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Design and Analysis of Wheel Rim with Magnesium Alloys (ZK60A) by Using Solidworks and Finite Element Method

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ABSTRACT

A wheel rim is a highly stressed component in an automobile that is subjected to bending and torsional loads. Because of the long life and high stresses, as well as the need for weight reduction, material and manufacturing process selection is important in rim design. There are competitions among materials and manufacturing processes, due to cost, performance, and weight. This is a direct result of industry demand for components that are lighter, to increase performance, and cheaper to produce, while at the same time maintaining fatigue strength and other functional requirements. Lighter wheels can improve handling by reducing unsprung mass , allowing suspension to follow the terrain more closely and thus improve grip, however not all alloy wheels are lighter than their steel equivalents. Reduction in overall vehicle mass can also help to reduce fuel consumption. Nowadays cars have been using steel alloy for its wheel rim. On moving with advancements the magnesium alloy can be used for the wheel rim .In this part structural analysis of wheel rim with magnesium alloy is done and compared the results with steel alloy. As magnesium alloy (ZK60A) matches the target of lighter wheel and having many benefits compared to other metals, it can compete with exists.

Keywords: Wheel rim, Aluminum alloy, Magnesium alloy, Material reduction, Solidworks and Ansys.

1. INTRODUCTION

In this paper work a brief introduction about the comparison between wheels rims of various material. A wheel rim is a highly stressed component in an automobile that is subjected to bending and torsional loads. Because of the long life and high stresses, as well as the need for weight reduction, material and manufacturing process selection is important in rim design. There are competitions among materials and manufacturing processes, due to cost, performance, and weight. This is a direct result of industry demand for components that are lighter, to increase performance, and cheaper to produce, while at the same time maintaining fatigue strength and other functional requirements. Magnesium wheels were originally used for racing, but their popularity during the 1960s lead to the development of other die-cast wheels, particularly of aluminum alloys. The term "mag wheels" became synonymous with die-cast wheels made from any material, from aluminum alloy wheels to plastic and composite wheels used on items like bicycles, wheelchairs, and skateboards.

However, true magnesium wheels are very rare, usually found only on high dollar sports cars. Magnesium suffered from many problems. It was very susceptible to pitting and corrosion, and would start to break down in just a few months. Cracking was a common problem, and the wheels were very flammable. Magnesium is used for flares and early flash lamps. Magnesium in bulk is hard to ignite but, once lit, is very hard to extinguish, being able to burn under water or in carbon dioxide, which are common extinguishing materials. Tires that caught fire could soon ignite the magnesium, creating difficulties for fire responders. Magnesium wheels required constant maintenance to keep polished. Alloys of magnesium were later developed to help alleviate some of the problems.

Mark Lisnyansky, President of Magnesium Inc. notes that, "Wheel weight is very important to overall performance as it is key component in "un-sprung" vehicle mass. Generally, the accepted rule for thumb for predicting performance benefits from sprung vs. un-sprung weight reduction is a factor of approximately 4:1. For every pound of un-sprung mass eliminated a four fold advantage is gained in vehicle performance parameters.

For example, forged magnesium, large diameter wheels (20"-22") increase the weight advantage over aluminum by eliminating, on average, 70-75 lbs. un-sprung mass, which would provide the same acceleration time and braking distance benefit as eliminating 250-300 pounds from the vehicle engine, chassis or passenger compartment.

"Mr. Lisnyansky goes on to say that, "By virtue of these lighter wheels, forged wheels are at least 20% lighter, sustaining equal loads with better characteristics, which is always easier on the car and its suspension. Lighter wheels also yield shorter breaking distance, which saves lives, shorter acceleration and reduces fuel consumption."

2. WHEEL RIM DESCRIPTION

The rim of a wheel is the outer circular design of the metal on which the inside edge of the tyre is mounted on vehicles such as automobiles. For example, in a four wheeler the rim is a hoop attached to the outer ends of the spokes-arm of the wheel that holds the tyre and tube. A standard automotive steel wheel rim is made from a rectangular sheet metal. The metal plate is bent to produce a cylindrical sleeve with the two free edges of the sleeve welded together. At least one cylindrical flow spinning operation is carried out to obtain a given thickness profile of the sleeve in particular comprising in the zone intended to constitute the outer seat an angle of inclination relative to the axial direction. The sleeve is then shaped to obtain the rims on each side with a radially inner cylindrical wall in the zone of the outer seat and with a radially outer frusto-conical wall inclined at an angle corresponding to the standard inclination of the rim seats. The rim is then calibrated.

To support the cylindrical rim structure, a disc is made by stamping a metal plate. It has to have appropriate holes for the center hub and lug nuts. The radial outer surface of the wheel disk has a cylindrical geometry to fit inside the rim. The rim and wheel disk are assembled by fitting together under the outer seat of the rim and the assembly welded together. Wheel rim is the part of automotive where it heavily undergoes both static loads as well as fatigue loads as wheel rim travels different road profile. It develops heavy stresses in rim so we have to find the critical stress point and we have to find for how many number cycle that the wheel rim is going to fail.

3. TYPES OF WHEEL RIM (MATERIAL)

Steel and light alloy are the main materials used in a wheel however some composite materials including glass-fiber are being used for special wheels.

