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Design and Fatigue Analysis of Four Wheeler Alloy Wheel

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CHAPTER 1
INTRODUCTION

1.1 History of Wheel-

Several thousand years ago was the start of the history of wheel when the human race began to use the log to transport heavy objects. The original of the wheel were the round slices ofa log and it was gradually re-inforced and used in this form for centuries on both carts and wagons.

This solid disc changed to a design having several spokes radially arranged to support the outer part of the wheel keeping it equidistant from the wheel center. A wooden wheel which used hard wood stakes as spokes was very popular as a wheel for many vehicles up to about 1920.

Afterwards the disc wheel, in which the spokes were replaced with a disc made of steel plate, was introduced and is still being used to this day. Furthermore, a light alloy has come to be used currently as a wheel material for many types of vehicle.Trucks have been basic backbone of the world's workforce for decades. They're big, powerful, and can really get you through the roughest of terrains. But a truck can't do its job without properly functioning wheels. Truck rims need to be replaced if they're bent or crackedfor the sake of your truck's life - and sometimes just for an upgrade. Knowing your truck rim options will greatly assist you in this process.

Most steel truck rims are created in the same way. It starts with a hard cast hub, with 4, 5 or even 6 holes for the bolts. A spun steel rim is then secured around this with a series of welds. The rim is properly balanced and then given a smooth finish. Although some steel rims are available in silver and chrome, most of those finishes are saved for alloy wheels.

Truck wheels need to be durable and able to carry around weight. You won't find many spoke designs with these rims. They're usually as solid as possible. But that doesn't mean your options aren't varied when looking for replacements. The most important thing to remember is to purchase the same size rims you're replacing unless you're also planning on vehicle modifications.

Lighter wheels can improve handling by reducing unsprung mass , allowing suspensionto 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 .

Better heat conduction can help dissipate heat from the brakes , which improves braking performance in more demanding driving conditions and reduces the chance of brake failure due to overheating.

1.2 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 giventhickness 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 seatand 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 hasto 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.

1.3 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.

1.3.1 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.

1.3.2 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.

1.3.3 Aluminium Alloy Wheel-

These wheels based on the use of light metals such as aluminium and magnesium have 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 featuresof each light alloy wheel are explained as below; Aluminium 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 Aluminium easily

1.3.4 Magnesium Alloy Wheel-

Magnesium is about 30% lighter than Aluminium, 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 Aluminium.

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.

1.3.5 Titanium Alloy Wheel-

Titanium is an excellent metal for corrosion resistance and strength (about 2.5 times) compared with Aluminium, 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.

1.3.6 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.

1.4 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 Aluminium 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 Aluminium alloy whee1.

1.4.1 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.

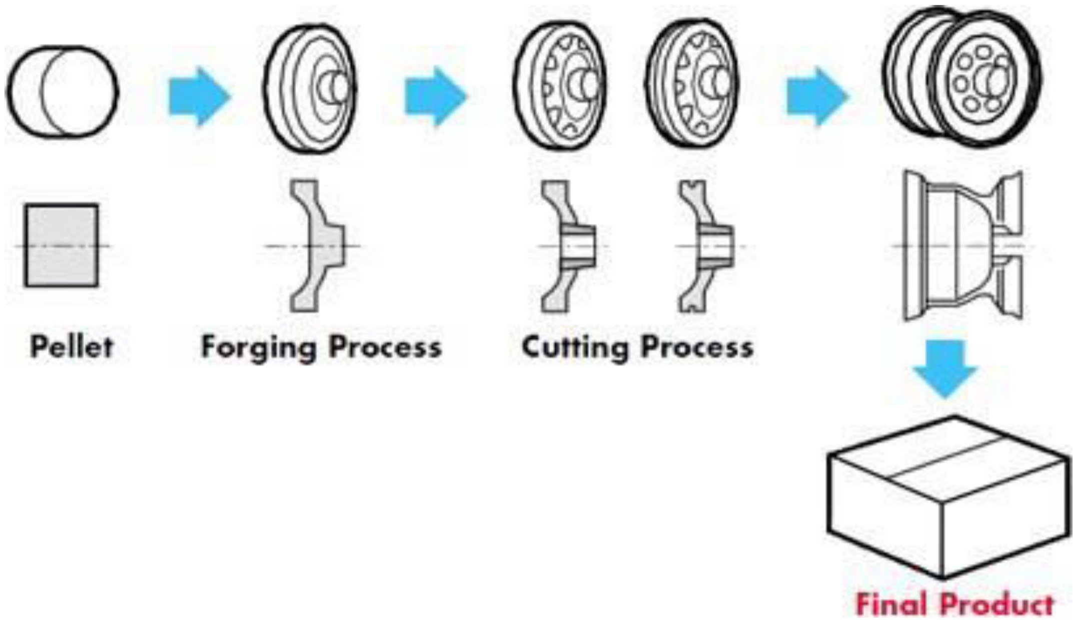

Fig No.1.1 Forging Method (For One Piece Rim)

1.4.2 Two Pieces 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.

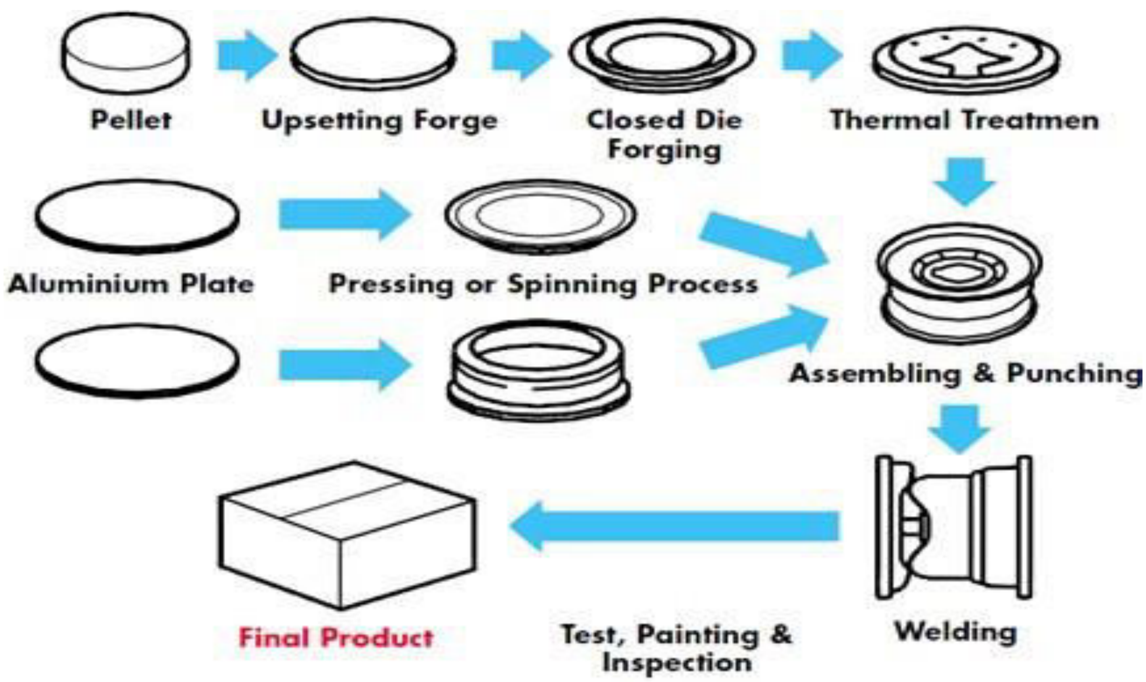

Fig. No. 1.2 Forging Method (For Two Pieces Rim)

1.4.3 Three Pieces Rim-

This is a method to manufacture each flange separately, and combining later to the discby welding. Each method is shown below.

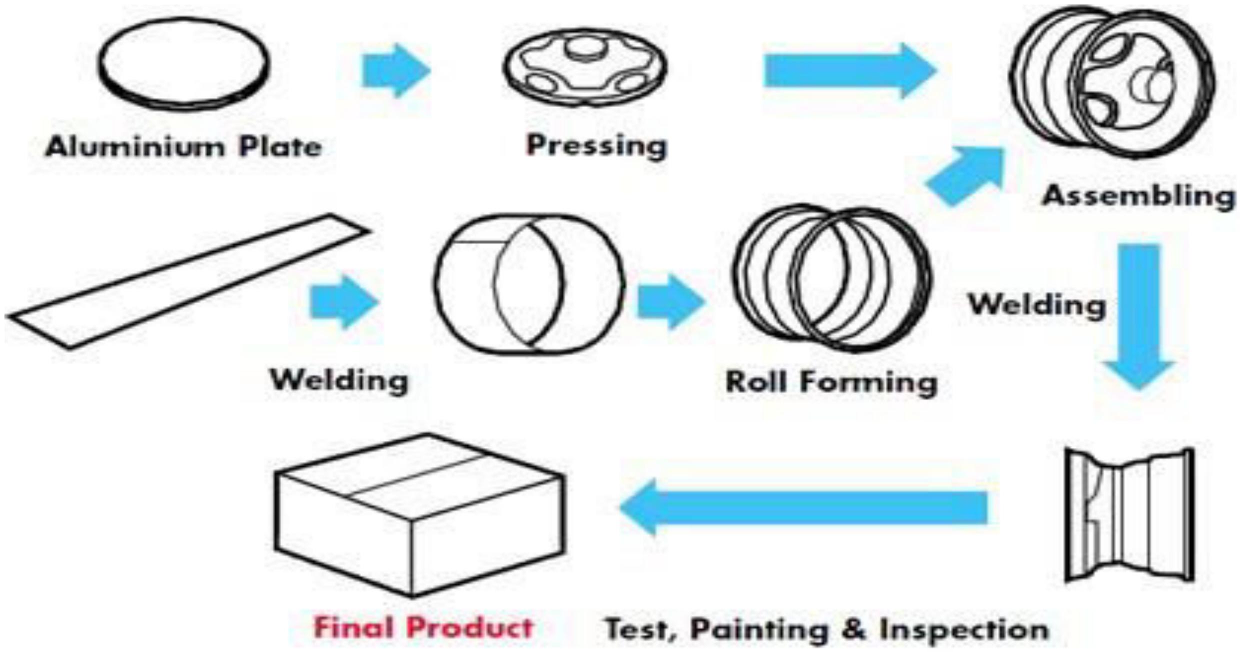

Fig No.1.3 Forging Method (For Three Pieces Rim)

