasing fillet between spoke and ring, satisfying the desired weight saving.

M Sabri Sidik et al. [17] studied the behavior of car wheel rim under different static loading conditions. The design and analysis is done by using CATIA and ABAQUS. There are two types of car wheel rims used in Malaysia one is steel and the other one is alloy wheel are modeled by using standard specification in CATIA.

It has been observed that the steel wheel rim induced more stress and deformation when compared to alloy wheel rim. It is because of higher yield strength in the steel. Steel wheel rim has the capacity to bear more stresses event at high impacts.

Jeetendra Kumar Chakrawarthi [18] made an analysis on a rotating wheel at different speeds.

Ravi Lidoriya et al. [19] designed a two wheeler and gave an importance to polymeric materials by which the weight can be reduced without decreasing the quality of vehicle and reliability. Weight reduction is directly proportional to consumption of fuel.

Mutua James et al. [20] studied the use of magnesium alloys in the optimization of automobile weight by using current trends.

Subba Rao Vlisi et al. [21] studied the fatigue and static analysis of alloy wheel under radial loads. To study this analysis the alloy wheel with A356.2 is carried by using finite element analysis package. Alloy wheels used in the passenger cars should go for two types of fatigue tests, the dynamic radial fatigue test and dynamic cornering fatigue test.

Emmanuel M. Adigio et al. [22] observed maximum stresses at the ventilation holes and spokes while performing the static analysis of the wheel.

Satya Prasad and Anil Kumar [23] optimized the aluminum wheel rim by the application of topology optimization for reducing the aluminum wheel mass.

P.H.Yadav and P.G.Ramdasi [24] used optistruct software for the optimization of the wheel rim parameters. In the work the wheel rim is optimized to reduce the weight of the wheel rim without increase of allowable strain.

J Stearns et al. [25] performed analysis to understand the pressure and radial loads influence on stress and displacement response of rotating bodies in automobiles. It mainly shows the use of finite element technique for analyzing the stresses and displacements distribution in the wheels when subjected to pressures and radial loads.

The global automotive industry is driven by environmental and safety standards, increased longevity due to extended warranty and lower costs of production. Consumers are demanding less frequent maintenance, more comfortable driving and better fuel economy, with no deterioration in performance. Technologies geared towards improving fuel economy and reduction of emissions. The use of light weight materials for body and chassis components is an area that promises significant improvement in the fuel economy and gas emission in future. The use of alternative materials such as aluminum, magnesium and polymer matrix composites (PMCs) instead of steel in automobile structural members is used to reduce weight of the vehicle.

The review of literature reveals that the most of the work has been done by modeling and the wheel rim and carried static analysis, dynamic analysis, fatigue analysis, modal analysis. These analyses are done by using various reliable software’s which had an ease in solving the component. Topology optimization, mass optimization is done by using different techniques.

Finite element methods are developed to know the frequencies in the alloy wheel. The general materials were changed with the existing material of wheel rim and the analysis is carried to know the performance of material. But no work is done so far in the area of composite

In this present work an attempt is made to change the existing material with the composites. And the work is also extended to comparisons are made between three and five bolt holes and the spokes with four, five, six number. And it is further extended to analyze the stresses at different speeds.

3. Design considerations of automobile wheel

Wheels have a vital importance for the safety of the vehicle and special care is needed in order to ensure their durability. The development of the wheel has strongly influenced the design, material selection and the manufacturing processes. They are loaded in a complex manner and further improvement in the wheel design will be possible only if their loading will be better understood. In order to achieve an optimum design of the wheel, the precise knowledge of the loading, the mechanical properties and allowable stresses of the material is required.

3.1 Design of Automobile Wheel Rim

In the modeling of the passenger car wheel rim, it have been taken the rim from 60 series 195/60 R 14.
Parameters for modeling wheel rim

S.No	**Parameters Taken For Modeling**	
1	Rim Nomeclature	7 -JJ-14 50 5 96.0
2	Flange Shape	JJ
3	Rim Diameter	14 inch
4	Rim Width	7 inch
5	Offset	70mm
6	Pitch Circle Diameter	98mm
7	Hub Diameter	48mm
8	Number Of Bolt Holes	5 nos.
9	Number of Spokes	5 nos.

The flange height, rim width, bead seats and rim diameter are taken with standard dimensions.
If the diameter of the hub is taken as 48 mm and the prime circle is taken as 25mm.

Then pitch circle diameter can be calculated as
$25 \times 2 + 48 = PCD$
Therefore, PCD = 98 mm

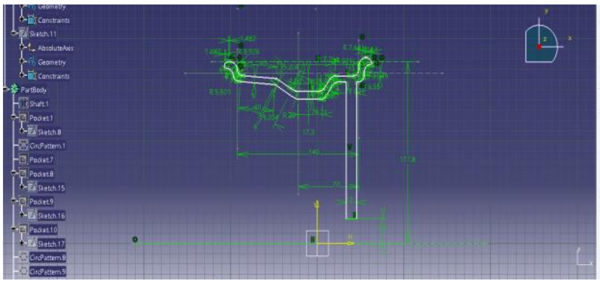

Figure3.1 Modeling of Wheel Rim with J Contour

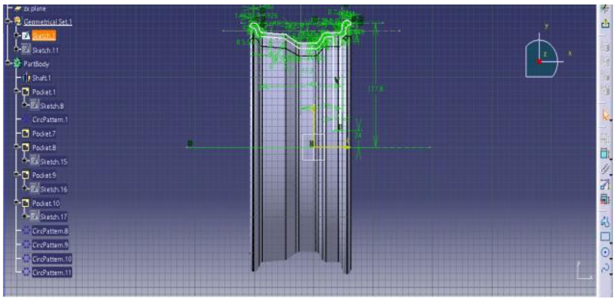

Figure 3.2 Front View of Wheel Rim

The above figure shows the front view of the wheel rim. There is a clear view of the J counter and shaft operation is performed. The total diameter of the wheel rim is 355.6mm. The diameter is taken as per the continental data book.

The pitch circle diameter taken is 5×98. Where 5 indicate the number of bolt holes and 98mm indicates the pitch circle diameter drawn. On the P.C.D the bolt holes are modeled for a wheel.

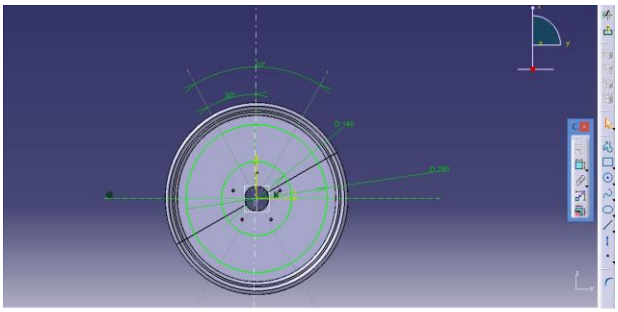

Figure 3.3 Modeling Of Spoke Design

For the five bolts design and to model four spokes on the disc surface certain angles are taken. Total disc of 360^0 made into equidistant parts and the spokes are drawn with an angle of 30^0.

Three bolt holes with four spokes

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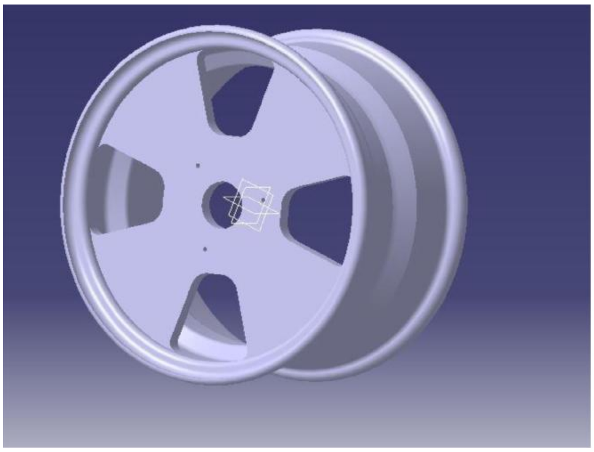