3.1 Wire Spoke Wheel

Wire spoke wheel is a structural where the outside edge part of the wheel (rim) and the axle mounting part are connected by numerous wires called spokes. Today's vehicles with their high horsepower have made this type of wheel construction obsolete. This type of wheel is still used on classic vehicles. Light alloy wheels have developed in recent years, a design to emphasize this spoke effect to satisfy users fashion requirements.

3.2 Steel Disc Wheel

Fig 1. Steel disc wheel

This is a rim which processes the steel-made rim and the wheel into one by welding, and it is used mainly for passenger vehicle especially original equipment tires.

3.3 Light Alloy Wheel

These wheels based on the use of light metals such as aluminum and magnesium has become popular in the market. These wheels rapidly become popular for the original equipment vehicle in Europe in 1960's and for the replacement tire in United States in 1970's. The features of each light alloy wheel are explained as below;

3.3.1 Aluminum Alloy Wheel

Aluminum is a metal with features of excellent lightness, thermal conductivity, corrosion resistance, characteristics of casting, low temperature, machine processing and recycling, etc. This metals main advantage is reduced weight, high accuracy and design choices of the wheel. This metal is useful for energy conservation because it is possible to re-cycle aluminum easily.

3.3.2 Magnesium Alloy Wheel

Magnesium is about 30% lighter than aluminum, and also, excellent as for size stability and impact resistance. However, its use is mainly restricted to racing, which needs the features of lightness and high strength at the expense of corrosion resistance and design choice, etc. compared with aluminum. Recently, the technology for casting and forging is improved, and the corrosion resistance of magnesium is also improving. This material is receiving special attention due to the renewed interest in energy conservation.

3.3.3 Titanium Alloy Wheel

Titanium is an excellent metal for corrosion resistance and strength (about 2.5 times) compared with aluminum, but it is inferior due to machine processing, designing and high cost. It is still in the development stage although there is some use in the field of racing.

3.3.4 Composite Material Wheel

The composite materials wheel, is different from the light alloy wheel, and it (Generally, it is thermoplastic resin which contains the glass fiber reinforcement material) is developed mainly for low weight. However, this wheel has insufficient reliability against heat and for strength. Development is continuing.

4. MANUFACTURING METHOD OF WHEEL RIM

The steel disk wheel and the light alloy wheel are the most typical installation. The method of manufacturing the light alloy wheel, which has become popular in recent years, is explained here. The manufacturing method for the light alloy wheel is classified into two. They are cast metal or the forged manufacturing methods. The aluminum alloy wheel is manufactured both ways, and the casting manufacturing method is used as for the magnesium alloy wheel. There are the following three methods of manufacturing the aluminum alloy wheel.

4.1 One Piece Rim

This is a method of the casting or the forge at the same time by one as for the rim and disc.

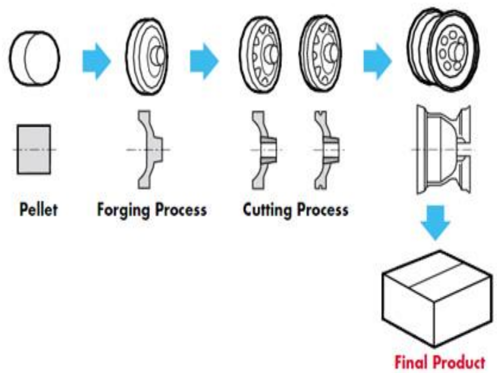


Fig 2. Forging method (one piece rim)

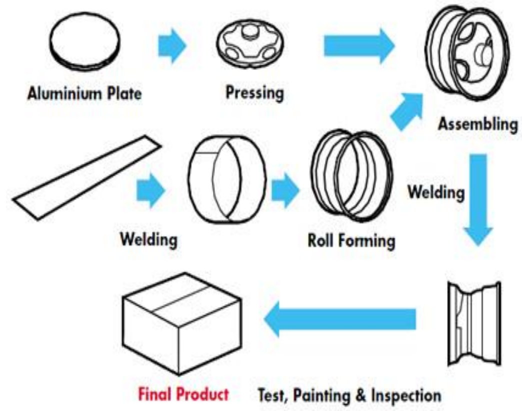


Fig 3. Forging method (two piece rim)

4.2 Two Piece Rim

This is the methods which separately manufacture the rim and disc similar to the manufacture of the steel wheel and these components are welded afterwards.

4.3 Three Piece Rim

This is a method to manufacture each flange separately and combining later to the disc by welding.