1.4.4 Casting Method-

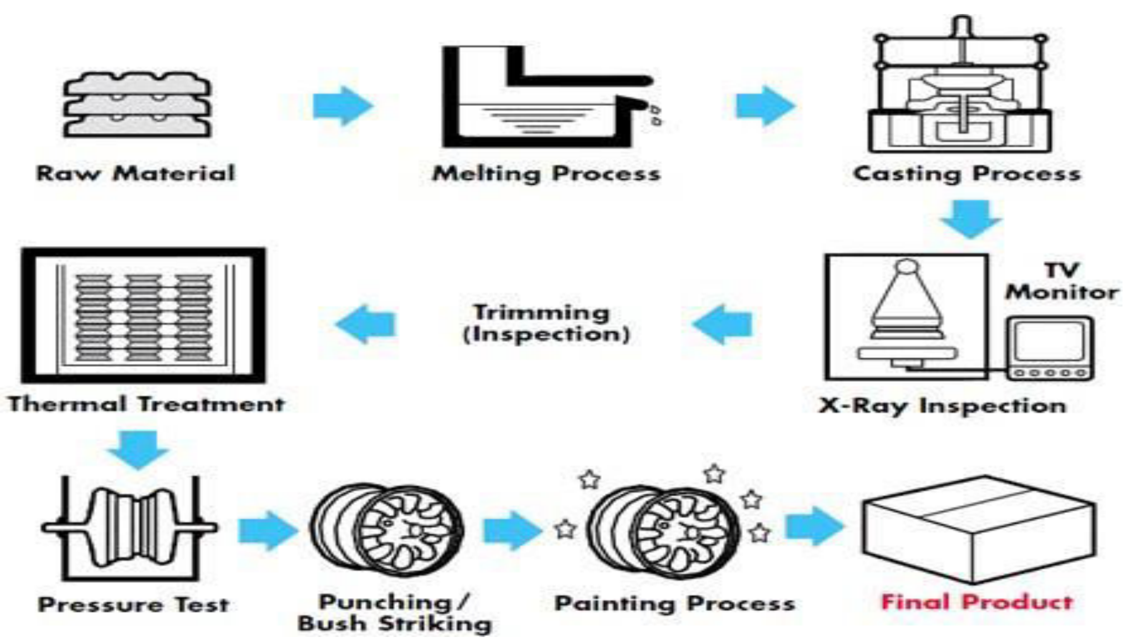

Fig .no.1..4 Casting Methods

1.5 Tests of Wheel-

Wheels are part of a vehicle and as such subjected to a high load. The durability of the wheel is important for the safe operation of the vehicle. Therefore, it is necessary to examine a wheel for both strength and fatigue resistance.

1.5.1Endurance Test in Direction of Radius of Rim-

The tire on the test rim is rotated under high pressure condition on steel drum and the durability of the rim is examined. Sometimes, test is done giving camber angle and adding a side force.

1.5.2 Test of Disc-

The rim flange is tested by applying a load from an arm mounted to the hub. A bending moment is applied while the rim rotates.

1.5.3 Impact Test-

The case where the wheel collides with curb of the road or a large obstacle is assumed and the fall impact examination is done.

1.5.4 Others-

The test for welding between rim and disc and the nut seat tightening etc. are provided in the vehicle test standard. Moreover, nondestructive testing such as X ray and color check, etc. are adopted to the light alloy wheel to detect the defects in the casting process. Bead Unseating Test, provided in the tire safety standards, for a mounted tire and the rim is also applied.In addition tests are carried out in the field with the assembly mounted on a vehicle under various road surfaces.

1.6 Use Limit of the Wheel-

Though we think it is possible to permanently use a wheel until it rusts away there is a limit to a wheels useful life. If a rim is used in severe operations such as racing or rallying hiddendamage is caused. This may result in an accident or sudden rim failure whilst damage is caused. This may result in an accident or sudden rim failure whilst the vehicle is in service. The life of a rim is varied according to using conditions. A rim normally lasts longer than a tire so at time of atire change a rim should be checked for damage or sign of failure. If any are found the rim should be scrapped. In the case of steel wheel, cracks and corrosions by rust at the joint parts of rim and disc, nut seats, between decoration holes of the rim or the flange is bent, you shouldscrap the rim.

1.7 Maintaining Rims -

Very necessary but often overlooked, it is vitally important to inspect your motorcycle rims and clean them on a regular basis to help prevent spoke failure or corrosion weak points. You can definitely suffer flat tires if a few spokes fail on your motorcycle rims. This can happen under ordinary everyday conditions. The broken spoke pushes into the wheel and punctures the tube. So always keep your wheels clean and check them for signs of corrosion or other damage.It may only take one bad spoke to ruin your ride. The Aluminium motorcycle rims are usually coated. Some chemicals used for bike maintenance of other systems (like brake fluid) can damage that coating. Once the bare Aluminium on the motorcycle rim is exposed to air it can begin to corrode. Wheels can come under a lot of stress and even small areas of corrosion can become a point of failure.Rim locks are used on wheels to prevent your tire from slipping around your motorcycle rims. This can occur if you are running your tires at very low pressures. They are quite common when bikers take to riding off road. If your tire turns on the rim it can pull the valve stem throughthe wheel or tear it off completely leaving you with a flat. They are fairly simple to install but it requires removal of the tires and tubes and this can be more work than the rim lock installation. The rear is the more critical of the motorcycle rims to lock as it is subjected to the forces of driving the bike forward. Install them opposite the valve stem to minimize the affect they will have on wheel balance.

1.8 Failure of A Wheel Rim –

a. Motorcycle Rims Problems-

If you have been in an accident or purchased a bike with unknown history it is possible that your motorcycle wheel could be out of true. The wheel might seem to oscillate laterally (side to side) or appear to move up and down (out of round). Motorcycle rims can be casually inspected by supporting the bike on the center stand or other stand and spinning them while viewing side onor edgewise. A really bad wobble will be obvious even to someone like me!. You can secure a sharp pencil to the fork or swing arm to help measure smaller variations. If the wheel is badly outof true, especially if the cause is from an accident, you may want to let a professional motorcycle rims shop or dealer does the repair. Sometimes the cause is just from lazy spoke maintenance (shame on you)! The wheel can slowly drift out of true over time. This kind of thing can be repaired yourself if you are up to it.

b. New Tire, new wobble?

If we have just had new tires installed and you feel or see a wobble it is more likely that the tire is the cause not bent rims. What can happen when mounting a new tire is the installer fails to get the new tire fully seated on the motorcycle rims. It may be close and because the tire has a tube in it there will be no leak to give it away. What we need to do is this.

- Examine the sidewall of the tire where it meets the rim to see if there is any indication that thetire is not fully seated. This might show up as a slight variation in the measurement between a mould line on the tire and the rims. This is best done on a center stand if we have one.
- Have the installer correct any problem you find. Sometimes stock rims can be difficult to seat properly (or unseat for that matter).
- Sometimes what the tire installer will do to correct the problem is overinflate the tire to force the tire to seat. TAKE CARE! I am not suggesting others to try , it can be very dangerous. Also make sure the tire is installed correctly, arrow pointing in the direction of travel. Also make sure the tire is installed correctly, arrow pointing in the direction of travel.

CHAPTER 2

LITERATURE SURVEY

N. Satyanarayana & Ch.Sambaiah, "*Fatigue Analysis of Aluminium Alloy Wheel Under Radial Load*", International Journal of Mechanical and Industrial Engineering (IJMIE), Vol-2, Issue-1, 2012[1]

In this paper a detailed "Fatigue Analysis of Aluminium Alloy Wheel under Radial Load". During the part of project a static and fatigue analysis of Aluminium alloy wheel A356.2 was carried out using FEA package. The 3 dimensional model of the wheel was designed using CATIA. Then the 3-D model was imported into ANSYS using the IGES format. The finite element idealization of this modal was then produced using the 10 node tetrahedron solid element. The analysis was performed in a static condition. This is constrained in all degree of freedom at the PCD and hub portion. The pressure is applied on the rim. We find out the total deformation, alternative stress and shear stress by using FEA software. And also we find out the life, safety factor and damage of alloy wheel by using S-N curve. S-N curve is input for a A356.2material. [1]

Liangmo Wang, Yufa Chen, Chenzhi Wang, Qingzheng Wang, " *Fatigue Life Analysis of Aluminium Wheels by Simulation of Rotary Fatigue Test*", Journal of Mechanical Engineering Nanjing University of Science & Technology, China 2010, [2]

To improve the quality of Aluminium wheels, a new method for evaluating the fatigue life of Aluminium wheels is proposed in that paper. The ABAQUS software was used to build the static load finite element model of Aluminium wheels for rotary fatigue test. Using the method proposed in this paper, the wheel life cycle was improved to over 1.0×10^5 and satisfied the design requirement. The results indicated that the proposed method of integrating finite element 1analysis and nominal stress method was a good and efficient method to predict the fatigue life of Aluminium wheels. In this paper, for predicting the wheel fatigue life, the nominal stress method was integrated into the CAD / CAE technology to simulate the rotary fatigue test. In addition, an actual prototype of the test was done to verify the analysis.In the rotary fatigue test, a wheel was spun to bear a moment to simulate the process of turning corner continued the wheel's ability bearing the moment, a wheel was mounted on a rotating table. A shaft was attached to the center of the wheel where a constant normal force was applied [2]

J. Janardhan, V. Ravi kumar,R. Lalita Narayna "*Radial Fatigue Analysis of An Alloy Wheel*". Journal of Engineering Research and Applications www.ijera.com Issue 12(Part 6), December 2014. [3]

A load of 2500N was applied on the hub area of the wheel and a pressure of 0.207N/mm2 is applied on the outer surface of the rim. The pitch circle holes are constrained in all degrees of freedom. The analysis is carried under these constraints and the results are taken to carryout for further analysis i.e fatigue module to find the life of the wheel. Various number of cycles the analysis has been done. Finally we found Equivalent (Von-Mises) Stress we find 9.205x1e6 Pa maximum stress. And the minimum stress is 0.041x1e6 Pa. and the deformation is observed as the 0.515x1e-1 mm after running the fatigue cycles we found that the infinite life at 1.0x109 cycles. Same analysis can be performed with alternate materials by applying load at different areas on the wheel, to reduce the weight, which ultimately reduces the overall cost, with increasein lifetime, and we can find the failure by changing loads by increasing or decreasing according to our requirements of that particular wheels we also change the models or design of the wheel and to test for the fatigue and comparing with the two models which will give the more life we can identify and we can develop that model. And also the various tests have to be done by other two tests such as cornering test and impact test [3]

P. Meghashyam S. Girivardhan Naidu, N. Sayed Baba, "*Design and Analysis of Wheel Rim using CATIA & ANSYS* " International Journal of Innovation in Application or Engineering & Management (IJAIEM), [4]

. [4]

V.Dharani kumar, 2 S.Mahalingam, 3A.Santhosh kumar, "*Review on Fatigue Analysis of Aluminium Alloy Wheel under Radial Load for Passenger Car*", © 2014 IJEDR | Volume 3, Issue 1 | ISSN: 2321-9939, Sathyabama University, Chennai, India[5]

In automobile industries aluminum is used to manufacturing different parts of motor vehicles. The major advantage was found in aluminum is less weight with high strength. This aluminum replaces steel wheels due to its physical and chemical property. The aluminum alloy A356 wheelwill subject to different loads under running conditions. Fatigue is most important factor to be considered for aluminum alloy wheel. In this paper, fatigue life of aluminum alloy wheel A356 has been reviewed about the radial loading and test conditions. The aluminum alloy wheel model was designed by using Solid works 14 software. Then 3D model was converted into IGES file then imported to ANSYS, we found the result of static and fatigue analysis of alloy wheel. Also we find out the life of wheel, factor of safety by using S-N curve.