Figure 3.4 Part design of 3 bolt holes with four spokes

Three bolt holes with five spokes

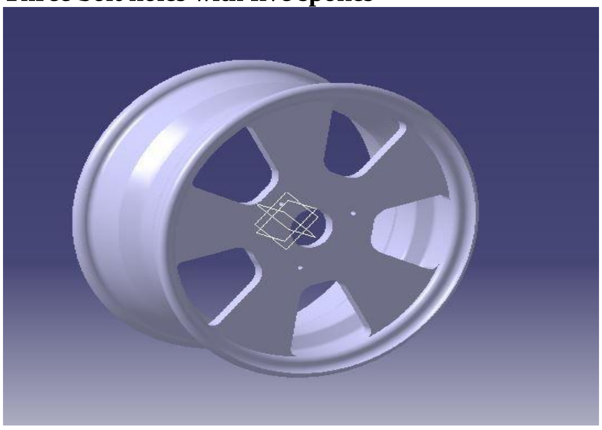

Figure 3.5 Part design of 3 bolt holes with five pokes

Three bolt holes with six spokes

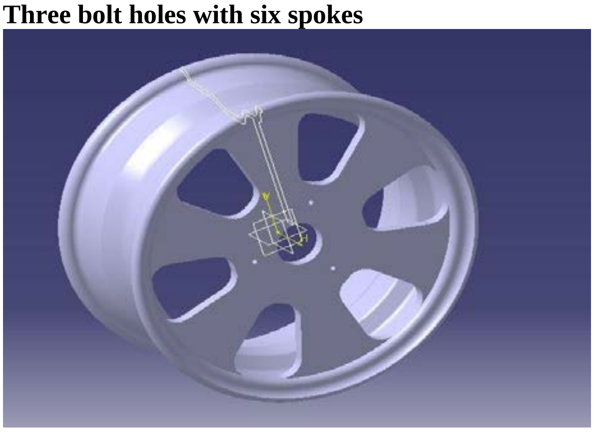

Figure 3.6 Part design of 3 bolt holes six spokes

Five bolt holes with four spokes

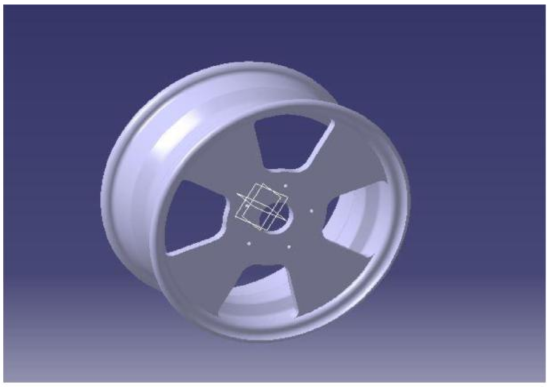

Figure 3.7 Part Model of 5 bolt hole with four spokes

Five bolt holes with five spokes

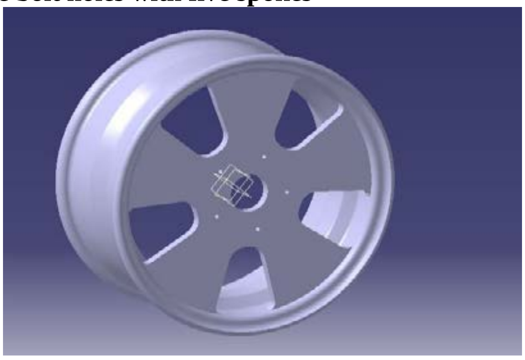

Figure 3.8 Part Body of 5 bolt holes with five spokes

Five bolt holes with six spokes

Figure 3.9 Part Model of 5 Bolt Holes with Six spokes

Checking for safe design:

There will be two major loads on the wheel rim

- Direct load or radial load
- Tangential load

Direct loads will be due to the weight of the vehicle and tangential loads will be due to torque it may be either accelerating torque or braking torque. To calculate direct load,

We know that direct stress = Load/Area

Here load on the rim is 530kgf. 530×9.81=5199.3N.

Let us take it as 5200N.

- Load = 5200N
- Area = $519_{mm}{}^2$
- Direct stress=$10.019_{N/mm}{}^2$
- Tangential load per arm can be given by

$W_T = T/(R\times n/2)$

$W_T = 2T(R\times n)$

here T = torque transmitted N-m
R= radius of the rim in
mm n= number of arms

By this maximum bending moment on the arm at hub end can be given by

$M=[(2T)/(R\times n)]\times R$

From this we get,

$M=2T/n$

Yeild stress =Direct stress + Bending stress

If these two stress are less than the yield stress of the material then we can say that design is safe.

Bending stress=(M/Z)

where Z is section modulus = I/Y

Therefore,

280=(P/A)+(M/Z)×2.25-------------(1)

where 2.25 is factor of safety for dynamic loading condition

As per OEM Specifications for passenger car we have,

- Maximum engine torque=138N-m@4250rpm
- 1st gear ratio =3.909
- Differential gear ratio=3.867
- Maximum torque at axle = 138×3.909×3.867

= 2086.022 N-m

Maximum torque at a wheel = 2086.022/2

= 1043.01N-
m M= 2T/n
M= 417204N-
mm Z = I/Y
= $bh^2/6$
= 3868.8848
M/Z= $107.835_{N/mm}{}^2$

By substituting in equation (1)

Yeild stress =Direct stress+Bending stress

aluminum alloy Sy=(P/A)+(M/Z)×2.25

aluminum alloy yeild Stress=280Mpa 280 = (10.019)+(107.835)×2.25

280>252.6477

Yeild stress of aluminum alloy is greater than the working stress. Therefore design is safe.

4. ANALYSIS OF WHEEL RIM BY USING ANSYS

Description of software

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:

The imported file geometry undergoes meshing after which boundary conditions are applied to the physical domain. The fine mesh is considered for good results.

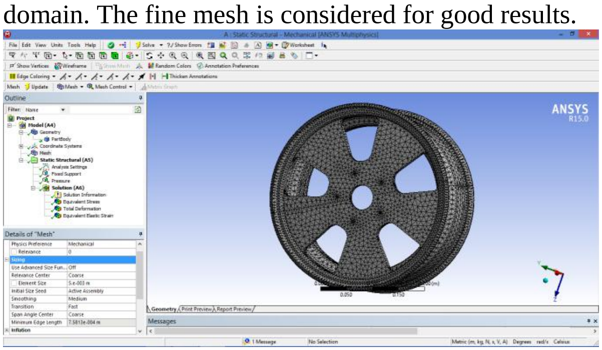

Figure 4.1 Meshing of Wheel Rim

After the processing stage the boundary conditions are applied on the wheel rim. The loads are applied. As we seen earlier, the designed wheel rim is with the load index 86 i.e., it has the capacity to bear 530 kg. The load given here is 5200N. But here the wheel rim is considered as it is in static condition. When the car is in stationary, the entire load on the wheel rim will be distributed throughout the rim because of the air. The air is a medium which circulates the entire force acting on the rim.

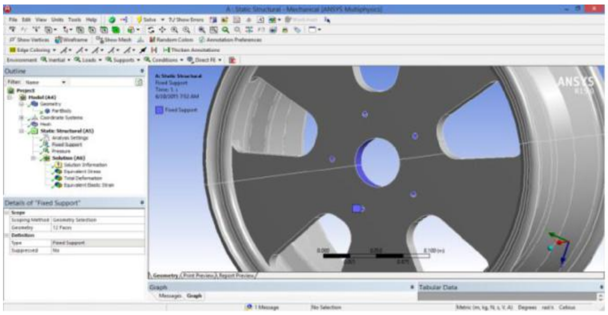

Figure 4.2 Fixed Supports on Wheel Rim

From the above figure, the fixed supports were given for the bolt holes and on the wheel hub. As the bolt holes are fix with the lug nuts in the real time conditions and the shaft is also mounted on the hub hole.

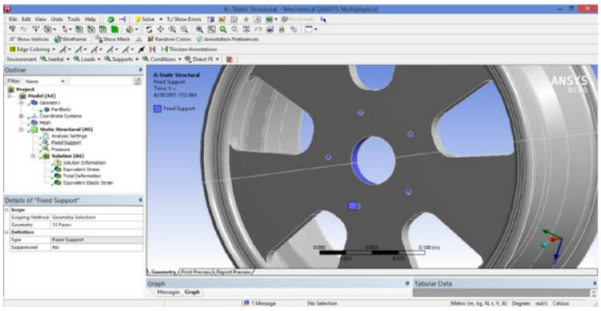
Figure 4.3 Fixed Supports on Wheel Rim

From the above figure, the fixed supports were given for the bolt holes and on the wheel hub. As the bolt holes are fix with the lug nuts in the real time conditions and the shaft is also mounted on the hub hole.
From the technical data we have seen earlier the pressure applied for the modeled wheel rim is 0.25Mpa. The pressure is applied along the wheel rim circumferentially in the Y direction.

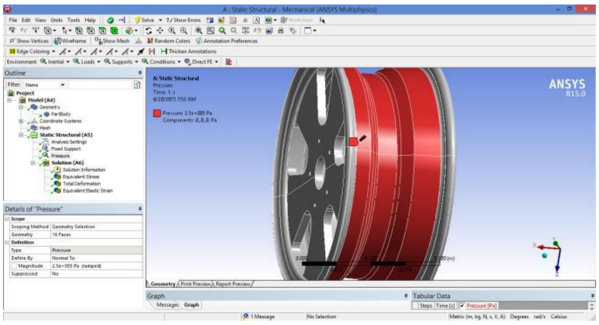

Figure 4.4 Pressures on Wheel Rim

Comparison of the three bolt hoes and five bolt holes by varying the number of spokes:

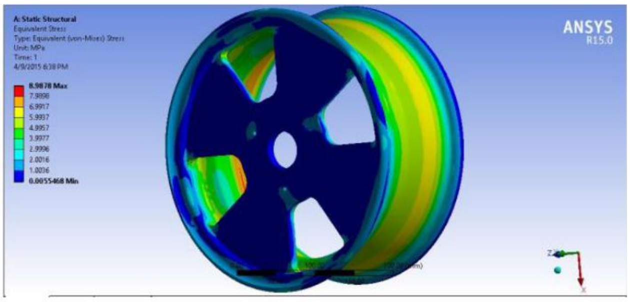

Figure 4.5 Von-Mises Stress On Wheel Rim Using 3 Bolt Holes and 4 Spokes

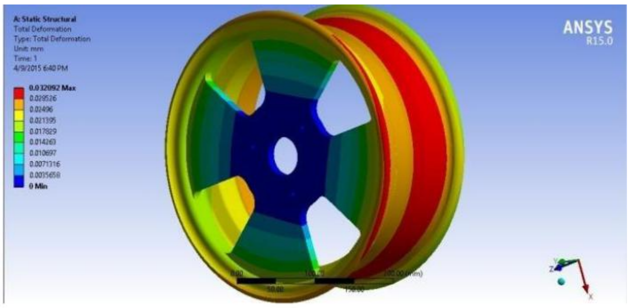

Figure 4.6 Deformation Stress On Wheel Rim Using 3 Bolt Holes and 4 Spokes

4.1.1 Three bolt holes with five spokes

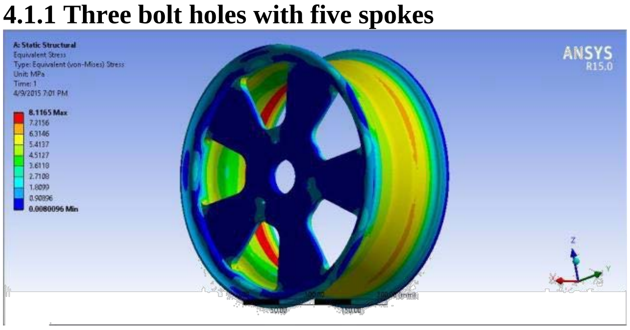

Figure 4.7 Von-Mises Stress on Wheel Rim Using 3 Bolt Holes and 5 Spokes

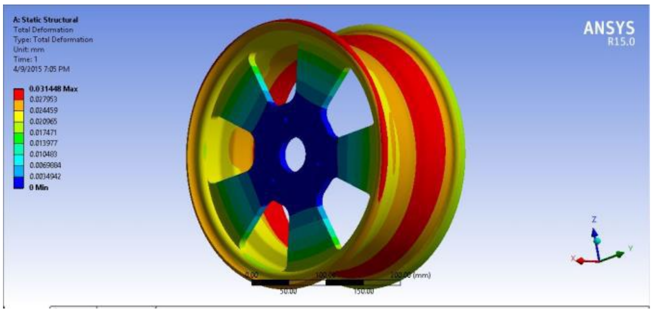

Figure 4.8 Deformations Stress on Wheel Rim Using 3 Bolt Holes and 5 Spokes

4.1.2 Three bolt holes with six spokes

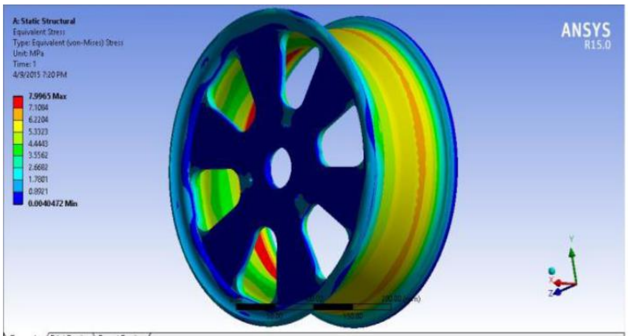

Figure 4.9 Von-Mises Stress on Wheel Rim Using 3 Bolt Holes and 6 Spokes

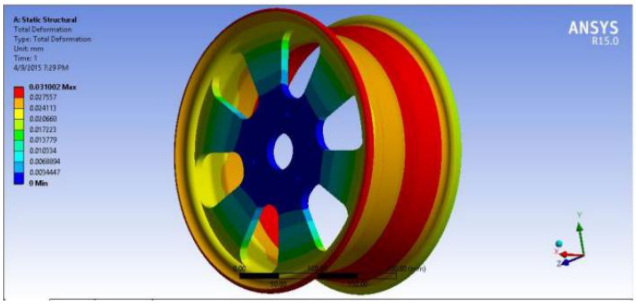

Figure 4.10 Deformation Stress on Wheel Rim Using 3 Bolt Holes and 6 Spokes

4.1.3 Five bolt holes with four spokes

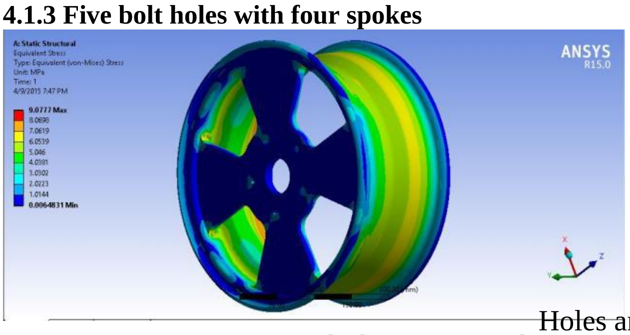

Figure 4.11 Von-Mises Stress on Wheel Rim Using 5 Bolt and 4 Spokes

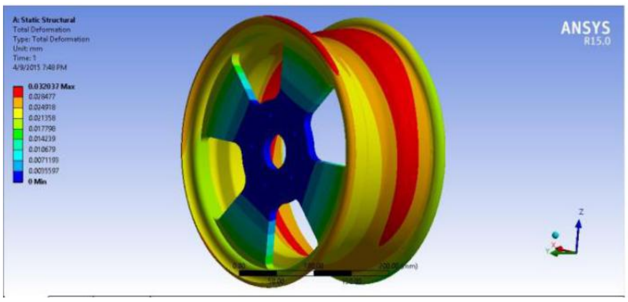

Figure 4.12 Deformation Stress on Wheel Rim Using 5 Bolt Holes and 4 Spokes

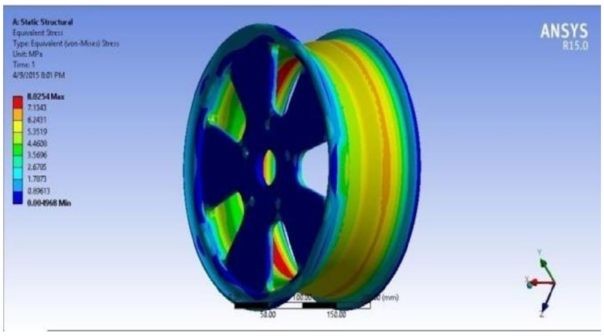

Figure 4.13 Von-Mises Stress On Wheel Rim Using 5 Bolt Holes and 4 Spokes

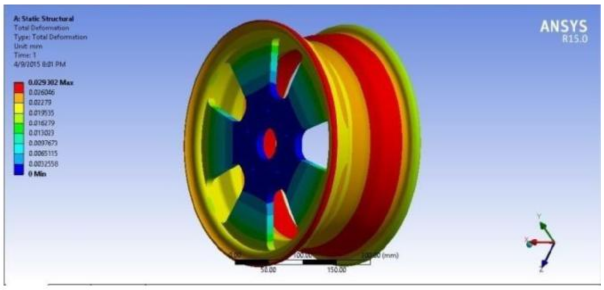

Figure 4.14 Deformation Stress in Wheel Rim Using 5 Bolt Holes and 5 Spokes

4.1.5 Five bolt holes with six spokes

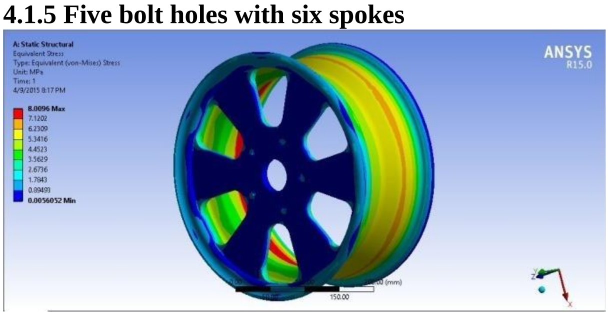

Figure 4.15 Von-Mises Stress in Wheel Rim Using 5 Bolt Holes and 6 Spokes
Holes

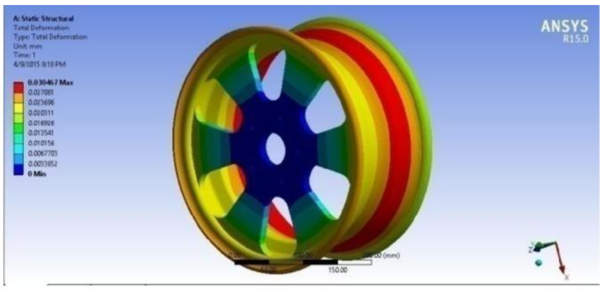

Figure 4.16 Deformation Stress in Wheel Rim Using 5 Bolt Holes and 6 Spokes

4.1.4 Five bolt holes with five spokes

Stress, deformation, weight of wheel with three, five bolt holes by varying number of spokes

Number of spokes	Von-Mises stress(MPa)		Deformation (mm)		Weight of wheel rim (Kg)	
	3 bolt holes	5bolt holes	3bolt Holes	5bolt holes	3bolt holes	5bolt holes
4 spokes	8.9878	9.0777	0.032092	0.032037	5.339	5.1291
5 spokes	8.1165	8.0254	0.031448	0.029302	5.1359	5.3084
6 spokes	7.9965	8.0096	0.031002	0.030467	5.1745	5.1732

By varying with different spokes with three and five bolt holes, taking stresses and deformation into account it is concluded five bolt designs with five spokes are good. The materials were replaced with this design and further analysis is continued.

5. ANALYSIS OF WHEEL RIM ON FIVE BOLT HOLES WITH FIVE SPOKES BY CONSIDERING DIFFERENT MATERIALS

By using the lighter wheels the handling can be improved because of the reduced unsprung mass and allowing the suspension to follow closely along the path and thus improving the grip. In passenger vehicles mainly in cars the functioning of the wheels should meet the passengers comfort and the life of the wheel rim should be high with low economy. The weight can be reduced by using the composite materials like glass fibers like boron fibers, carbon fibers, armid fiber, basalt fiber, ceramic fiber, silicon carbide are used. Each material has their own advantages to replace with the existing materials.

5.1 Aluminum alloy

Mainly in the manufacturing of the alloy wheels the material used is LM13 and LM25.