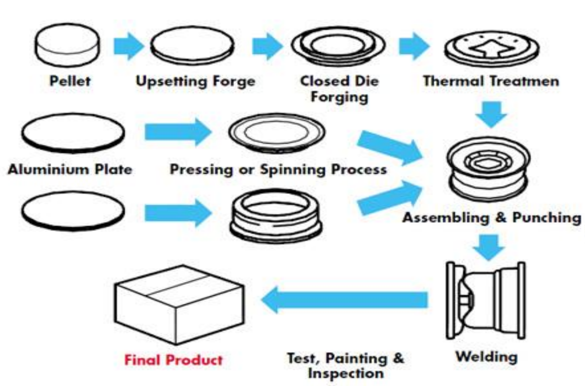


Fig 4. Forging method (three piece rim)

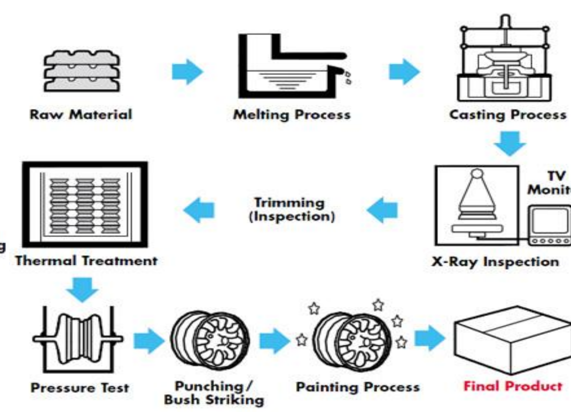


Fig 5. Casting method

5. STUDY ON MATERIAL REDUCTION

As the automotive industry addresses environmental concerns, the problem of fuel consumption and weight reduction has come to the force. Reducing the weight of automobiles is one of the primary means by which their fuel consumption is lowered. The two basic approaches are in automotive design and in materials selection, and they are closely related. Regarding materials, there has been a trend toward the use of light metals and their alloys in automotive components, particularly automotive bodies. The most commonly used materials are aluminum, magnesium, and their alloys, though some research has also been done on the use of titanium, zinc, and nonmetallic materials.

In order to find the relation between material reduction and mileage we used the data's in the consumer report. It provides curb weight in kilogram and mileage in km/lit. Curb weight is the base weight of the vehicle (i.e.) the weight of the vehicle without any external load.

Fuel economy is, of course, affected by many design factors besides curb weight. Some factors that can be examined are engine HP, transmission characteristics and aerodynamic design. Not all of these can be evaluated quantitatively. However, my study shows that as curb weight increases, fuel economy of the vehicle decreases. The graph of weight versus mileage shows a nice downward trend. There is much less scatter and I can develop a simple linear regression equation (using classical least squares fitting) relating curb weight to mileage.

However, considering the difficulties in testing and the large variations in engine, transmission and aerodynamic characteristics between vehicles, I decided to use a simpler method, and simply connected the extreme points by a straight line. The data point can then be shown to fall between the parallels with the equation y = mx + c where the constants m is the slope and c is y-intercept. We did an analysis with vehicle weight and fuel economy from the data obtained from the consumer report. Let us consider 10 different suv's from different manufacturers. The raw data is shown in table 1.

Table 1: Curb weight and mileage

Name	Curb weight(kg)	Mileage(km/l)
Santa fe	1920	14.66
Nissan x-trail	1618	15.1
Skoda yeti	1543	17.67
Ford endeavour	2014	12.22
Xuv 500	1865	15.1
Safari	2040	13.2
Aria	2220	14.5
Scorpio	1850	14

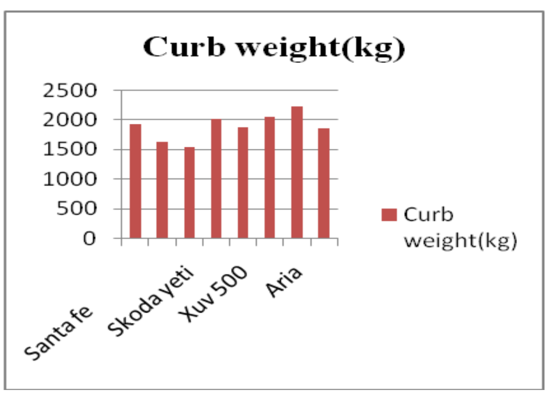


Fig 6. Comparison of Curb Weight in Vehicle

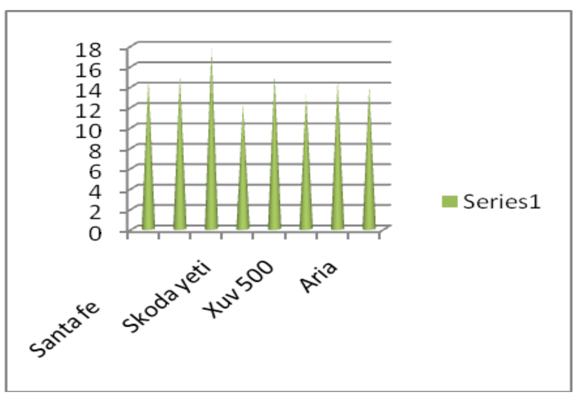


Fig 7. Comparison of Mileage in Vehicle

Here x-curb weight, y-mileage the five points do not fall on a perfect straight line. But, the x-y graph does show a nice downward trend with some scatter. From the graph1 using the straight line equation we can deduce the follow;

$$y = mx+c$$
$$y = - 0.01123x + 25$$

The slope is negative which means fuel economy decreases as curb weight increases. The reciprocal of the slope has the units of kilogram per km/lit and is equal to 156.25.

In other words, if the vehicle weight decreases by about 89.04 kg (or roughly 90kg), the fuel economy will increase by 1 kmpl.

The intercept c = 25 also has a special significance and represents the highest mpg conceivable if vehicle weight goes x goes to zero. In other words, to develop vehicles with fuel economies significantly greater than 25kmpl.