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Sourav Das, "*Design and Weight Optimization of Aluminium Alloy Wheel*" International Journalof Scientific and Research Publications, Volume 4, Issue 6, June 2014. [6]

This paper deals with the design of aluminum alloy wheel for automobile application which is carried out paying special reference to optimization of the mass of the wheel Finite Element analysis it shows that the optimized mass of the wheel rim could be reduced to around 50% as compared to the existing solid disc type Al alloy wheel. The FE analysis shows that the stress generated in the optimized component is well below the actual yield stress of the Al alloy. The Fatigue life estimation by finite element analysis, under radial fatigue load condition, is carried out to analyze the stress distribution and resulted displacement in the alloy wheels. S-N curve of the component depicts that the endurance limit is 90 MPa which is well below the yield stress of the material and safe for the application. The FE analysis indicated that even after a fatigue cycle of 1020 , the damage on the wheel is found only 0.2%. [6]

S Vikranth Deepak,CNaresh& Syed Attaf Hussain , "*Modelling and analysis of alloy wheel For four wheeler vehicle*" , Int. J. Mech. Eng. & rob. Res. 2012 issn 2278 – 0149 ,Vol.1, no. 3, october 2012[77]

Alloy wheels are automobile wheels which are made from an alloy of aluminum or magnesiummetals Or sometimes a mixture of both. Alloy wheels differ from normal steel wheels becauseof their lighter weight, which improves the steering and the speed of the car. Alloy wheels willreduce the unstrung weight of a vehicle compared to one fitted with standard steel wheels. Thebenefit of reduced unstrung weight is more precise steering as well as a nominal eduction infuel consumption. Alloy is an excellent conductor of heat, improving heat dissipation from thebrakes, reducing the risk of brake failure under demanding driving conditions. At p resent fourwheeler wheels are made of Aluminum Alloys. In this project, Aluminum alloy are comparing with other Alloy. In this project a parametric model is designed for Alloy wheel used in four wheeler by collecting data from reverse engineering process from existing model. Design is evaluated by analyzing the model by taking the constraints as ultimate stresses and variables astwo different alloy materials and different loads and goals as maximum outer diameter of the wheel and fitting accessories areas like shaft of the axle and bolts PCD of the car. Car model is Ford Fiesta. [7]

Sreenath A.R. and: Srihari , "*Structural Analysis and Comparative Study of Aluminium and Magnesium Alloy Wheel*", International Journal of Scientific & Engineering Research, Volume 5, Issue 7, July-2014 [8]

The main aim of this paper is to promote use of magnesium alloy for motorcycle wheels to reduce weight. Structural analysis of wheels made of A356.2, AM60B and redesigned AM60B under same service conditions were carried out, revealing that the peak stress is reduced. The peak stress in the redesigned Magnesium alloy wheel is found to be less than that in Aluminium alloy wheel, revealing the fact that proper designing of Magnesium alloy wheel can meet service conditions along with improved fuel efficiency due to reduced weight. [8]

1Ravi Lidoriya, 2SanjayChaudhary and 3Anil Kumar Mohopatra, "*Design and Analysisof Aluminium Alloy Wheel using PEEK Material*", International Journal of Mechanical Engineering and Research , Volume 3, Number 5 ,2013, [9] .

In the design of automobile, the industry is exploring polymericmaterial in order to obtain reduction of weight without significant decrease in vehicle quality and reliability. This is due to the fact that the reduction of weight of a vehicle directly impacts its fuel consumption. Particularly in city driving, the reduction of weight is almost directly proportional to fuel consumption of the vehicle. Thus in this project work the entire wheel design of two wheeler waschosen and analyzed by applying different load and redesign the wheel again to minimize the deformation and material will be changed from Aluminium to PEEK(polyether ether ketone)The following materials were chosen:- Aluminium Alloy,PEEK (Polyether ether ketone),PEEK with 30% Glass fiber,PEEK-90 HMF 20, PEEK-90 HMF 40. The whole design is made by using NX

7.5. The whole design has been made as per original equipment manufacture (OEM'S) requirement. Analysis has been done by Ansys 13.0 software to determine the various stresses, strain and fatigue life of the wheel. The software has helped us really to achieve our goal.As the whole analysis is done by the means of software therefore result and observation are trust worthy and meet with our expectation. [9]

BGN Satya Prasad, M Anil kumar, "*Topology Optimization of Alloy Wheel* ", a research ofthe Hyundai Motor India Engineering Hydrabad. [10]

India is one of the largest automotive industries in the world and one of the fastest growing globally. Now all automakers are concentrating on India for the promising growth in the sector. So competition in this industry is very high. Hence, there is a need to focus more on product development. The development of the product needs to be started from conceptual design with low cost, high performance and quality. There is a large scope for reducing the mass of aluminum wheel. In this paper the application of topology optimization to reduce the mass of aluminum wheel is discussed .

The alloy wheel, having passed all the tests with proper margin for safety, can be sent for production. Here a mass reduction of 340gm per wheel is achieved which mounts to 1.7kg percar considering the spare wheel. This mass reduction results in two benefits. Decrease in total weight of the car and decrease in cost of production. Optimization techniques help largely in reducing the mass of solid components which results in overall body weight reduction and thus lesser cost. Lesser weight in turn gives better performance and better fuel efficiency. These result in many indirect benefits to mankind which includes conservation of natural resources to some extent, reduction in air pollution and so on. [10]

CHAPTER 3

PROBLEM DESCRIPTION

The automotive industry is a crucial industry of the economy. The retail sales of automotive fuel in 2009 formed 29% of the income of R365 906 million of the motor trade industry in South Africa Retail sales of motor vehicle and sales of new motor vehicle parts and accessories are 49% and 9% respectively as indicated by Statistics South Africa . It is evidentthat wheels (rims) play a crucial role in everyday life, due to the size of the motor trade industry, which contributes 6% to the GDP of South Africa . The industry is a significant size, but carbon fiber rims for passenger cars have a non-existent share of the market. Steel and Aluminium rims currently dominate the market [14] and therefore the development of a carbon fiber passenger car rim (wheel) will stimulate additional market growth in the motor trade industry.

In the development of new material for wheels (rims), it is essential that fatigue testingbe conducted on the wheels in order to validate the wheel`s structural and material integrity. The material shift from the conventional steel to Aluminium wheels in the late 90s was part and parcel of the research done to develop fatigue curve results for Aluminium wheels . Carbon fiber is an extremely strong and light material. Its use as a suitable material to manufacture passenger car rims will be investigated in this report.

3.1 Design Of Wheel Rim (Nomenclature)—

Initially the 2D drawing of wheel rim is done by using CATIA according to dimensions specified in the Table 3.1

Parameter	Dimenssions
Outer diameter	450 mm
Hub hole diameter	150 mm
Bolt hole diameter	20 mm
Rim width	254 mm