The material properties are defined in the engineering material module

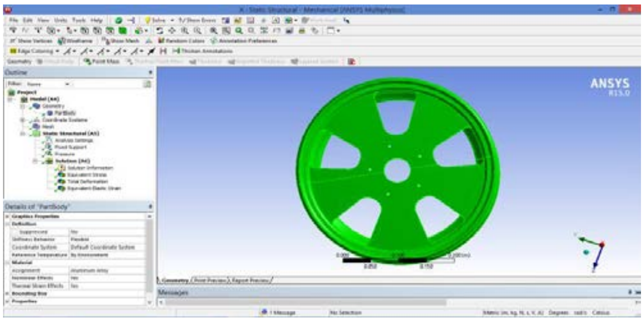

Figure 5.1 Material Defined to the Geomentry

Stress, deformation, strain in the wheel rim (minimum and maximum) can be observed in the below figure:

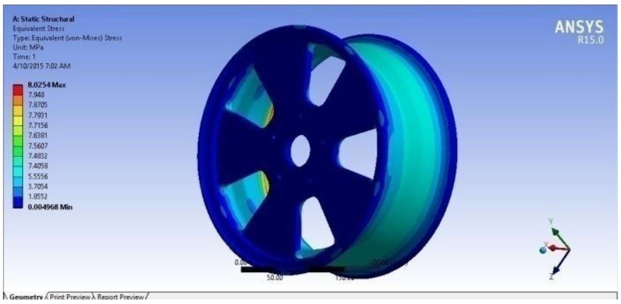

Figure 5.2 Von-Mises Stress on Aluminum Alloy Wheel Rim

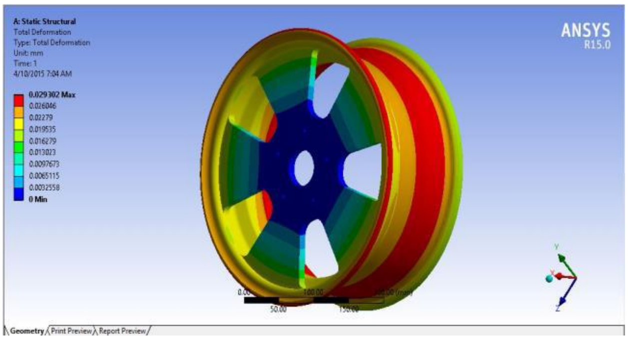

Figure 5.3 Deformations on Aluminum Alloy Wheel Rim

Material	
Assignment	LM13 aluminum alloy
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Length X	169.8 mm
Length Y	363.12 mm
Length Z	363.12 mm
Properties	
Volume	1.9164e+006 mm³
Mass	5.3084e-003 t
Centroid X	0.22426 mm
Centroid Y	-1.3814e-003 mm
Centroid Z	6.6329e-003 mm
Moment of Inertia Ip1	110.7 t·mm²
Moment of Inertia Ip2	68.793 t·mm²
Moment of Inertia Ip3	68.809 t·mm²
Statistics	
Nodes	113790
Elements	62203

Weight of Wheel Rim By Using Aluminum Alloy

From the above diagram if the colour contours are observed the stresses, deformations and strains can be observed. The stresses are more at the wheel bolt holes and the stress concentrations are at the edges of the spokes.

5.2 Magnesium Alloy

Magnesium is a metal which is 30% lighter than the aluminum. This metal is excellent in size, stability, impact resistance and is considered for low budget and strongest material. It is having good stiffness and mechanical properties. Magnesium is good for machining when compared to other metals and it also possesses casting, forging, welding characteristics. The metal is very dangerous when it is in the form of dust or powder because of its low density and also there is a high risk for fire. The main disadvantage with this material is, it have a tendency to corrode internally when it is exposed to salty air. To overcome these problems the technology is improved in casting, forging and corrosion resistance for magnesium material.

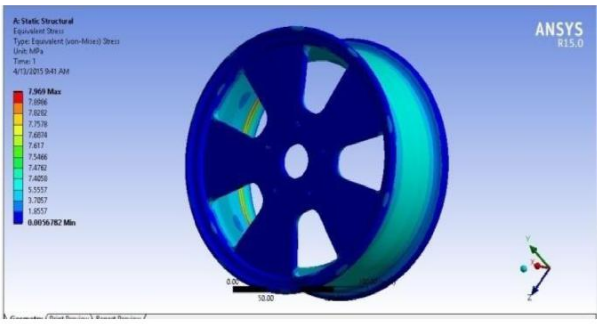

Figure 5.4 Von-Mises Stress on Magnesium Alloy Wheel Rim

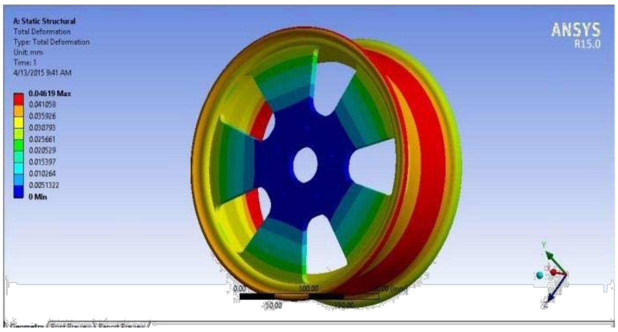

Figure 5.5 Deformations on Magnesium Alloy Wheel Rim

Material	
Assignment	Magnesium Alloy
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Length X	169.8 mm
Length Y	363.12 mm
Length Z	363.12 mm
Properties	
Volume	1.9164e+006 mm³
Mass	3.4495e-003 t
Centroid X	0.22426 mm
Centroid Y	-1.3814e-003 mm
Centroid Z	6.6329e-003 mm
Moment of Inertia Ip1	71.934 t·mm²
Moment of Inertia Ip2	44.703 t·mm²
Moment of Inertia Ip3	44.714 t·mm²
Statistics	
Nodes	113790
Elements	62203

Weight of Wheel Rim By Using Magnesium Alloy **5.3 Titanium alloy**

From past two decades the titanium became prominent material for designers of racing cars. Titanium is a well known material due to its magnificent property of corrosion resistance. The main advantage of the material is its strength which is more than the steel alloys. It is almost about 2.5 times greater than aluminum. But the main disadvantage is it is very costly and the designing, machining cost is high. But still it is used in the top end cars as the price is not the issue. Oxides of titanium are about 0.5% in earth's crust. So this became costly as it is exotic material. This is used in manufacturing of threaded fasteners, tubular sheet suspension linkages fabrication, exhaust systems, brake disc top hats and hubs. This material has more application in automobile industry due to its light weight. The exhaust made from the titanium is lighter than 321stainless steel and endlessly lighter than mild steel and also very much stronger at high temperatures. Still this material is in development stage although there is a large usage in sport cars.

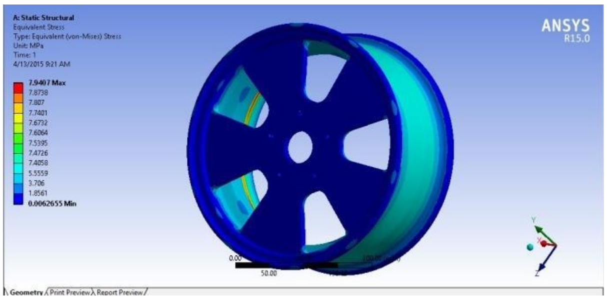

Figure 9.6 Von-Mises Stress on Titanium Alloy Wheel Rim

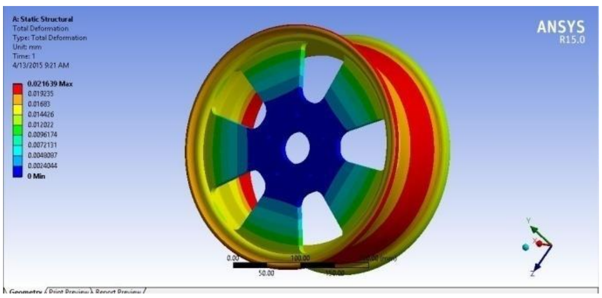

Figure 9.7 Deformations on Titanium Alloy Wheel Rim

Material	
Assignment	Titanium Alloy
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Length X	169.8 mm
Length Y	363.12 mm
Length Z	363.12 mm
Properties	
Volume	1.9164e+006 mm³
Mass	8.8538e-003 t
Centroid X	0.22426 mm
Centroid Y	-1.3814e-003 mm
Centroid Z	6.6329e-003 mm
Moment of Inertia Ip1	184.63 t·mm²
Moment of Inertia Ip2	114.74 t·mm²
Moment of Inertia Ip3	114.76 t·mm²
Statistics	
Nodes	113790
Elements	62203

Weight of Wheel Rim by Using of Titanium Alloy

5.4 Gray cast iron

Grey cast iron has graphite structure and it is also one type of cast iron. The name itself indicates when the fracture starts in the material it forms grey color due to the presence of graphite. This material is used as cast material due to its weight. Cast iron is used in pumps housings, cylinder blocks, casting where the stiffness of the component is important than tensile strength. Because of their high thermal conductivity and specific heat capacity it is used in disc brake rotors.

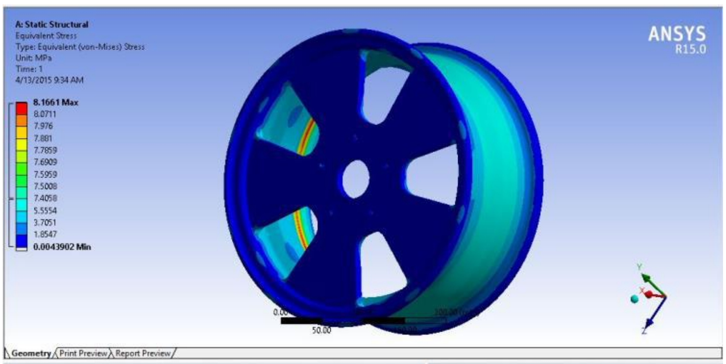

Figure 5.8 Von-Mises Stress on Gray Cast Iron Wheel Rim

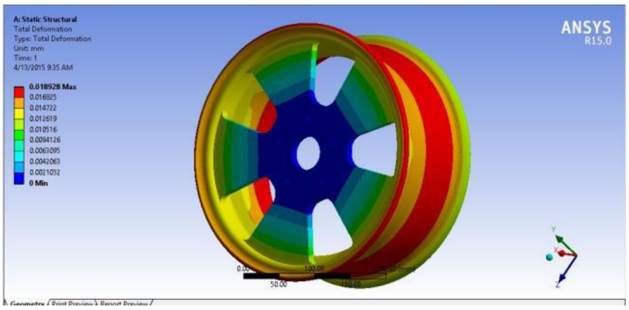

Figure 5.9 Deformations on Gray Cast Iron Wheel Rim

Material	
Assignment	Gray Cast Iron
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Length X	169.8 mm
Length Y	363.12 mm
Length Z	363.12 mm
Properties	
Volume	1.9164e+006 mm³
Mass	1.3798e-002 t
Centroid X	0.22426 mm
Centroid Y	-1.3814e-003 mm
Centroid Z	6.6329e-003 mm
Moment of Inertia Ip1	287.73 t·mm²
Moment of Inertia Ip2	178.81 t·mm²
Moment of Inertia Ip3	178.85 t·mm²
Statistics	
Nodes	113790
Elements	62203