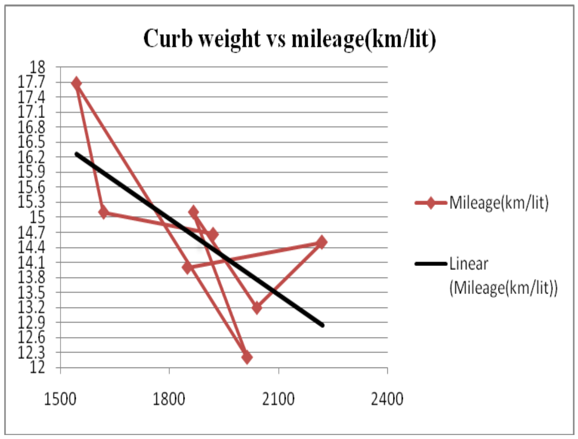
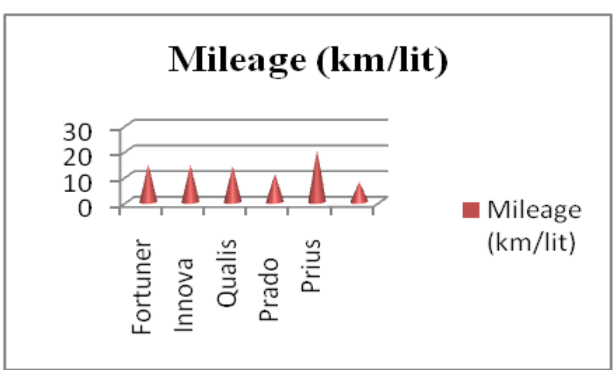


Fig 8. Comparison of Mileage Vs Curb Weight

I also analyzed the data for vehicles produced by a single manufacturer, e.g. Toyota. The data for 6 different vehicles were chosen from this list.

Table 2: Comparison of curb weight and mileage

Name	Curb weight(kg)	Mileage (km/l)
Fortuner	1955	14.66
Innova	1640	14.44
Qualis	1570	14
Prado	1900	11
Prius	1390	20.4
Land cruiser	2720	8



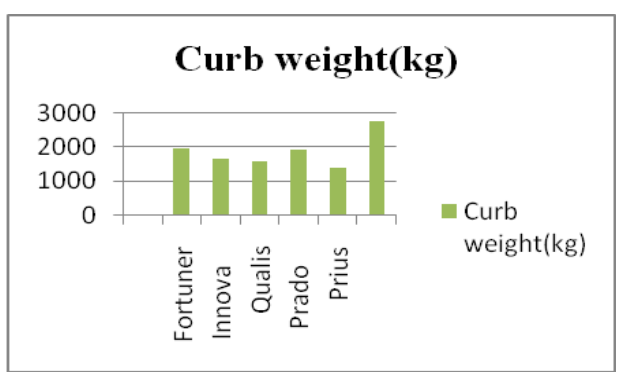


Fig 9. Comparison of Mileage in Vehicle *Fig 10. Comparison of Curb weight in Vehicle*

The x-y graph again reveals a nice downward trend with significant scatter. We can deduce the following linear regression equation.

$$y = mx + c$$
$$y = -0.02136x+82$$

The slope h = -0.02136 is higher and implies that for this manufacturer (Toyota), every 46kg reduction in vehicle weight will yield an improvement in fuel economy of 1kmpl. The intercept c = 51.03 is also higher.

The conclusion is that every 100kg reduction in weight will yield a fuel economy improvement of 2.17kmpl and the theoretical highest possible mpg is about 82 mpg, if we focus only on weight reduction.

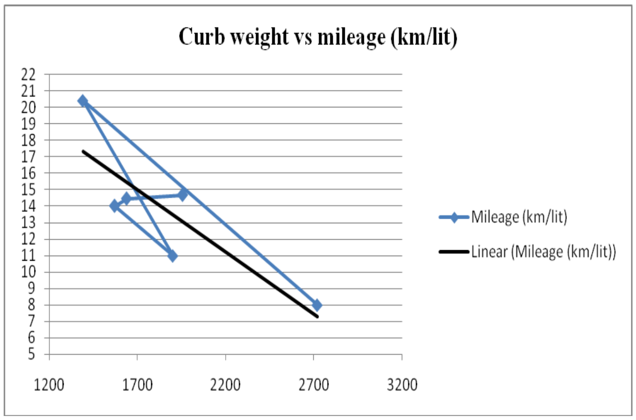


Fig 11. Comparison of Mileage Vs Curb Weight

6. Role of Magnesium in Material Reduction

Let us assume that 100kg of steel components are replaced by magnesium, the volume occupied is found by using the formula

Density = mass/volume

For a steel

Density = 7800kg/m^3

Mass = 100kg

Therefore,

Volume= 12.82*10^-3

For magnesium

Density = 1800kg/m^3

Mass = Density x volume

Determined mass value is 23.07kg

From the above we can conclude that 100kg of steel components are

Replaced by of magnesium

Hence, the thumb rule based on the data is 100kg of steel equals nearly 23kg of magnesium.