Table No.3.1 Wheel Rim Dimensions

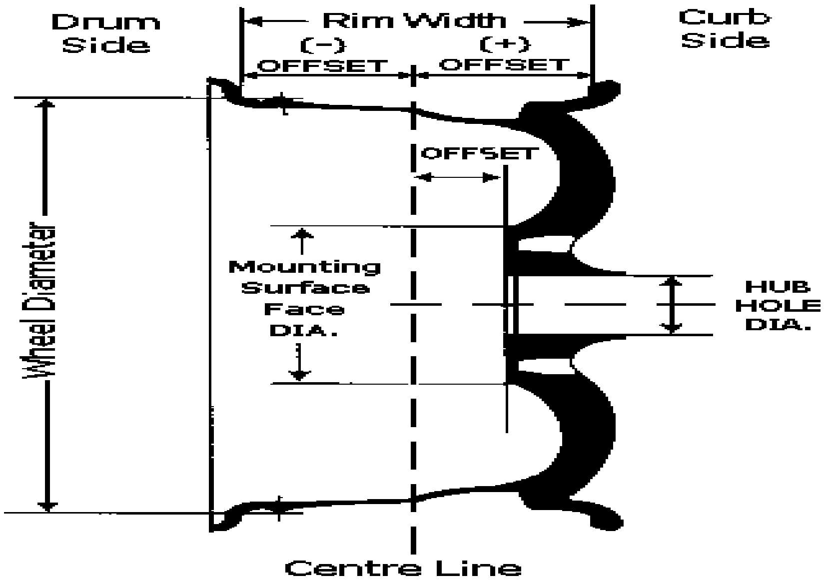

Fig.3.1 Wheel Rim Nomenclature

3.2 **2D Model of Wheel Rim-**

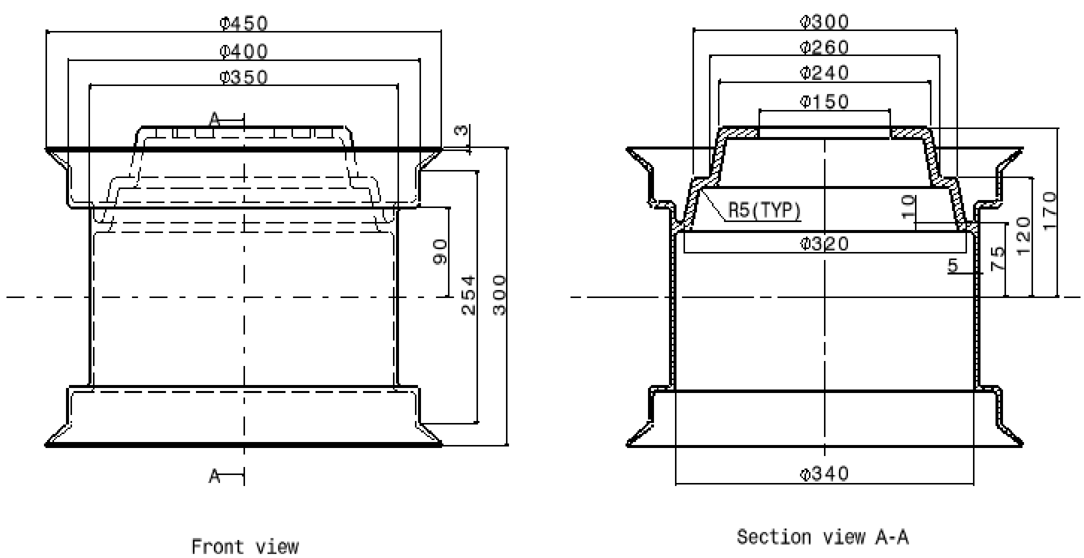

Fig 3.2 2D Drawing of Wheel Rim

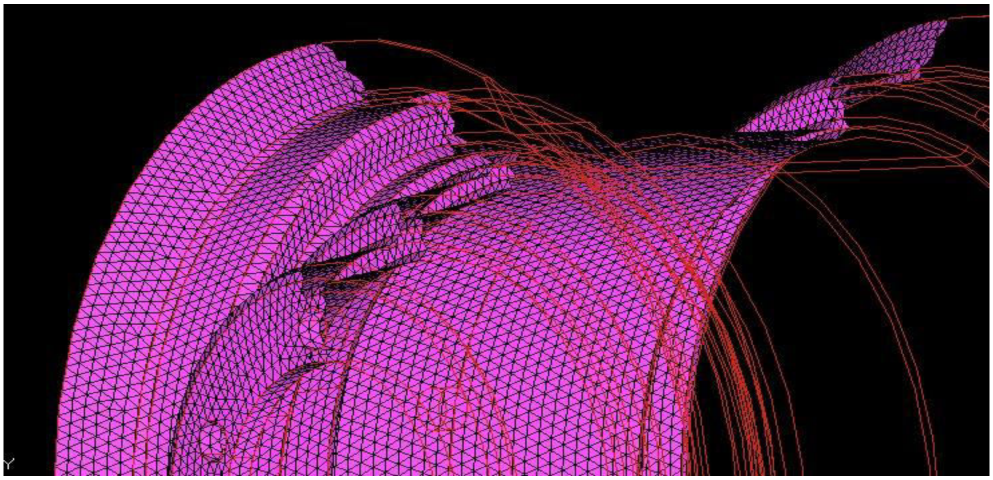

Fig 3.3 2D Meshing In Hypermesh

3.3 3D Model Of The Wheel Rim-

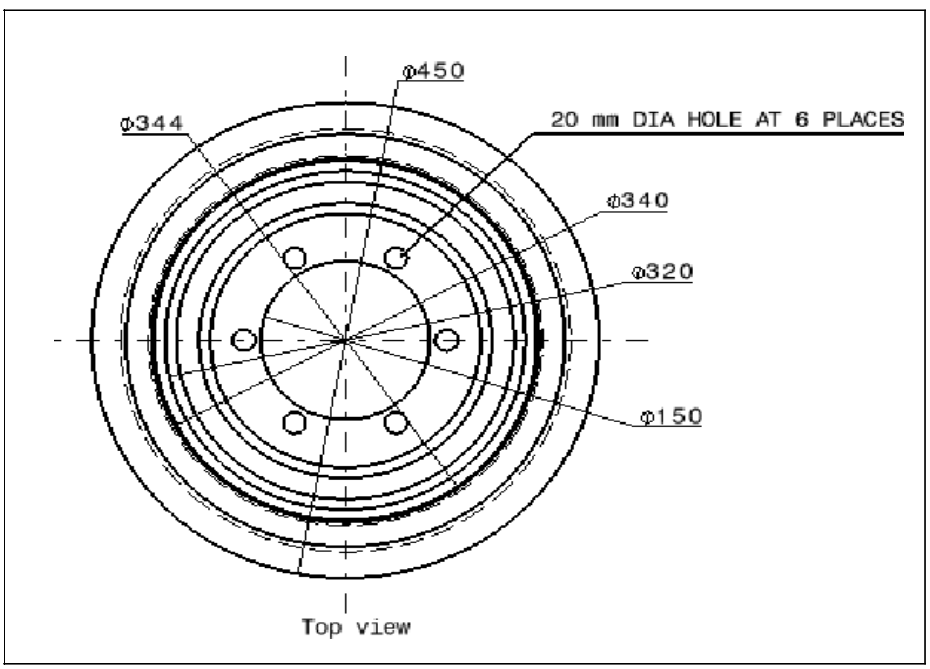

Fig. No. 3.4 3D Model Of The Wheel Rim

3.4 Generating the Mesh In Hypermesh Software-

Brief introduction of Hyper Mesh Software-

Altair Hyper Mesh is a high-performance finite element pre- and postprocessor for popular finite element solvers - allowing engineers to analyze product design performance in a highly interactive and visual environment.

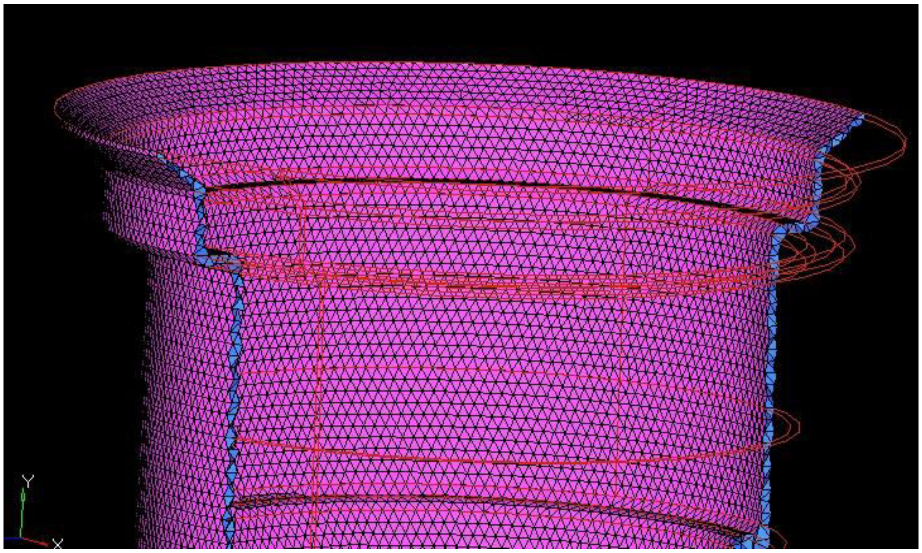

Fig 3.5 3D Meshing In Hypermesh

Hyper Mesh user-interface is easy to learn and supports many CAD geometry and finite element model files - increasing interoperability and efficiency. Advanced functionality within Hyper Mesh allows users to efficiently mesh high fidelity models. This functionality includes user defined quality criteria and controls, morphing technology to update existing meshes to new design proposals, and automatic mid-surface generation for complex designs with of varying wall thicknesses. Automated tetra-meshing and hexa-meshing minimizes meshing time while batch meshing enables large scale meshing of parts with no model clean up and minimal user input. The wheel rim solid model (.iges file format) is imported to HYPERMESH and the model is meshed with solid tetra element and saved in .hm file format thus finite element model is created

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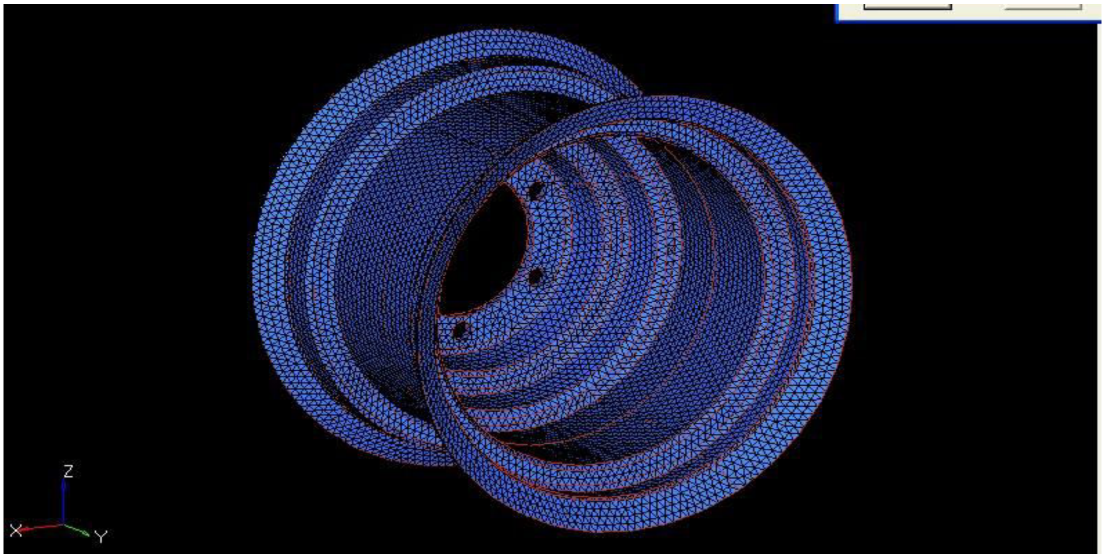

Fig3.6 Meshing Finished Model

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Benefits

- Reduce time and engineering analysis cost through high-performance finite element modeling and post-processing.
- The industry's broadest and most comprehensive CAD and CAE solver direct interface support.
- Reduce overhead costs of maintaining multiple pre- and post-processing tools, minimize "new user" learning curves, and increase staff efficiency with a powerful, intuitive, consistent finite element analysis environment.
- Reduce redundancy and model development costs through the direct use of CAD geometry and legacy finite element models.
- Simplify the modeling process for complex geometry through high-speed, high- quality auto meshing, hexa-meshing and tetra meshing.
- Dramatically increase end-user modeling efficiency by eliminating the need to perform manual geometry clean up and meshing with Batch Meshed technology.

The process of generating a mesh of nodes and elements consists of three general steps.

- Set the element attributes.
- Set mesh controls (optional).
- Meshing model.

CHAPTER 4

FINITE ELEMENT ANALYSIS

4.1 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.

4.2 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 eachof these 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 ofminimum 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

- Elimination method
- Penalty method
- 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

4.3 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) isincreased, 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 weare 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 betterto 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.

4.4 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.

4.4.1 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.

4.4.2 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-

- Displacements are assumed to be linearly dependent on the applied load.
- A linear relationship is assumed between stress and strain.
- Changes in geometry due to displacement are assumed to be small and hence ignored.
- 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.

4.4.3 Non Linear Static Analysis-

In many engineering problems, the behavior of the structure may depend on the load historyor may result in large deformations beyond the elastic limit. The assumptions/ features in Nonlinear analysis is-

- The load-displacement relationships are usually nonlinear.
- In problems involving material non-linearity, the stress-strain relationship is a nonlinear function of stress, strain, and/or time.
- Displacements may not be small; hence an updated reference state may be needed.
- The behavior of the structure may depend on the load history; hence the load may have tobe 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.

4.4.4 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 are:

- 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.

- 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.

- 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.

- 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, the effect can be accounted for by an adjustment of the stiffness matrix, called spin softening.

4.5 Description of Element Used In Static Analysis In Ansys –

Static Analysis-

The wheel was constrained around flange edge of the rim and loaded with a constant force at the end of the shaft, see Fig2.2. The load shaft and wheel were connected by bolts. Dueto the main concern being wheel deformation, the load shaft in the FEA analysis was defined as arigid body, using tie connection with wheel. J area under the wheel rim was under fullconstraints.