Weight of Wheel Rim by Using Gray Cast iron

5.5 Structural steel

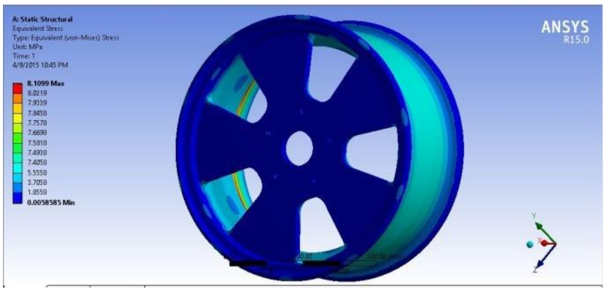

Figure 5.10 Von-Mises Stress on Structural steel Wheel Rim

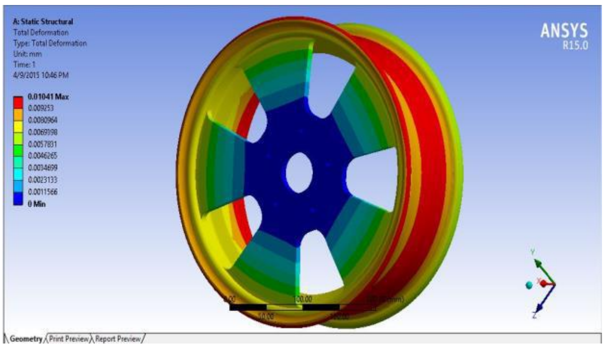

Figure 5.11 Deformations on Structural steel Wheel Rim

Material	
Assignment	Structural Steel
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Length X	169.8 mm
Length Y	363.12 mm
Length Z	363.12 mm
Properties	
Volume	1.9164e+006 mm³
Mass	1.5044e-002 t
Centroid X	0.22426 mm
Centroid Y	-1.3814e-003 mm
Centroid Z	6.6329e-003 mm
Moment of Inertia Ip1	313.71 t·mm²
Moment of Inertia Ip2	194.95 t·mm²
Moment of Inertia Ip3	195. t·mm²
Statistics	
Nodes	113790
Elements	62203

Weight of Wheel Rim By Using Structural Steel **5.6 Stainless steel**

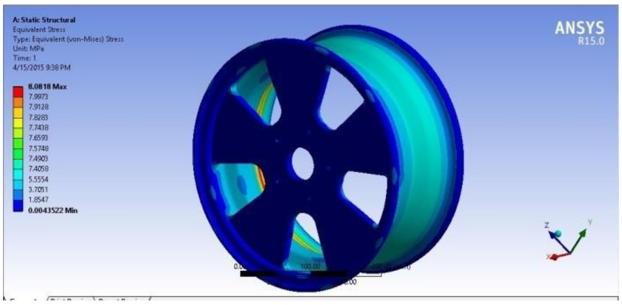

Figure 5.12 Von-Mises Stress on Stainless steel Wheel Rim

Figure 9.13 Deformations on Stainless steel Wheel Rim

Material	
Assignment	Stainless Steel
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Length X	169.8 mm
Length Y	363.12 mm
Length Z	363.12 mm
Properties	
Volume	1.9164e+006 mm³
Mass	1.4852e-002 t
Centroid X	0.22426 mm
Centroid Y	-1.3814e-003 mm
Centroid Z	6.6329e-003 mm
Moment of Inertia Ip1	309.71 t·mm²
Moment of Inertia Ip2	192.47 t·mm²
Moment of Inertia Ip3	192.52 t·mm²
Statistics	
Nodes	113790
Elements	62203

Weight of Wheel Rim By Using Stainless Steel **5.8 Boron fibers**

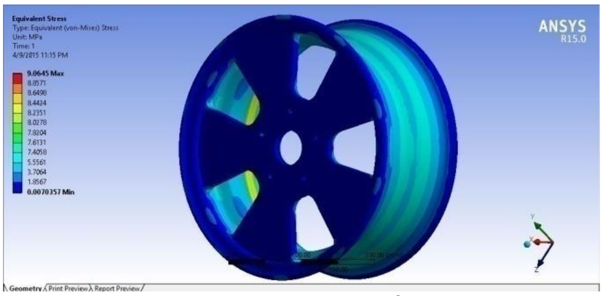

Figure 5.16 Von-Mises Stress on Boron fibers Wheel Rim

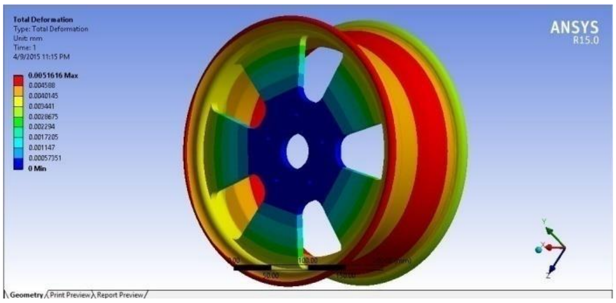

Figure 5.17 Deformations on Boron fibers Wheel Rim

Material	
Assignment	Boron
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Length X	169.8 mm
Length Y	363.12 mm
Length Z	363.12 mm
Properties	
Volume	1.9164e+006 mm³
Mass	4.791e-003 t
Centroid X	0.22426 mm
Centroid Y	-1.3814e-003 mm
Centroid Z	6.6329e-003 mm
Moment of Inertia Ip1	99.908 t·mm²
Moment of Inertia Ip2	62.087 t·mm²
Moment of Inertia Ip3	62.102 t·mm²
Statistics	
Nodes	113790
Elements	62203

Weight of Wheel Rim by Using Boron Fiber

5.9 Carbon fibers

Glass fibers suffer from low elastic stiffness [of course, possess excellent strength characteristics) and limited char strength [relatively low melting point) for ablative applications. This necessitated the use of carbon fibers in place of glass fibers for ablative and structural applications. These are produced from certain precursors-polyacrylonitrile [PAN) fiber and viscose rayon 3fiber. In view of their superior heat stability, carbon fibers can be used for reinforcing ceramics, metals, and plastics, giving engineers and technologists a completely new range of materials. This has high strength to weight ratio with good stiffness. This will not rust or corrode as steel.

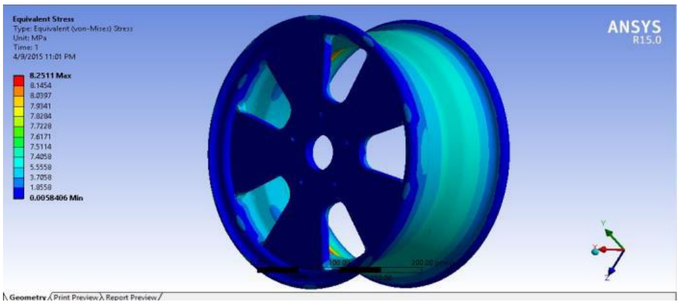

Figure 5.18 Von-Mises Stress on Carbon fibers Wheel Rim

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499
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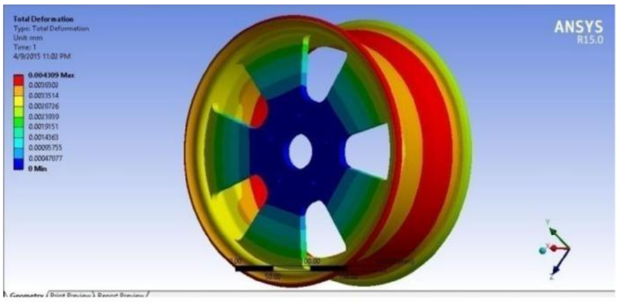

Figure 5.19 Deformations on Carbon fibers Wheel Rim

Material	
Assignment	Carbon Fibers
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Length X	169.8 mm
Length Y	363.12 mm
Length Z	363.12 mm
Properties	
Volume	1.9164e+006 mm³
Mass	3.8328e-003 t
Centroid X	0.22426 mm
Centroid Y	-1.3814e-003 mm
Centroid Z	6.6329e-003 mm
Moment of Inertia Ip1	79.926 t·mm²
Moment of Inertia Ip2	49.67 t·mm²
Moment of Inertia Ip3	49.682 t·mm²
Statistics	
Nodes	113790
Elements	62203

Weight of the wheel rim by Using Carbon Fibers

5.10 Silicon carbide

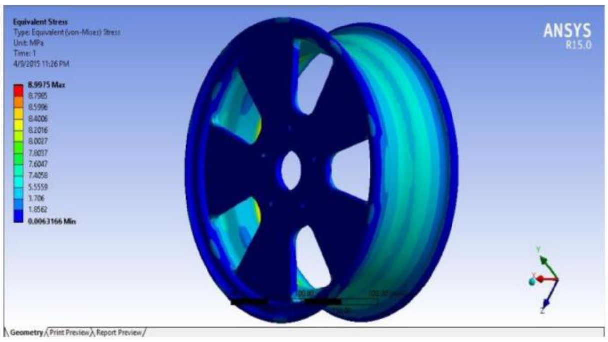

Figure 5.20 Von-Mises Stress on Silicon carbide Wheel Rim

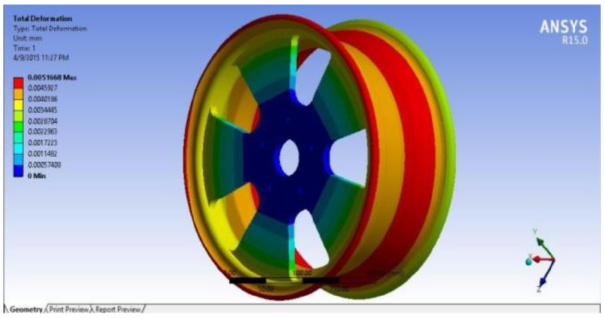

Figure 5.21 Deformations on Silicon carbide Wheel Rim

Material	
Assignment	Silicon Carbide
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Length X	169.8 mm
Length Y	363.12 mm
Length Z	363.12 mm
Properties	
Volume	1.9164e+006 mm³
Mass	6.7074e-003 t
Centroid X	0.22426 mm
Centroid Y	-1.3814e-003 mm
Centroid Z	6.6329e-003 mm
Moment of Inertia Ip1	139.87 t·mm²
Moment of Inertia Ip2	86.922 t·mm²
Moment of Inertia Ip3	86.943 t·mm²
Statistics	
Nodes	113790
Elements	62203