6.1 Utility of Magnesium alloy

Considering its characteristics of low density, its extensive use in vehicles would obtain major reductions of weight and corresponding fuel savings. The data indicate that overall weight saving would lead to fuel saving without drastic change in design. Considering the large number of vehicles around, this weight saving could lead to a significant reduction of carbon dioxide released to the atmosphere, reducing the impact on global warming.

Our objective is to utilize the value of magnesium alloy in wheel rim for improving the effects. Because, Wheels play a major role in the ride and handling of a vehicle. From a ride standpoint, the weight of the wheel has much to do with the ability of the suspension to control the tire/wheel motion over bumps. This is the “unsprung weight” issue that seems to come up frequently when talking about vehicle performance.

Unsprung weight is the weight of the vehicle that is not supported by the suspension. This includes the wheel tire, and brake components. Since the suspension does not support this weight, it is not easily controlled when a bump or impact is incurred. The lighter the unsprung weight, the less affect it has on ride, and the easier it is for the shock and spring to work together to keep the tire in consistent contact with the road surface.

ZK60A is a wrought magnesium base alloy containing zinc and zirconium. Increased strength is obtained by artificial aging from the as-fabricated form. ZK60A-T5 has the best combination of strength and ductility at room-temperature of the wrought magnesium alloys.

6.2 Chemical Composition

Zinc	4.8-6.2%
Zirconium	0.65%min
Magnesium	balance

6.3 Physical Properties

Table 3: Properties and values of ZK60A

Property	Value in metric units
Density	1.83*10e3
Modulus of elasticity	45pa
Thermal expansion	26.0*10e-6
Specific heat capacity	1000 j/(kg*k)
Thermal conductivity	120w/(m*k)
Electric resistivity	6.08*10-8 ohm*m
Tensile strength(F)	340 Mpa
Yield strength(F)	260 Mpa
Elongation(F)	11 %
Shear strength(F)	185 Mpa
Hardness(F)	75 HB (500)
Tensile strength(T5)	365 Mpa
Yield strength(T5)	305 Mpa
Elongation(T5)	11%
Shear strength(T5)	180 Mpa
Hardness(T5)	88 HP (500)
Annealing temperature	290C
Liquidus temperature	635C
Solidus temperature	520C

6.4 Machining

ZK60A, like all magnesium alloy forgings, machines faster than any other metal. Providing the geometry of the part allows, the limiting factor is the power and speed of the machine rather than the quality of the tool material. The power required per cubic centimeter of metal removed varies from 9 to 14 watts per minute depending on the operation.

6.5 Surface Treatment

All the normal chromating, anodizing, plating, and finishing treatments are readily applicable.

6.6 Corrosion resistance

ASTM B117 salt spray test

Corrosion rate0.6 mg/ cm2 /day 50 mpy

6.7 Applications

Forging in ZK60A find application in high strength parts for use primarily where the service temperature is below 150°C. ZK60A forgings can be used where pressure tightness or machinability are required. Those parts are dimensionally stable during and after machining is also an important design consideration.

Forgings in ZK60A find application in high strength parts for satellites, helicopter gearboxes and rotor hubs, bicycle frames, road wheels, missile frames and interstage fairings, brake housings and landing gear struts.

7. MODELING OF WHEEL RIM

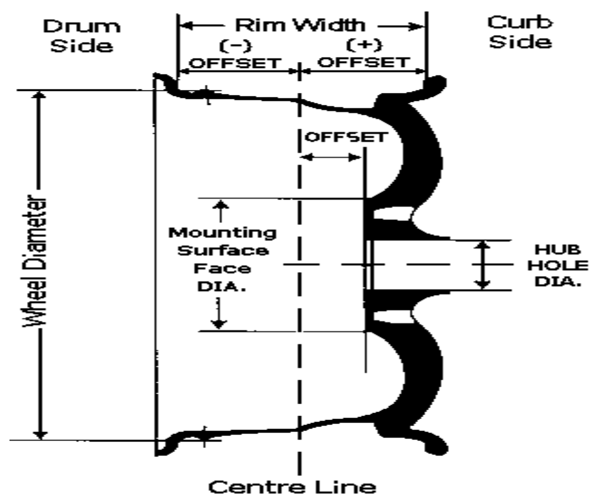


Fig 12. Wheel Rim Nomenclature

7.1 2D model of the wheel rim

Initially the 2D drawing of wheel rim is done by using SOLID WORKS according to dimensions specified in the Table 4.