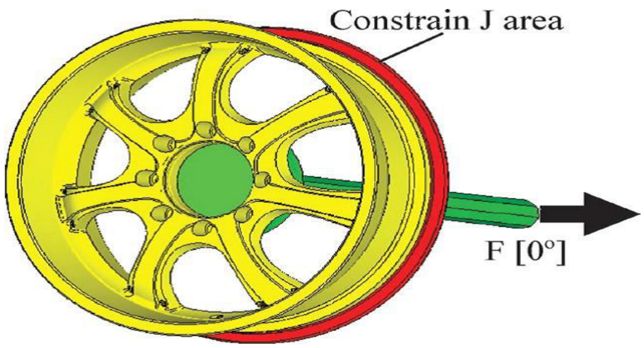

Fig 4.1 Finite Element Model

In Aluminium alloy wheel fatigue test, failure occurs at 1×10^5 cycles In the above static analysis constraints are applied on the circumference of the rim, and got fatigue strength of $1*10^5$ cycles in wheel rotary fatigue test. To improve the results we are applying constraints on the wheel bolt holes of the rim. Fatigue analysis is done in MSC fatigue software, as it has following benefits, MSCFatigue Basic is a module of the MSC.Fatigue product line which uses stress or strain results from finite element (FE) models, variations in loading and cyclic material properties to estimate life to failure. Both the traditional S-N and the more state-of-the-art local strain or crack initiation methods are available. Usage of MSC.Fatigue brings fatigue analysis up front in the design-to-manufacturing process and creates an MCAE environment for integrated durability management.

We are also doing analysis on other materials like steel alloy, forged steel, and magnesium alloy for fatigue strength and comparing the results.According to the FEA results of the baseline design, the Aluminium alloy wheel design could be improved by reinforcing the weaker area.

4.5.1 SOLID45 Element Description-

SOLID45 is used for the 3-D modeling of solid structures. The element is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions.

The element has plasticity, creep, swelling, stress stiffening, large deflection, and large train capabilities. A reduced integration option with hourglass control is available.

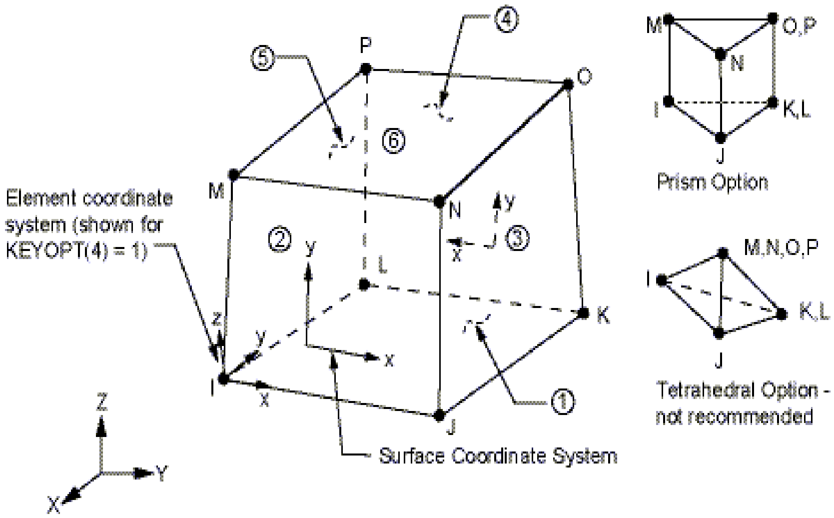

Fig 4.2 SOLID45 Geometry

4.5.2 SOLID45 Assumptions and Restrictions-

- Zero volume elements are not allowed.
- Elements may be numbered either as shown in Figure 45.1: “SOLID45 Geometry” or may have the planes IJKL and MNOP interchanged.
- The element may not be twisted such that the element has two separate volumes. This occurs most frequently when the elements are not numbered properly.
- All elements must have eight nodes.
    - A prism-shaped element may be formed by defining duplicate K and L and duplicate O and P node numbers (see Triangle, Prism and Tetrahedral Elements).
    - A tetrahedron shape is also available. The extra shapes are automatically deletedfor tetrahedron elements.

4.5.3 The Procedure For A Model Analysis Consists Of Four Main Steps-

- Build the model.
- Apply loads and obtain the solution.
- Expand the modes.
- Review the results.

4.5.4 Importing the Model-

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

4.5.5 Boundary Conditions and Loading-

- Centrifugal force, $F=mr\omega^2$ N

- ω =2*()*N/60 rad/s
- M=24 kg
- For N=600 rpm
- ω =62.8 rps

By substituting, we get centrifugal force=21.3kN which acts at each node of the circumference of the rim

- Displacements
  - Translation in x, y, z directions is zero.
  - 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.

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4.5.6 Displacement plots:

Steel Alloy- Displacement Of Steel Alloy is 0.166 mm

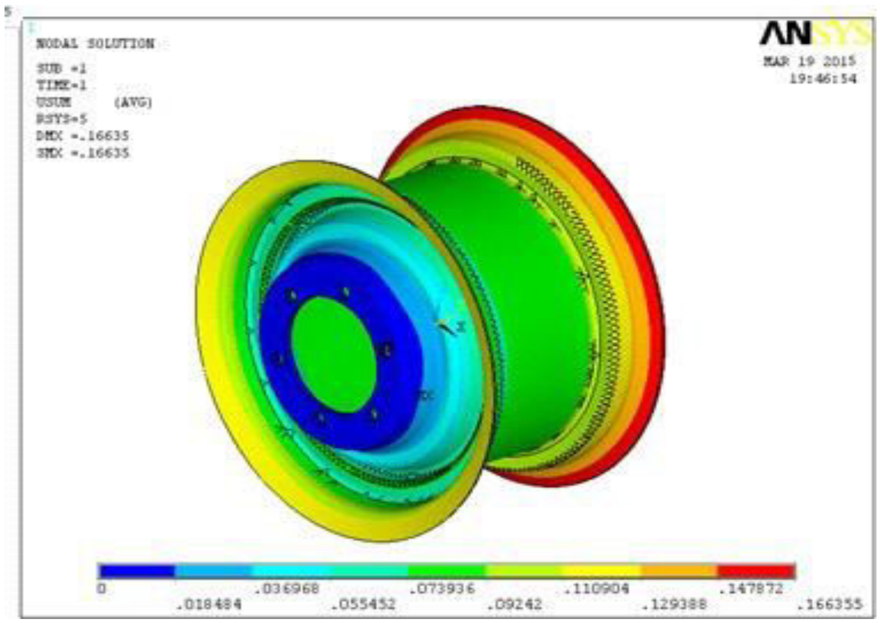

Fig 4.3 Displacement Of Steel Alloy

- **Aluminium Alloy- Displacement Of Aluminium Alloy Is 0.204mm**

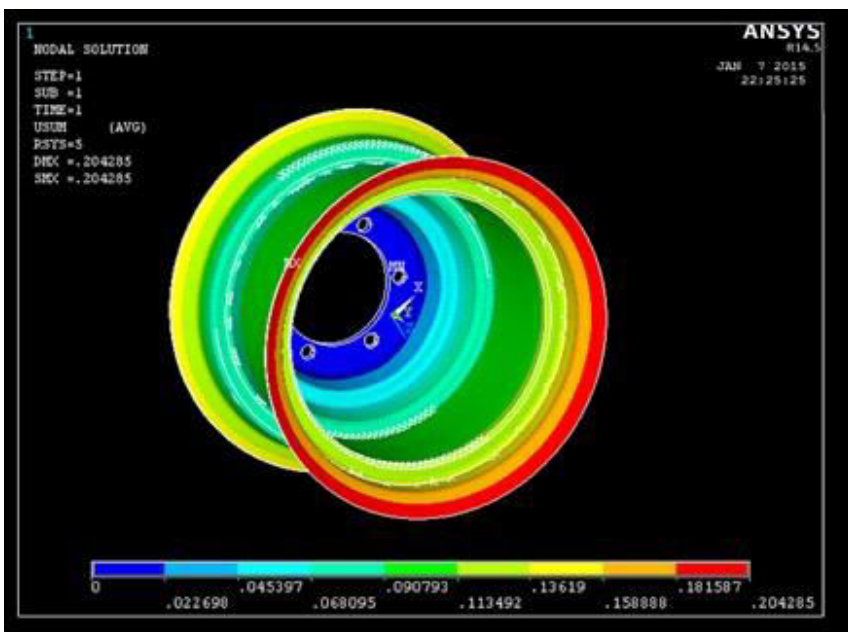

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Fig 4.4 Displacement Of Aluminium Alloy

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Magnesium (mg) Alloy-Displacement Of Magnesium Alloy is 0.2136mm