Weight of Wheel Rim By Using Silicon Carbide

5.11 PEEK with 30% carbon reinforced

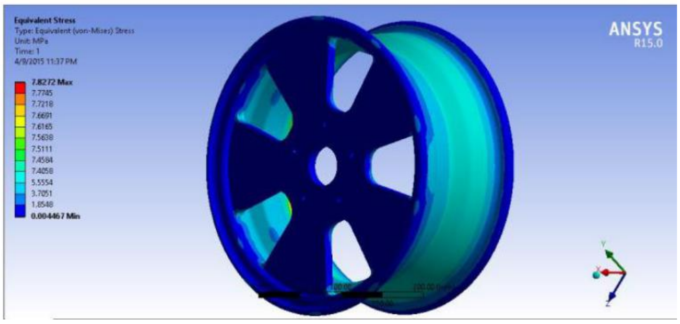

Figure 5.22 Von-Mises stress on PEEK with 30% of Carbon Reinforced

Chaitanya Sureddi

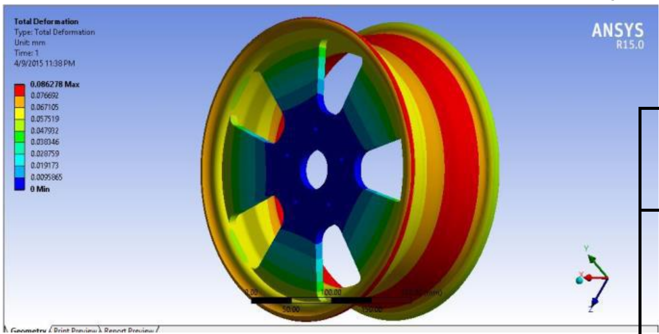

Figure 5.23 Deformation on PEEK with 30% of Carbon Reinforced

Material	
Assignment	polyetheretherketone.30%carbon reinforced
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Length X	169.8 mm
Length Y	363.12 mm
Length Z	363.12 mm
Properties	
Volume	1.9164e+006 mm³
Mass	2.7405e-003 t
Centroid X	0.22426 mm
Centroid Y	-1.3814e-003 mm
Centroid Z	6.6329e-003 mm
Moment of Inertia Ip1	57.147 t·mm²
Moment of Inertia Ip2	35.514 t·mm²
Moment of Inertia Ip3	35.522 t·mm²
Statistics	
Nodes	113790
Elements	62203

Mass of Wheel by Using PEEK with 30% carbon reinforced

Stress, deformation and weight on wheel rim by various materials are below.

S.No	Materials	Vonmises(Mpa)		Deformation(mm)		Weight of wheel (KG)
		Minimum	Maximum	minimum	Maximum	
1	Structural steel	0.0058585	8.1099	0	0.01041	15.044
2	Stainless steel	0.0043522	8.0818	0	0.010785	14.852
3	Magnesium alloy	0.0056782	7.969	0	0.04619	3.4495
4	Aluminum alloy	0.004968	8.0254	0	0.029302	5.3084
5	Titanium alloy	0.0062655	7.9407	0	0.021639	8.8538
6	Grey cast iron	0.0043902	8.1661	0	0.018928	13.798
7	Copper alloy	0.0053602	7.9972	0	0.018905	15.906
8	Carbon fiber	0.0058406	8.2511	0	0.004309	3.8328
9	Boron fiber	0.0070357	9.0645	0	0.0051616	4.791
10	Silicon carbide	0.0063166	8.9975	0	0.0051668	6.7074
11	Peek with 30% carbon reinforced	0.004467	7.8272	0	0.086278	2.74

From the above results in table , it is observed, the existing material in aluminum alloy the stress is 8.0254 MPa, deformation is 0.029mm and weight of the wheel is 5.3Kg

By replacing the materials on the wheel rim the stress and deformation is minimum at PEEK with 30% carbon reinforced. The stresses in copper, titanium and magnesium alloy are minimum. But, by considering weight it is concluded that PEEK with 30% carbon reinforced is best material form wheel rim.

THERIOTICAL CALCULATIONS OF MASS OF AUTOMOBILE WHEEL

The mass of the rim can be calculated

as $m=\Pi.D.b.t.\rho$

Where,

D is diameter of rim in mm

b is width of rim in mm

t is thickness of rim in mm

ρ is density of material kg/m^3

For aluminum alloy

$m= \Pi(355.6)(141)(12)(2770)/1000^3$
$= 5.2359kg$

For structural steel

$m= \Pi(355.6)(141)(12)(7850)/1000^3$
$= 14.838kg$

For Magnesium Alloy

$m= \Pi(355.6)(141)(12)(1800)/1000^3$
$= 3.40kg$

For Titanium Alloy

$m= \Pi(355.6)(141)(12)(4620)/1000^3$
$= 8.732kg$

For Carbon Fiber

$m= \Pi(355.6)(141)(12)(2000)/1000^3$
$= 3.780kg$

For Silicon Carbide

$m= \Pi(355.6)(141)(12)(3500)/1000^3$
$= 6.6157kg$

For Boron Fiber

$m= \Pi(355.6)(141)(12)(2500)/1000^3$
$= 4.7255kg$

For PEEK with 30% carbon reinforced

$m= \Pi(355.6)(141)(12)(1430)/1000^3$
$= 2.7030kg$

Comparisons of analytical and theoretical calculations

Materials	Weight (kg) Numerical (software)	Weight (kg) Analytical (Hand Calculation)	Error (%)
Structural Steel	15.044	14.838	1.388%
Stainless Steel	14.852	14.6491	1.385%
Gray Cast Iron	13.798	13.6095	1.385%
Aluminum Alloy	5.3084	5.2359	1.384%
Magnesium Alloy	3.4495	3.40	1.455%
Copper Alloy	15.906	15.688	1.389%
Titanium Alloy	8.8538	8.732	1.394%
Silicon Carbide	6.7074	6.6157	1.386%
Carbon fiber	3.8328	3.780	1.396%
Boron Fiber	4.791	4.7255	1.386%
Polyetheretherketone with 30% carbon reinforced	2.74	2.7030	1.368%

From the above table analytical and numerical calculation is compared for all the materials. The error is about 1.3 to 1.4% so we can consider our results are under well below the limits.

6. ANALYSIS OF AUTOMOBILE WHEEL BY VARYING VELOCITIES

Further, the work is extended to analyze the automobile wheel rim at different velocities at 40kmph, 80kmph, 120kmph, and 160kmph. When the automobile is moving, the wheel rim is rotated with high velocities and develops radial loads. The stress due to weight of the car and the radial loads are observed in the wheel by using ANSYS 15.0. The wheel rim material is taken is aluminum alloy.

Radial loads

According to the association of european wheel manufacturers

$F_r= k\times F_v\times g$

where

F_r is radial load in N.

F_v is design load of wheel, 530kg

k is acceleration test factor taken as

2.2 Therefore

F_r=2.2×530×9.81

= 11438.46N

Meshing

Auto mesh is done on the wheel rim with an element size of 5mm. Tetrahedral elements are formed on the wheel rim.

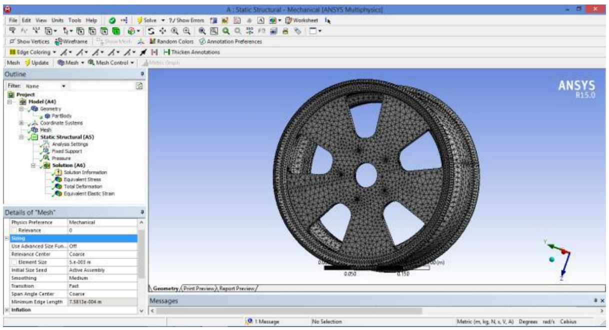

Figure 6.1 Meshed Structure of the Wheel rim

Boundary conditions:

So, fixed supports and the pressure are taken including the radial loads as the boundary conditions for the wheel rim in the processing stage. The shaft is connected to the wheel hub and the wheel rim is fixed with the help of bolt holes. These bolt holes and the hub region is taken as the fixed supports.

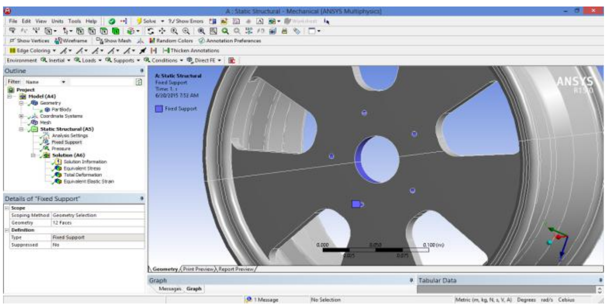

Figure 6.2 Constraints on The wheel rim From the technical data we have seen earlier the range of pressure to be applied on the wheel rim is 0.25Mpa.

The pressure is applied along the wheel rim circumferentially in the Y direction.

The radial loads are calculated for the wheel rim and they are applied on the rim flanges on both the sides. The total radial load acting is 11438.46N. This load is shared on the both sides of the flanges on the wheel.