Table 4. Dimensions of Material

S. No	Diameter	Dimensions (mm)
1	Outer	450
2	Hub hole	150
3	Bolt hole	20
4	Rim width	254

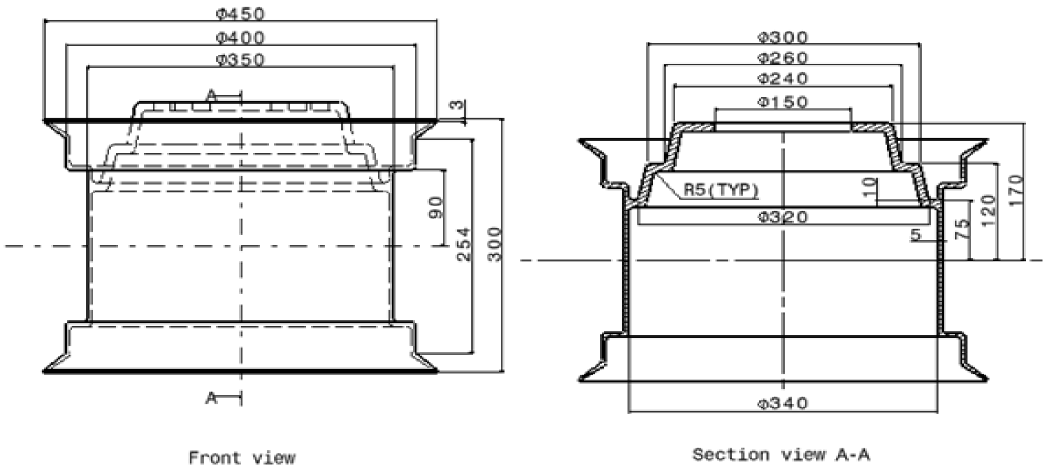


Fig 13. 2D Dimensions of Wheel

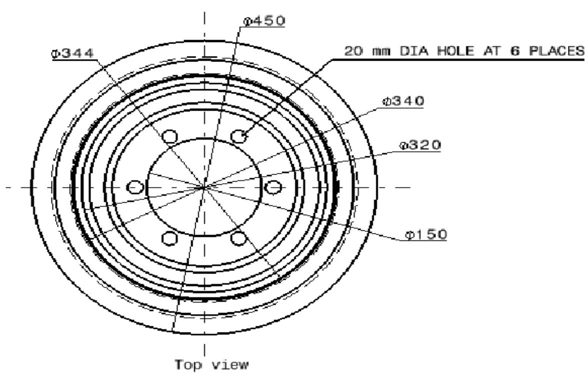


Fig 14. 2D drawing of wheel rim

Fig 15. 3D Model of Wheel Rim

8. FINITE ELEMENT ANALYSIS

8.1 Introduction to finite element method

The finite element method is a powerful tool for the numerical procedure to obtain solutions to many of the problems encountered in engineering analysis. Structural, thermal and heat transfer, fluid dynamics, fatigue related problems, electric and magnetic fields, the concepts of finite element methods can be utilized to solve these engineering problems. In this method of analysis, a complex region defining a continuum is discretized into simple geometric shapes called finite elements the domain over which the analysis is studied is divided into a number of finite elements. The material properties and the governing relationship are considered over these elements and expressed in terms of unknown values at element corner .An assembly process, duly considering the loading and constraint, results in set of equation. Solution of these equations gives the approximate behavior of the continuum.

8.2 Steps involved in FEM

The different steps involved in the Finite element method are as follows:

Step1: Discretization of continuum

The first step in any FEM is to divide the given continuum in to smaller region called element. The type of elements has to be taken depending on type of analysis carried out like one dimensional, two dimensional, and three dimensional.

Step 2: Selection of displacement model

For the continuum discretized in to number of element, displacement variation over each of this element is unknown .Hence a displacement function is assumed for each of the element, this function is called displacement model.

Step 3: Derivation of elemental stiffness matrix

The equilibrium equation for an element is determined by using the principal of minimum potential energy.

Step 4: Assembly of the element stiffness matrix

This step involves determining of global stiffness matrix. This is done by using the compatibility conditions at the nodes. The displacement of a particular node must be the same for every element connected to it. The externally applied loads must also be balanced by the forces on the elements at these nodes.

Step 5: Apply the boundary conditions

To obtain a unique solution of the problem, some displacement constraints (i.e. boundary conditions) and loading conditions must be prescribed at some of the nodes. This may be of the following forms

1) Elimination method
2) Penalty method
3) Multi constraint method

These boundary conditions are incorporated into the system of linear algebraic equations, which can then be solved to obtain a unique solution for the displacements at each node.

Step 6: To find unknown displacement, strain and stress

After solving the global equations, displacements at all the nodal points are determined. From the displacement values, the element strains can be obtained from the stress-strains relations. In FE formulation only the displacements are the independent variables, that is, forces, strains and stresses are obtained from the displacements

8.3 Convergence study

Convergence is a process of refining mesh, as the mesh is refined, the finite element solution approach the analytical solution of the mathematical model. This attribute is obviously necessary to increase the confidence in FEM results from the standpoint of mathematics.

The fundamental premise of FEM is that as number of elements (mesh density) is increased, the solution gets closer and closure, however solution time and compute resources required also increases dramatically as we increases the number of elements to the true solution. The objective of analysis decides how to mesh the given geometry, if we are interested in getting accurate stress; a fine mesh is needed, omitting geometric details at the location we needed. If we are interested in deflection results, relatively course mesh is sufficient.

There are two convergence studies, h-convergence study and p-convergence study h-Convergence study is done by increasing number of elements which can be done by making mesh size finer, and it is important to maintain continuity in meshing and element check should be done for aspect ratio, warping angle, skew ratio and others The elements must have enough approximation power to capture the analytical solution in the limit of a mesh refinement process. p- Convergence study is done by increasing number of nodes.

Meshing of a given model will be done depending on geometry of the model, it is better to have more degrees of freedom hence more number of elements so that results obtained will be closure to analytical results. In two bay panel analyses, crack region is meshed with more number of elements when compared with other parts of fuselage, for obtaining a converged solution which in turn a better solution.