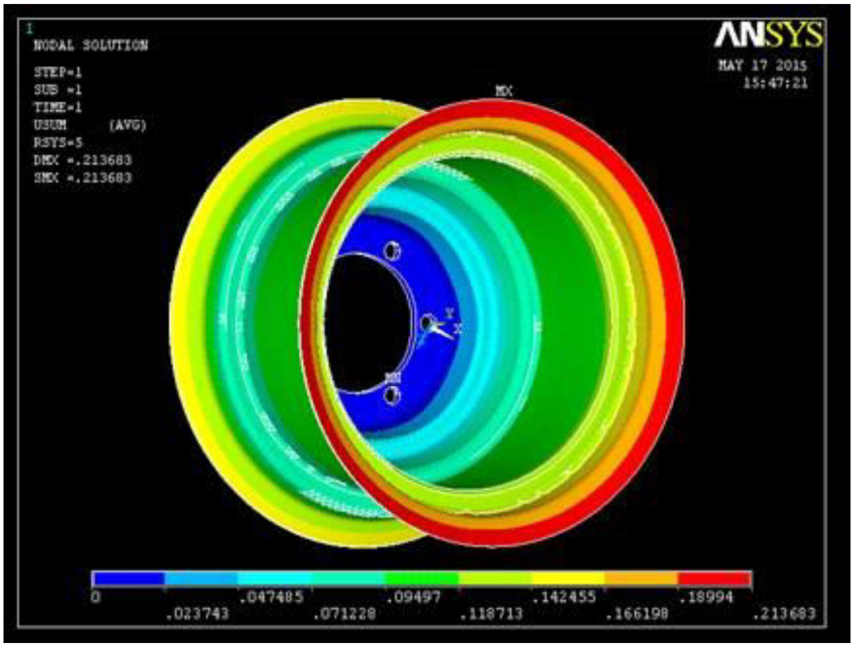

Fig 4.5 Displacement Of Magnesium

- **Forged Steel- Displacement Of Forged Steel is 0.1923mm**

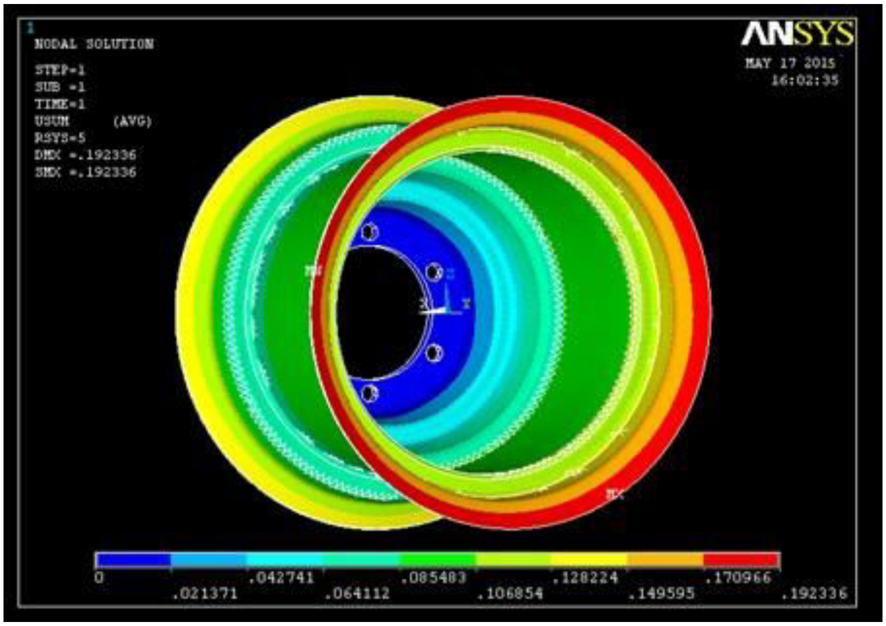

Fig 4.6 Displacement Of Forged Steel

Composite Carbon Fibre Wheel-

Displacement Of Composite Carbon Fibre Wheel Is 0.21327mm

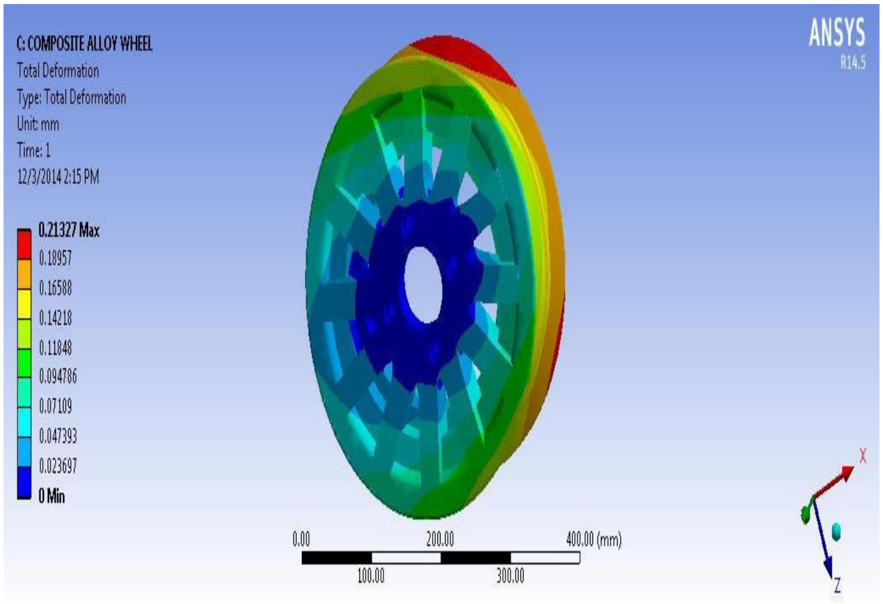

Fig 4.7 Displacement Of Composite Carbon Fibre Wheel

4.5.7 Plots of Von-mises Stresses-

Steel Alloy - Max vonmises stress=140.056 MPa, Min vonmises stress=3.202 MPa

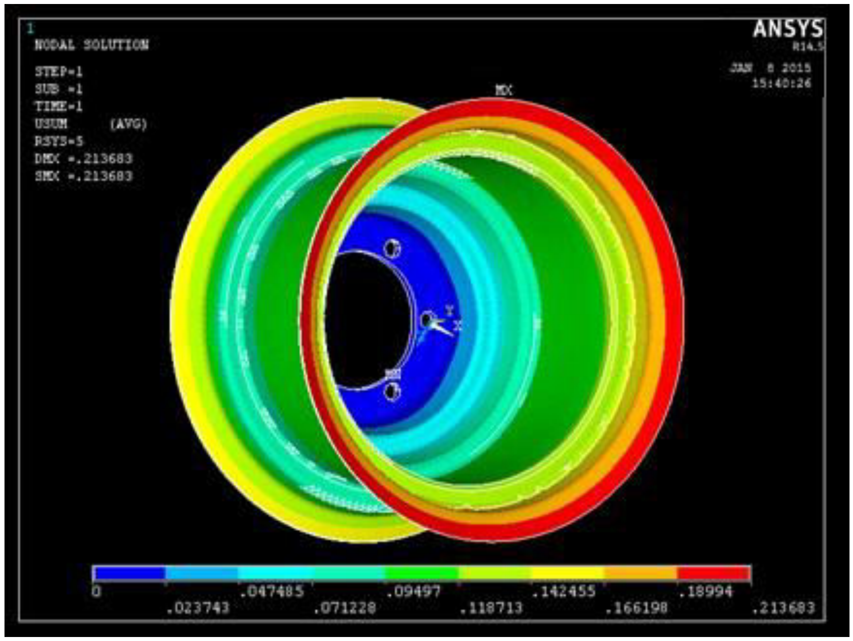

Fig 4.8 Von Mises stresses for Steel Alloy

Aluminium Alloy - Max vonmises stress=48.326 MPa,Min vonmises stress=0.92 MPa

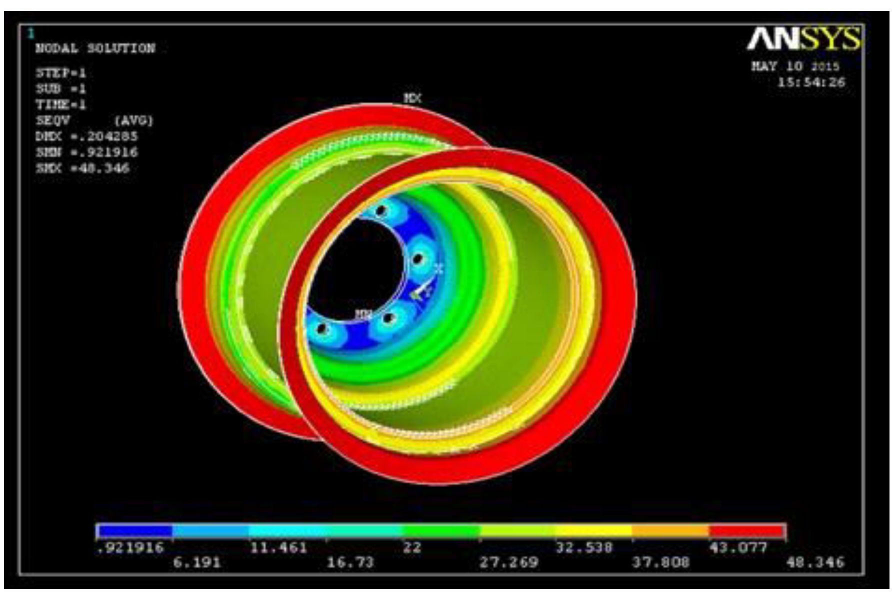

Fig 4.9 Von Mises stresses for Aliminum Alloy

Magnesium Alloy- Max vonmisesstress=32.294MPa,,Minvonmisesstress=0.6954 Mpa

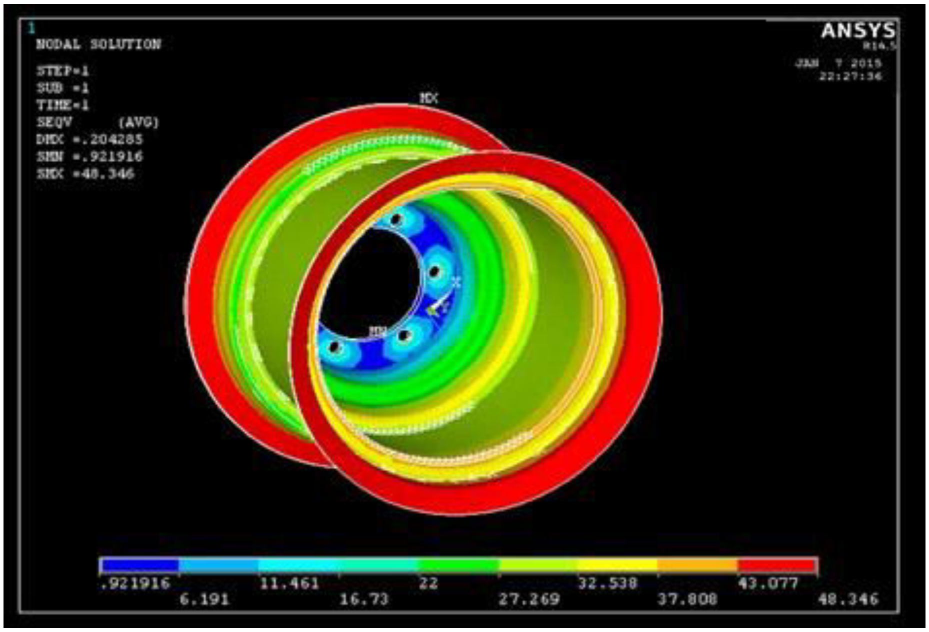

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Fig 4.10 Von Mises stresses for Magnesium Alloy

Forged Steel - Max vonmises stress=135.931 MPa,Min vonmises stress=2.452 MPa

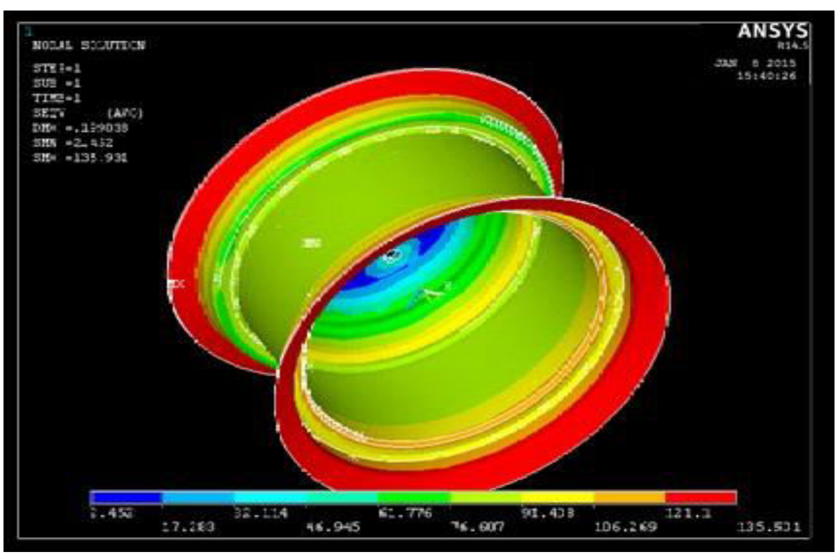

Fig 4.11Von Mises stresses for Forged Steel

- **Composite Carbon Fibre Wheel-**

Maximum vonmises stress=14.214MPa, Minimum vonmises stress=0.03557 MPa

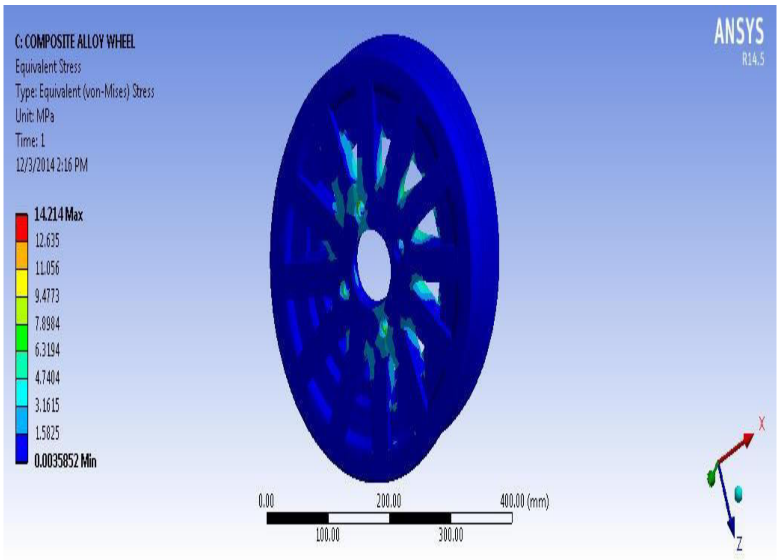

Fig 4.12 Von Mises stresses for Composite Fibre Wheel

CHAPTER 5

EXPERIMENTAL ANALYSIS

There are various methods and machines for fatigue testing out of which two are explained here