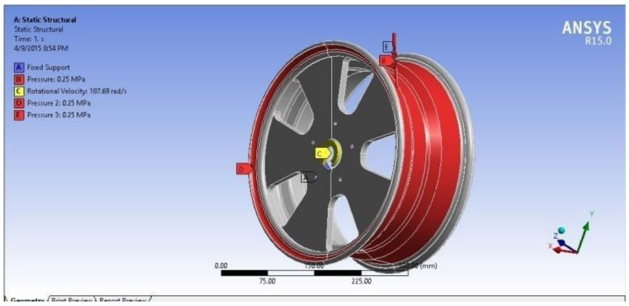

Figure 6.3 Pressure and Radial Loads on the Wheel Rim Post processing:

Each force passes through the tyre and tends to compress the wheel in radial direction. We know that

v=ωr

Where,

v = velocity in m/sec

ω = angular velocity in rad/sec r = radius of wheel rim

At 40Kmph

V = ωr

ω = v/r

$= \frac{40\times5}{18\times0.177}$

= 62.5625 rad/sec

The rotational velocity of 62.56rad/sec is applied on the wheel rim as shown below:

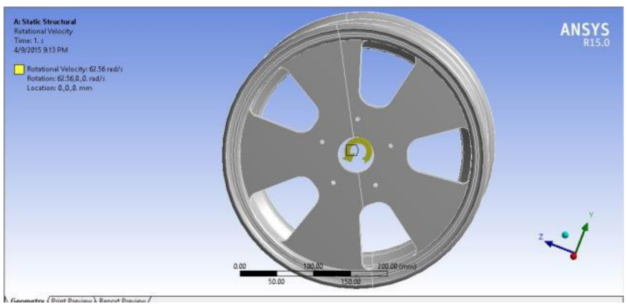

Figure 6.4 Rotational Velocities on Wheel Rim at 40Kmph

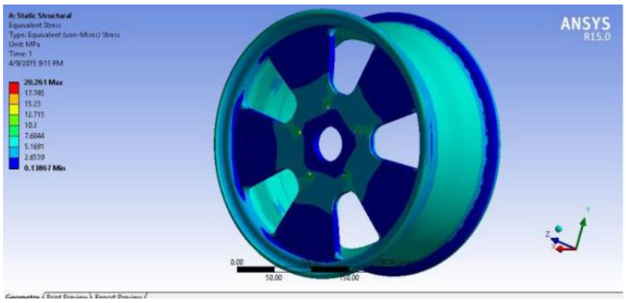

Figure 6.5 Von-Mises stress on Wheel at 40Kmph

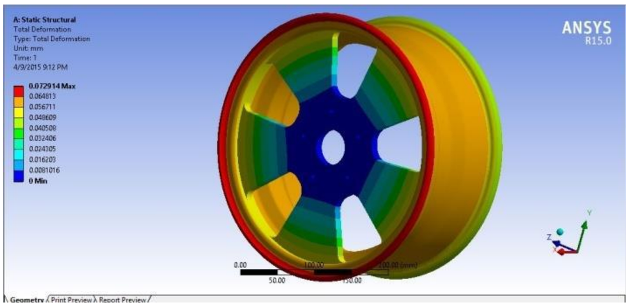

Figure 6.6 Deformations in Wheel Rim at 40Kmph

At 80 Kmph

V = ωr

ω = v/r

$= \frac{80 \times 5}{18 \times 0.177}$

= 125.125 rad/sec

The rotational velocity of 125.125rad/sec is applied on the wheel rim as shown below:

Figure 6.6 Rotational Velocities on Wheel Rim at 80Kmph

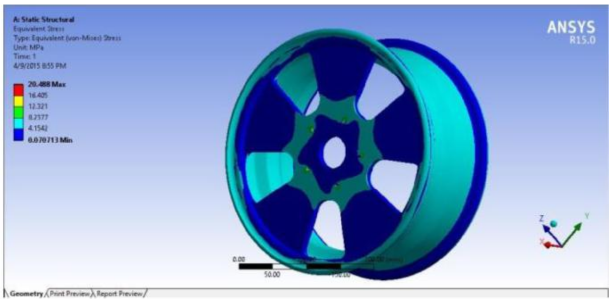

Figure 6.7 Von-Mises stress on Wheel at 80Kmph

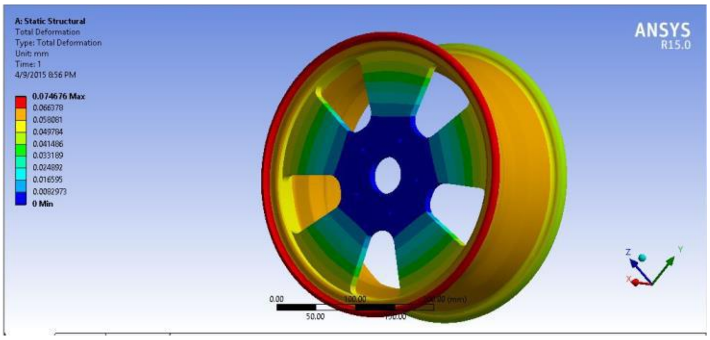

Figure 6.8 Deformations in Wheel Rim at 80Kmph

At 120Kmph

V = ωr

$= \frac{120 \times 5}{18 \times 0.177}$

= 187.687rad/sec

The rotational velocity of 187.687rad/sec is applied on the wheel rim as shown below:

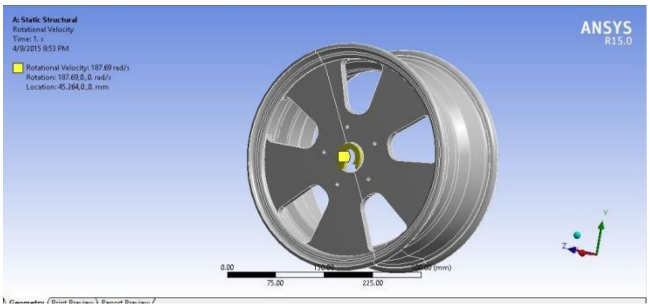

Figure 6.9 Rotational Velocities on Wheel Rim at 120Kmph

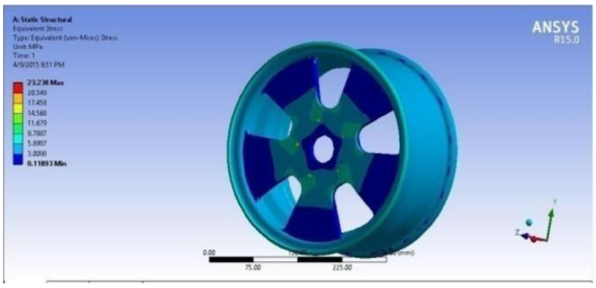

Figure 6.10 Von-Mises stress on Wheel at 120Kmph

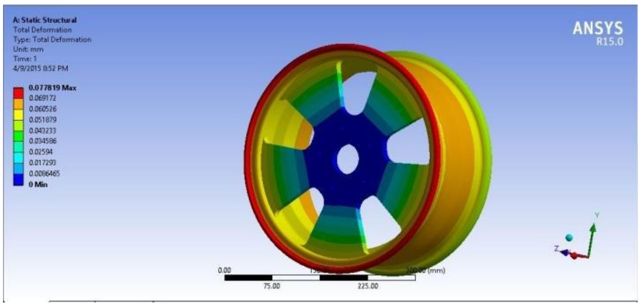

Figure 6.11 Deformations in Wheel Rim at 120Kmph

At 160Kmph

V = ωr

ω = v/r

$= \frac{160 \times 5}{18 \times 0.177}$

= 250.25 rad/sec

The rotational velocity of 250.25rad/sec is applied on the wheel rim as shown below:

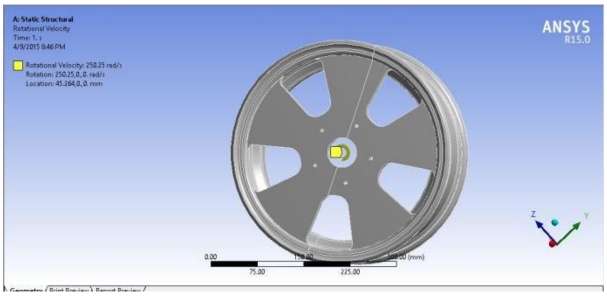

Figure 6.12 Rotational Velocities on Wheel Rim at 160Kmph

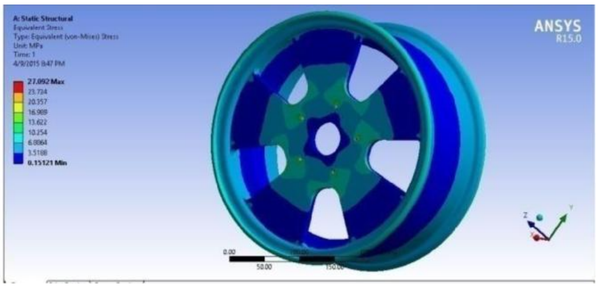

Figure 6.13 Von-Mises stress on Wheel at 160Kmph

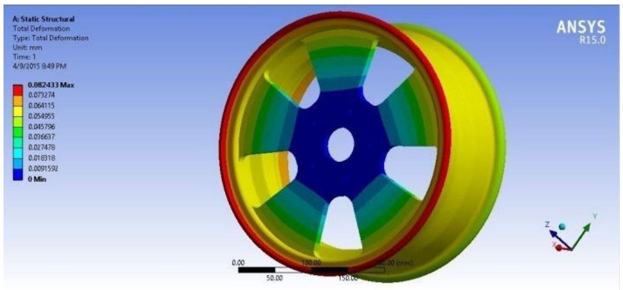

Figure 6.14 Deformations in Wheel Rim at 160Kmph

Stress and deformations at different speeds

S .No	Speed(kmph)	Von-Mises Stress(MPa)	Deformation(mm)
1	40	20.261	0.072914
2	80	20.488	0.074676
3	120	23.238	0.077819
4	160	27.092	0.082433

From the results it has been observed that by increasing the speed the von-mises stresses and deformations are also increased. However, they are well below the design stresses.