8.4 Structural analysis

Structural analysis is probably the most common application of the finite element method. The term structural implies not only civil engineering structures such as bridges and buildings, but also naval, aeronautical, and mechanical structures such as ship hulls, aircraft bodies, and machine housings, as well as mechanical components such as pistons, machine parts, and tools.

8.5 Static Analysis

Static analysis calculates the effects of steady loading conditions on a structure, while ignoring inertia and damping effects, such as those caused by time-varying loads. A static analysis can, however, include steady inertia loads (such as gravity and rotational velocity), and time-varying loads that can be approximated as static equivalent loads (such as the static equivalent wind and seismic loads commonly defined in many building codes). Static analysis involves both linear and nonlinear analyses. Nonlinearities can include plasticity, stress stiffening, large deflection, large strain, hyper elasticity, contact surfaces, and creep. The FE analysis used for the major part of this work is static analysis which involves both linear and nonlinear structural analysis. Hence more prominence is imparted on Linear and nonlinear analysis in further sections.

8.5.1 Linear Static Analysis

In linear analysis, the behavior of the structure is assumed to be completely reversible; that is, the body returns to its original undeformed state upon the removal of applied loads and solutions for various load cases can be superimposed.

The assumptions in linear analysis are:

1) Displacements are assumed to be linearly dependent on the applied load.
2) A linear relationship is assumed between stress and strain.
3) Changes in geometry due to displacement are assumed to be small and hence ignored.
4) Loading sequence is not important and the final state is not affected by the load history. The load is applied in one go with no iterations.

8.5.2 Non Linear static analysis

In many engineering problems, the behavior of the structure may depend on the load history or may result in large deformations beyond the elastic limit. The assumptions/ features in nonlinear analysis are:

1) The load-displacement relationships are usually nonlinear.
2) In problems involving material non-linearity, the stress-strain relationship is a nonlinear function of stress, strain, and/or time.
3) Displacements may not be small, hence an updated reference state may be needed.
4) The behavior of the structure may depend on the load history; hence the load may have to be applied in small increments with iterations performed to ensure that equilibrium is satisfied at every load increment.

From the above assumptions, the finite element equilibrium equation for static analysis is:

$$[K]\,\{U\} = [F]$$

Where $[K]$ is the linear elastic stiffness. When the above assumptions are not valid, one performs nonlinear analysis.

8.5.3 Geometric nonlinearity

Geometric nonlinearity occurs when the changes in the geometry of a structure due to its displacement under load are taken into account in analyzing its behavior. In geometric nonlinearity, the equilibrium equations take into account the deformed shape. As a consequence of this, the strain-displacement relations may have to be redefined to take into account the current (updated) deformed shape. That is, the stiffness [K] is a function of the displacements {u}.

Some common geometric nonlinearity is:

1) Large strain assumes that the strains are no longer infinitesimal (they are finite). Shape changes (e.g. area, thickness, etc.) are also accounted for. Deflections and rotations may be arbitrarily large.
2) Large rotation assumes that the rotations are large but the mechanical strains (those that cause stresses) are evaluated using linearized expressions. The structure is assumed not to change shape except for rigid body motions.
3) Stress stiffening Stress stiffening also called geometric stiffening or incremental stiffening is the stiffening of a structure due to its stress state. This stiffening effect normally needs to be considered for thin structures with bending stiffness very small compared to axial stiffness, such as cables, thin beams, and shells and couples the in-plane and transverse displacements.
4) Spin softening*:* The vibration of a spinning body will cause relative circumferential motions, which will change the direction of the centrifugal load which, in turn, will tend to destabilize the structure. As a small deflection analysis cannot directly account for changes in geometry.

8.6 Description of element used in static analysis in Ansys

The procedure for a model analysis consists of four main steps:

1. Build the model.
2. Apply loads and obtain the solution.
3. Expand the modes.
4. Review the results.

a. Importing the Model:

The finite element meshed model (.hm file format) of wheel rim is imported from Hyper Mesh Software to **ANSYS** Software.

- Centrifugal force, $F=mr\omega^2$ N
- ω =2*(22/7)*N/60 rad/s
- M=4 kg
- For N=600 rpm
- ω =62.8 rps

By substituting, we get centrifugal force=3.54 kN which acts at each node of the circumference of the rim

For mg alloy

- Centrifugal force, $F=mr\omega^2$ N
- ω =2*(22/7)*N/60 rad/s
- M=1 kg
- For N=600 rpm
- ω =62.8 rps

By substituting, we get centrifugal force=0.819kN which acts at each node of the circumference of the rim.

b. Boundary conditions and Loading:

To get compressive and tensile stress, a load of 21.3kN is applied on the bolt holes of the wheel rim.

- Displacements
  a. Translation in x, y, z directions is zero.
  b. Rotation in x, y, z direction is zero.
- Angular velocity in X direction is zero,
  Y direction is 62.8 rps,
  Z direction is zero.
- These conditions are applied on the six holes provided on the rim.

In the same way, Centrifugal force is also applied in the loading condition on the holes. Analyzed picture of the wheel rim with the steel alloy and magnesium alloy is listed in APPENDIX 1 and APPENDIX 2.