5.1 Single Axle Rotary Fatigue Testing -

The SAE (Society of Automotive Engineers) J328 for passenger car and light truck steel wheels is the industry standard for fatigue test specification An excellent and a concise overview of the development of experimental fatigue tests for wheels was compiled by Kinstler One test method is the radial loading of a wheel assembly (tyre on the wheel), which is at a camber angle relative to the rotating drum . This method is a build on to the straight driving radial testing, but in this case it was meant to simulate cornering driving conditions. The wheel assembly is loaded against the rotating drum using camber angles ranging from 5^{o} to 30^{o} . This test proved to be difficult to execute; due to the low tyre life, which required frequent tyre changes to complete thetest. The test made it difficult to evaluate the wheel for cracks and deflection .

A second approach is to clamp the wheel assembly to a rotating table and apply a bending moment to the wheel (rim), through a shaft attached to the hub. Increased shaft deflection, fatigue cracking on the wheel and a decreased clamping force (loose clamps and nuts) is used as indication to terminate the test. The method allows for easy and fast testing execution. The absence of the tyre allowed for higher test factors and cycles of wheel rotation, but these settings varied from each wheel manufacturer. Therefore the SAE standardised the test equipment and procedure such as loading and cycles.Muthuraj et al.carried out experimental stress analysis on aluminium alloy wheels (original and modified design) using strain gauges to capture strains during the dynamic cornering fatigue test. Stresses were calculated through Hooke`s law of elasticity using the strains obtained through the strain gauges. The elastic strain and isotropic

Young`s modulus in the wheel allows for the use of Hooke`s law. The local strain approach was used to predict fatigue failure of the wheel, using the stress strain curve. The experimental fatigue testing of metallic wheels is illustrated in this section, but relevance can be drawn with regards to carbon fibre rims. The Ducati rim was subjected to CFT conditions and instrumented with strain gauges to evaluate the longitudinal strains. The highlighted research papers evaluate the experimental data of metallic rims as intended.

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Fig 5.1. Single Axle Rotary Fatigue Testing Machine

Wang et al. simulated the dynamic cornering fatigue test of a steel passenger car wheel. The strain data are obtained from the instrumented wheel at points A, B, C, D and E as illustrated in Figure 8. The points are instrumented with 45 degree rosettes, which consist of three strain gauges orientated at 0, 45 and 90 degrees . The strains on the wheel were measuredat four positions (0, 90, 180 and 270 degree orientations) during the cornering fatigue simulation, where the force application was aligned with these positions as illustrated in Figure 8.

The captured strains at the points were utilised to calculate the von Mises stresses. The strain data illustrated the strain variation with the position of the wheel and the application of the force . The data indicate a sinusoidal wave relationship between the strains obtained and the position of the wheel and force application. This relationship was expected as the largest strains are experienced only when the orientation of the strain gauges was in line with the forceapplication path.

5.2 Biaxial fatigue testing-

After installation of the strain gauges, the wheels undergo fatigue testing or biaxial wheel testing. Biaxial wheel tests show the actual structural properties of newly developed wheels; biaxial wheel tests have virtually transferred the test track into the laboratory.

Since the wheels rotate in the test stands, the signals are transmitted to the QuantumX MX410 measuring amplifier via wireless telemetry. This compact, four-channel amplifier has been specially developed for acquiring and analyzing highly dynamic, mechanical processes.Every channel of the MX410 universal module supports six transducer technologies and offers sampling rates of up to 96 kHz/channel with 24 bit resolution.

It provides the highly precise results that are required for acquiring highly dynamic forces and accelerations. The conditioned measurement signal is available as both a digital value and an analog signal. The MX410 can thus be easily connected to different analysis systems. It uses both Ethernet and FireWire for communication. Results can be recorded, visualized and analyzedon a PC using

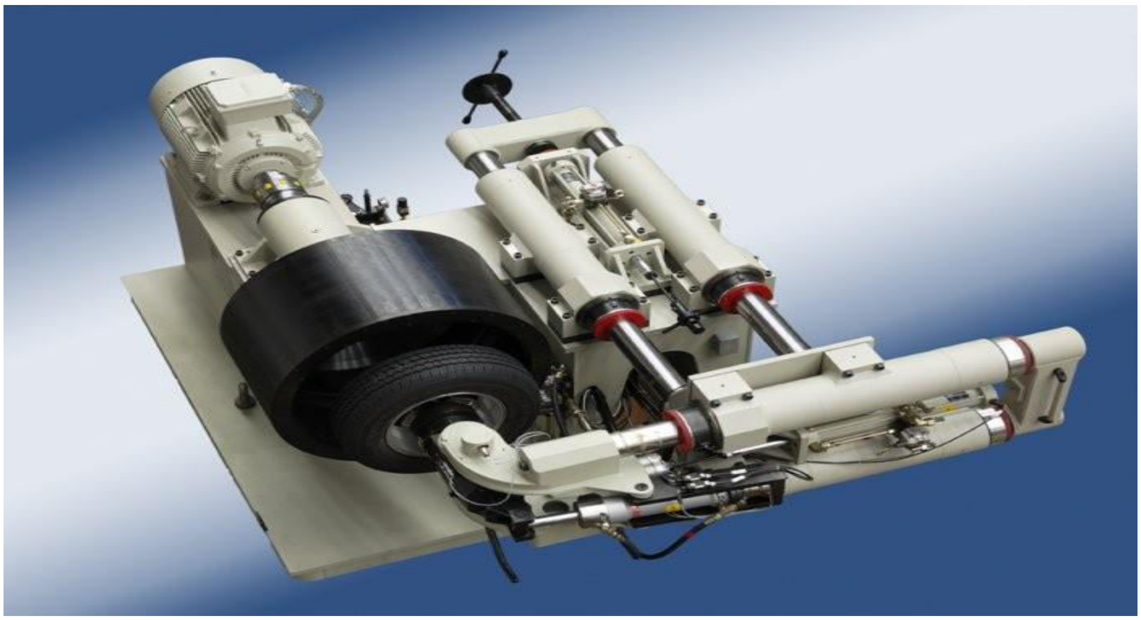

Fig..5.2 Biaxial Fatigue Testing Machine

The simulation assumes favorable conditions. Subsequent practical tests investigate whether the theoretical findings can be verified by test results. For this purpose, strain gauges(SG) are installed in the area of the calculated maximum load. Strain gauges respond to tensile or compressive force with a change in electrical resistance.

5.3 Dynamic Rotay Fatigue Testing Machine-

Depending on the type of vehicle, real bending moments for cars or vans range between 2.5 KNm and about 10 KNm. The TÜV guideline for aluminum cast car wheels requires that200,000 load cycles at 75% bending moment and 1,800,000 load cycles at 50% bending moment need to pass the test without any cracks. After the required load cycles, the surface is inspected for cracks.

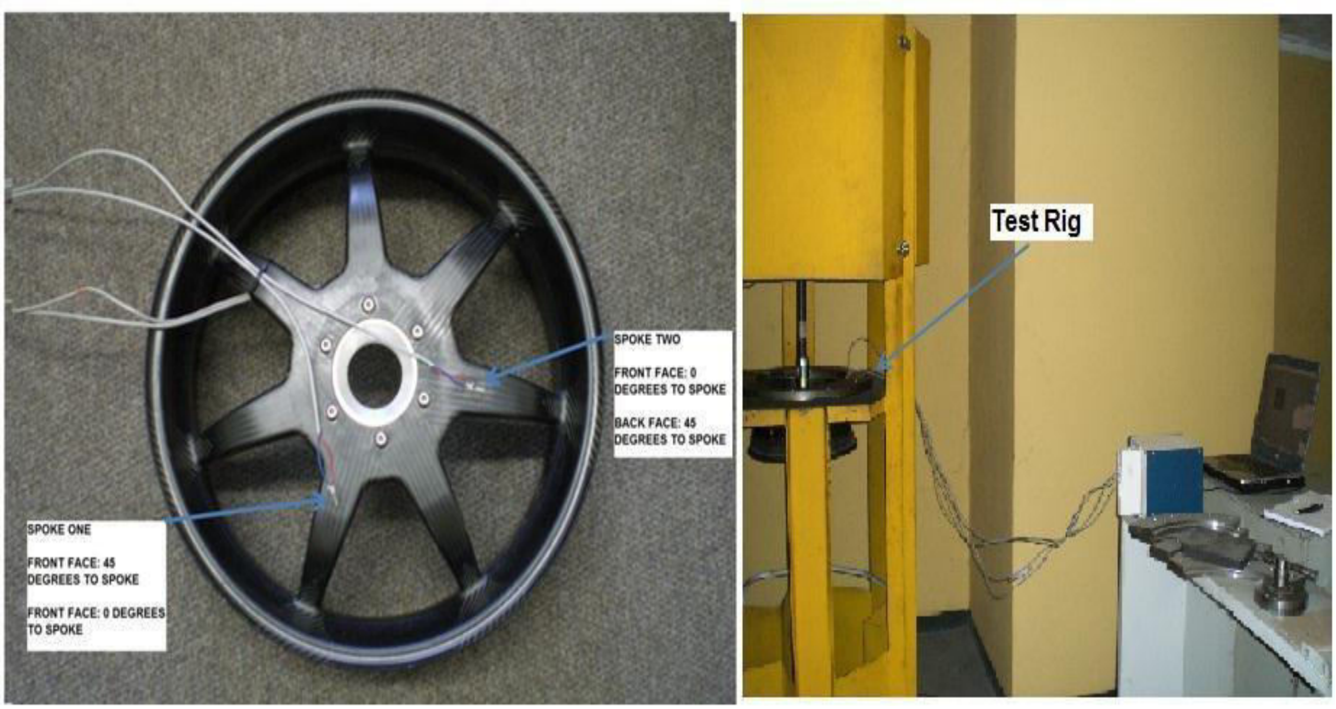

Figure 5.3 Experimental Setup For Composite Wheel

Experimental Results-

Material	**Fatigue Strength (Cycles)**
Steel alloy	$1.97*10^5$
Aluminium alloy	$1.02*10^5$
Magnesium alloy	$0.9*10^5$
Forged steel	$1.67*10^5$
Composite wheel	$2.27*10^5$

Table 5.1 Fatigue Strengths By Experimentation.