CALCULATIONS OF STRESS VARIABLES IN AUTOMOBILE WHEEL

Further the design parameters of automobile wheel are calculated theoretically by taking properties of different materials at different speeds of vehicle. **Stresses at different speeds**

Here by taking centrifugal force into account

$F = mr\omega^2$

Here an element is taken from the wheel rim

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$dF = (dm) r\,\omega^2$

Where,

$dm = \rho\, dv$ (1)

$dv = t.dA$ (2)

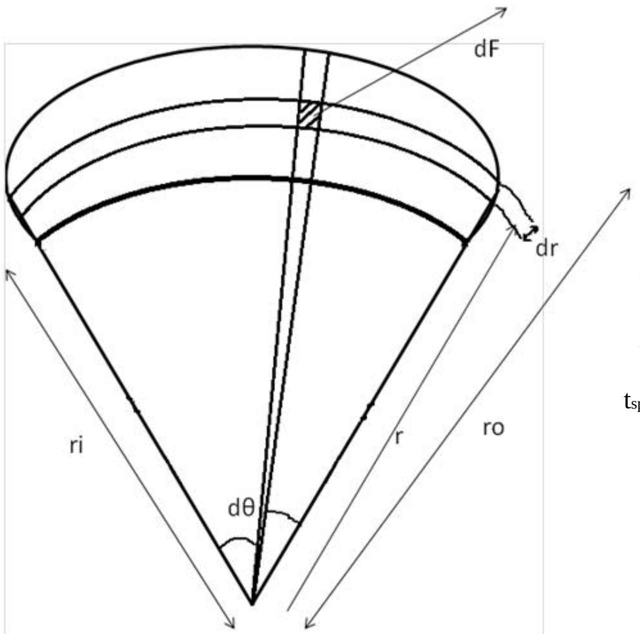

Figure 11.1 Line diagram of spoke on wheel rim

The element is taken as dF, the area can be written as $dA = (r d\theta)dr$ (3)

By substituting equations (1),(2)and (3)

$dF = \rho.t.r(d\theta)\, dr\, r\,\omega^2$

dF_y for a given r = $\int_{\theta=\theta_1}^{\theta=\theta_2} dF \sin\theta$

$= \int_{\theta_1}^{\theta_2} (\rho.t.r^2.\omega^2.dr)\, d\theta.\sin\theta$

$dF_y = \rho.t.r^2 dr\,(\cos\theta_1 - \cos\theta_2)$

Here $\theta_1 = 54^0$

$\theta_2 = 126_0$

$dF_y = \rho.t.r^2 dr\,(\cos 54 - \cos 126)$

$= 1.175\, \rho.t.r^2.\omega^2\, dr$

For entire body $r = r_o$

Then $F_y = \int dF_y$

$= 1.175 \int_{r=r_i}^{r=r_o} \rho.t.\omega^2 r^2 dr$

$= \frac{1.175\,\rho.t\,\omega^2}{2}(r_o^2 - r_i^2)$ (4)

$m = \rho V$

$V = t A$

$A = \frac{1}{2}(r_o^2 - r_i^2)\theta$

Therefore,

$m = \frac{1}{2}\rho.t(r_o^2 - r_i^2)\theta$ (5)

By dividing (4) and (5) equations

$F_y = \frac{1.175\,\rho.t\,\omega^2}{2}(r_o^2 - r_i^2)$

$m = \frac{1}{2}\rho.t(r_o^2 - r_i^2)\theta$

$= 1.175\times\frac{2}{2}\times\frac{\omega^2}{\Delta\theta}(\frac{r_o^2-r_i^2}{r_o^2-r_i^2})$

$F_y = 1.175\times\frac{2}{2}\times\frac{m}{\Delta\theta}(\frac{r_o^2-r_i^2}{r_o^2-r_i^2})\times\omega^2$

Here

$m = 3.6\times\Delta\theta$

$r_o = 177.8mm$

$r_i = 171.8mm$

$F_y = 1.175\times\frac{2}{2}\times 3.6\times\frac{\Delta\theta}{2\pi}\times\frac{1}{\Delta\theta}(\frac{r_o^2-r_i^2}{r_o^2-r_i^2})\times\omega^2$

$= 0.448\,(\frac{177.8^2-171.8^2}{\ldots})\times\omega^2$

$= 117.47\times\omega^2$

From the above expression the centrifugal force is in the form of ω^2

To know the area of the spoke

$A_{spoke} = b_{critical}\times t_{spoke}$

Here $b_{critical} = 62mm$

$t_{spoke} = 12mm$

Stress= $\frac{117.47\times\omega^2\times10^{-3}}{62\times12mm^2}$

$= 0.1578\times10^{-3}\times\omega^2$ MPa

By substituting the angular velocity (rad/sec) in the above equation the results were in the below table:

Stress at different speeds

S.no	speed (Kmph)	ω (rad/sec)	Stress (σ) MPa
1	40	62.56	0.617
2	80	125.125	2.488
3	120	187.687	5.553
4	160	250.25	9.88

RESULTS AND DISCUSSIONS

The scope of the present investigation is concerned for the development of wheel rim by performing mass optimization. By changing the materials with PMC and the stress, deformation and weight is minimized and the mass optimization is achieved. In further, the wheel is compared with three and five bolt hole designs by varying the number of spokes. Further it is extended to observe the stresses at different speeds.

Mass optimization of wheel rim is done by using two methods:

- By performing analysis on three, five bolt holes by varying the number of spokes by which the stress, deformation and weight of wheel is observed.

- By using poly matrix composites on wheel rim by which the stress, deformation and weight can be reduced.

Stresses, deformation and weight of wheel at three and five bolt holes at different number of spokes

Number of spokes	Von-Mises stress(MPa)		Deformation (mm)		Weight of wheel rim (Kg)	
	3 bolt holes	5bolt holes	3bolt holes	5bolt holes	3bolt holes	5bolt holes
4 spokes	8.9878	9.0777	0.032092	0.032037	5.339	5.1291
5 spokes	8.1165	8.0254	0.031448	0.029302	5.1359	5.3084
6 spokes	7.9965	8.0096	0.031002	0.030467	5.1745	5.1732

By taking four spokes making the comparisons for the three, five bolt holes the stress are 8.98MPa and 9.077MPa, deformation is 0.032mm and weight is 5.33kg and 5.129kg respectively. By taking five spokes making the comparisons for the three, five bolt holes the stress are 8.11MPa and 8.02MPa, deformation is 0.031 and 0.029mm and weight is 5.13kg and 5.3kg respectively and by taking six spokes making the comparisons for the three, five bolt holes the stress are 7.99MPa and 8 MPa, deformation is 0.031mm and 0.03mm, weight is 5.17kg and 5.17kg respectively.

By varying with different spokes with three and five bolt holes, taking stresses and deformation into account it is concluded five bolt designs with five spokes are good.

Results by varying different materials:

Stresses, deformation and weight of wheel at different materials

S.No	Materials	Vonmises(Mpa)		Deformation(mm)		Weight of wheel (KG)
		Minimum	Maximum	inimum	Maximum	
1	Structural steel	0.0058585	8.1099	0	0.01041	15.044
2	Stainless steel	0.0043522	8.0818	0	0.010785	14.852
3	Magnesium alloy	0.0056782	7.969	0	0.04619	3.4495
4	Aluminum alloy	0.004968	8.0254	0	0.029302	5.3084
5	Titanium alloy	0.0062655	7.9407	0	0.021639	8.8538
6	Grey cast iron	0.0043902	8.1661	0	0.018928	13.798
7	Copper alloy	0.0053602	7.9972	0	0.018905	15.906
8	Carbon fiber	0.0058406	8.2511	0	0.004309	3.8328
9	Boron fiber	0.0070357	9.0645	0	0.0051616	4.791
10	Silicon carbide	0.0063166	8.9975	0	0.0051668	6.7074
11	Peek with 30% carbon reinforced	0.004467	7.8272	0	0.086278	2.74

From the above results in table, it is observed, the existing material in aluminum alloy the stress is 8.0254 MPa, deformation is 0.029mm and weight of the wheel is 5.3Kg.

The stresses in copper, titanium and magnesium alloy are minimum. By replacing the materials on the wheel rim the stress and deformation is minimum by using PEEK with 30% carbon reinforced. By considering weight it is concluded that PEEK with 30% carbon reinforced is best material form wheel rim.

Results at various speeds

Comparisons of stresses analytically and theoretically

Velocity (Kmph)	Numerical(software) MPa	Analytical (Hand calculation) Mpa	Error (%)
40kmph	1.398	0.617	55.86%
80kmph	2.112	2.468	14.40%
120kmph	4.453	5.553	19.80%
160kmph	8.608	9.88	12.87%

From the above table we can observe at lower speeds (40 Kmph) the centripetal force is very high. When the speed is increased to next higher cases as observed in table, the error is low.

CONCLUSIONS

Based on the work done following conclusions are given

1. The deisgn of wheel rim used in this research is proved which is in safe limit by using mechanics of materials.
2. The analyzed work on automobile wheel rim is done by static analysis and validation is done by using analytical methods when compared values are in good agreement.
3. The five bolt holes with five spokes design gave good results when compared to the other designs with three bolt holes by varying spokes.
4. The weight of the wheel is minimized by using poly matrix composites without increase in the stress and deformation.
5. From the analysis results, stresses are more at the bolt holes than the remaining area of wheel which agreed from literature review.
6. By using PMC's 48.3% of the weight is reduced and the stress are well below the design stresses.
7. By considering four wheels of passenger car, nearly 12kg of the weight is reduced by which the fuel consumption is decreased.
8. At different speeds it has been observed that, by increasing the speed the von-mises stresses are increased.

Scope of work

The work can be extended with the fatigue analysis, Dynamic stiffnes test, vibrational analysis and fabrication of wheel to calculate more dynamic forces.

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