9. RESULTS AND DISCUSSIONS

9.1 Material properties

- **Steel alloy:**

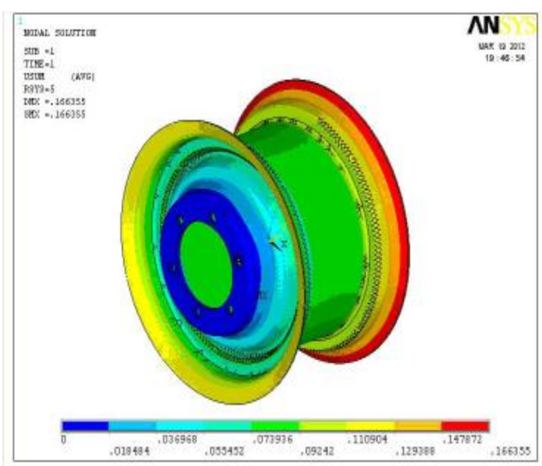
Young's modulus (E) $=2.34*10^5$ N/mm^2
Yield stress (σ_{yield}) =240 N/mm^2
Density ρ =7800kg/m^3

- **Magnesium alloy:**

Young's modulus (E) =45000N/mm^2
Yield stress (σ_{yield}) =130 N/mm^2
Density ρ =1800kg/m^3

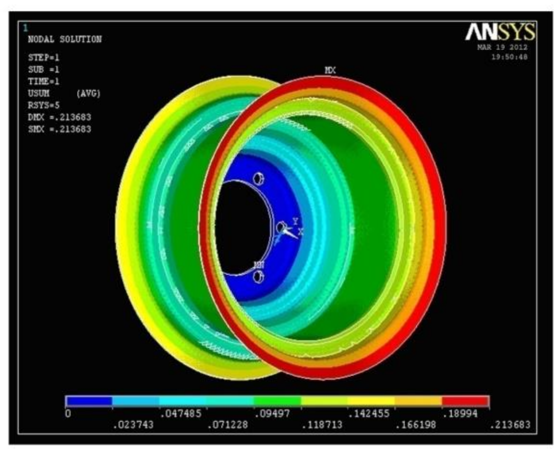
9.2 Appendix I (Displacement)

Fig 16. Steel alloy



Displacement=0.166 mm

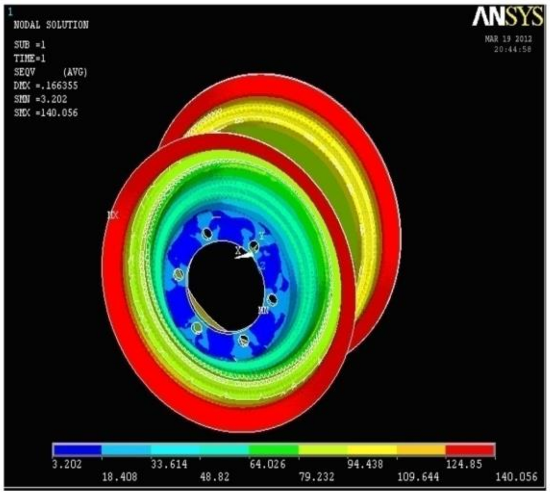
Fig 17. Magnesium (mg) alloy



Displacement=0.21mm

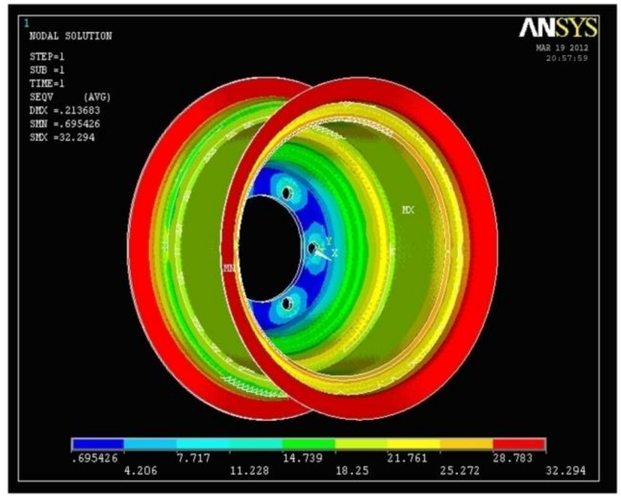
9.3 Appendix II (Vonmises Stress)

Fig 18. Steel alloy



Max vonmises stress=140.056 Mpa
Min vonmises stress=0.6954 Mpa

Fig 19. Magnesium (mg) alloy



Max vonmises stress=32.294 Mpa
Min vonmises stress=3.202 Mpa

9.4 Results obtained from software:

Steel alloy:-
Displacement = 0.166mm
Von misses stress (σ_v) =140.056 N/mm^2
Magnesium alloy:-
Displacement = 0.21mm
Von misses stress (σ_v) =32.204 N/mm^2

10. CONCLUSION

1. Stress developed in the steel alloy is 140.056Mpa which is below the yield stress of the material.
2. Stress developed in the magnesium alloy is 32.294Mpa which is below the yield stress of the material.
3. Comparatively stress developed in the magnesium alloy is lower than the stress developed in steel alloy. By using magnesium alloy the unsprung mass of the vehicle is reduced which improves the vehicle performance.

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