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CHAPTER 6

FATIGUE ANALYSIS

6.1 Fatigue Mechanisms-

The basic feature that underlies all the specific fatigue failure mechanisms is the existence of repeated or cyclic stresses at some point of the component. This could be considered the basic definition of fatigue. The cyclic stresses or strains give origin to damage accumulation until it develops into a crack that finally leads to failure of the component. Keeping in mind the basic assumption for a fatigue failure, different definitions will be provided for the specific fatigue failure mechanisms. The different fatigue failure mechanisms are essentially related to the way those cyclic stresses arise in a specific point of the component, or to the cause of the stresses. Sometimes they are also related to the existence of other concurrent or synergistic damaging mechanisms such as wear or corrosion.

The fatigue failure mechanisms are divided into two classes: the primary mechanisms and the secondary mechanisms, according to the following definition: Primary mechanisms**:** mechanisms that are able by themselves to initiate and propagate fatigue cracks;Secondary mechanisms**:** mechanisms that are not able by themselves to promote fatigue fracture but may either initiate cracks or help on crack propagation of pre-existing cracks.A definition for the different fatigue mechanisms, either primary or secondary mechanisms, will be subsequently given. Some schemes of the mechanisms are shown on the damaged components section.

6.1.1 Primary Mechanisms-

- Mechanical Fatigue **-** Mechanical fatigue is the widest definition and is traditionally related to components where external loads are applied for example on the connections/supports. In this definition cyclic stresses flow through the component and concentrate in critical points of the component due to loads/restraints that are applied in other points. If mechanical fatigue occurs at high temperature another mechanism, creep, is often active.
- Thermal fatigue **-** Thermal fatigue exists under two different situations: the first is in a singular component due to different temperatures (cyclic) in different areas of the same component; the second situation is, for a component with two dissimilar materials, for a certain temperature (cyclic) in both materials at the same time. In the first situation stresses arise due to the difference in temperature; in the second situation stresses arise

through different dilatation coefficients of the same component (with at least two different materials). Due to high temperatures involved in the process and depending on the thermal cycle shape creep may also be active.

Thermal/Mechanical Fatigue –

Thermal/mechanical fatigue exists when both mechanical and thermal fatigue act at the same time. It is common to have superposed thermal and fatigue cycles. Due to high temperature involved creep is sometimes active in thermal/fatigue situations.

- Contact Fatigue **-** Contact fatigue exists when two free bodies are in contact but they are not attached one to another. It occurs mainly when there is a rolling contact. The contact forces are the responsible for the Hertzian stresses and strains in the components. On the contact surface between the free bodies and due to the contact deformation there may exist a very small relative displacement between the bodies. Thus sometimes, another mechanism, fretting, may be considered as associated with rolling contact fatigue..

- Impact Fatigue **-** Impact fatigue is characterized by the existence of an impact contact. Thus there is a load between the two bodies plus the impact energy due to the prior movement of at least one of the bodies.

- Cavitation Fatigue **-** Cavitation fatigue exists when bubbles are created inside a liquid in an under-pressure region and, when those bubbles reach higher pressure zones they implode and the wave pressure that born from the implosion impacts a solid surface. These waves are the responsible for the stresses and strains at the solid bodies.

- Creep Fatigues **-** Creep fatigue is a superposition of mechanical fatigue and creep (deformation at high temperature at a constant load). According to the high temperature level and load fatigue cycle waveform creep may be more or less active but is almost always present.

6.1.2 Secondary Mechanisms-

- Wear-Fatigue **-** Wear fatigue exists when two bodies are not attached one to another but normal contact forces plus the tangential forces due to the sliding movement between both bodies.

- Fretting Fatigue **-** Fretting fatigue is similar to wear fatigue because there is wear betweenthe two bodies due to a relative displacement. The main difference is that the two bodies are commonly connected or attached one to the other for example with screws, and the relative displacement between both components is very small (traditionally between 1 to 100 ì m)

- Abrasion Fatigue **-** Abrasion fatigue exists when two solid bodies are not in direct contact one to the other but a third body (for example dust) promotes the contact and load transmission between the initial two bodies. The third body (for example dust) may be involved in oil or water. Initially they cause pitting or spalling like on contact fatigue but in cases where a pre-existing crack exists they may promote crack propagation.

- Corrosion Fatigue **-** corrosion fatigue exists when structural metals operate in deleterious environments. This detrimental environment accelerates fatigue crack growth. Even materials immune to SCC – Stress Corrosion Cracking are susceptible to CC – Corrosion Cracking (or corrosion fatigue cracking).

- Hydrodynamic Fatigue – (trapped water/oil fatigue) - There are at least two different ways in which hydrodynamic fatigue is present. One is when there is load transmission between two rigid bodies by means of a liquid (for example oil) and there is a pre- existing crack. The liquid enters the crack and promote crack propagation by exerting opening loads on the crack surfaces. The other situation is when two solid bodies are in direct contact, for example under rolling contact, and there is a pre-existing crack with liquid inside. When one body contacts the other body on the crack position, the crack closes and the liquid is trapped inside the crack. The pressure on the trapped liquid promotes crack propagation.

6.2 MSC Fatigue Software-

MSC Fatigue is a FE-based durability and damage tolerance solver that enables users with minimal knowledge of fatigue to perform comprehensive durability analysis. Some estimates put annual costs in the United States due to premature fatigue fractures in structural components at as much as 4% of the gross domestic product. Yet testing against repeated loadingcycles, sometimes millions of times over, is often too expensive and time consuming to be practical. Finite element analysis programs can tell you where stress "hot spots" exist, but on their own can't tell you whether those hot spots are critical areas for fatigue failure, or when fatigue might become a problem. To avoid contributing further to this statistic, many manufacturers simply accept long prototype-development cycles, overweight components, unpredictable warranty claims, and loss of customer confidence.MSC Fatigue enables durability engineers to quickly and accurately predict how long products will last under any combination of time-dependent or frequency-dependent loading conditions. Benefits include reduced prototype testing, fewer product recalls, lower warranty costs, and increased confidence that your product designs will pass required test schedules.MSC Fatigue is an advanced fatigue life estimation program for use with finite Element analysis. When used early in a development design cycle itis possible to greatly enhance product life as well as reduce testing and prototype costs, thus ensuring greater speed to market. It is jointly developed in close cooperation between MSC.

Although many definitions can be applied to the word, for the purposes of this manual, fatigue is failure under a repeated or otherwise varying load which never reaches a level sufficient to cause failure in a single application. It can also be thought of as the initiation and growth of a crack, or growth from a preexisting defect, until it reaches a critical size, such as separation into two or more parts.

Fatigue analysis itself usually refers to one of two methodologies: either the stress life or S-N method, commonly referred to as total life since it makes no distinction between initiating or growing a crack, or the local strain or strain-life (ε-N) method, commonly referred to as the crack initiation method which concerns itself only with the initiation of a crack. Fracture specifically concerns itself with the growth or propagation of a crack once it has initiated. Durability is then the conglomeration of all aspects that affect the life of a product and usually involves much more than just fatigue and fracture, but also loading conditions, environmental concerns, material characterizations, and testing simulations to name a few. A true product durability program in an organization takes all of these aspects (and more) into consideration.

6.3 The Fatigue "Five-Box Trick"-

Almost without exception, each exercise is constructed around the concept of the fatigue "Five-box trick." The Illustration to the right Depicts this well. For any life analysis whether it be Fatigue or fracture there are always three inputs.

The first three boxes are these inputs:

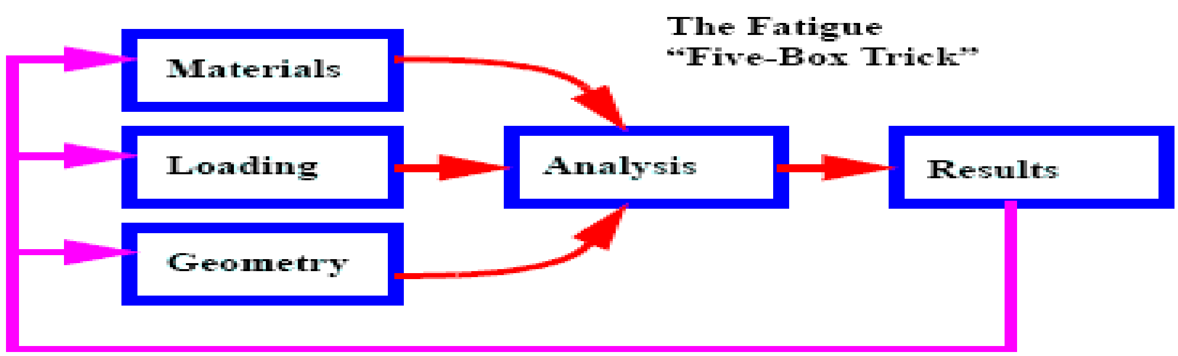

Fig 6.1 The Fatigue "Five-Box Trick

- Cyclic Material Information :- Materials behave differently when they are Subject to cyclicas opposed to monotonic loading. Monotonic material Properties are the result of material tests where the load is steadily increased until the test coupon breaks. Cyclic materialparameters are obtained from Material tests where the loading is reversed and cycled until failure at various load levels. These parameters differ depending on the fatigue analysis type involved.
- Service Loading Information :-The proper specification of the variation of the loading is extremely important to achieve an accurate fatigue life prediction. The loading can bedefined in various manners. Whether it be time based, frequency based, or in the form of some sort of spectra depends on the fatigue analysis type to be used. When working with finite element models the loading can be force, pressure, temperature, displacement, or a number of other types. Loading in the test world usually refers to the acquisition of a response measurement, usually from a strain gauge.

- Geometry Information:- Geometry has different meanings depending on whether you are working from a finite element model or from a test specimen. In the testing world, the geometry input is the Kt (stress concentration factor) since the point of failure is usuallyaway from the actual point of measurement. Therefore a geometry compensation factor (Kt) is defined to relate the measured response to that at the failure location. You can think of this as a fudge factor. With a finite element model the local stresses and strains are known at all locations (Kt=1 at all locations). The FE geometry gives us the entire stress distribution needed for fatigue life calculations. For crack growth analysis the geometry definition takes on yet another form as a compliance function. The correctness and accuracy of each of these inputs is important in that any error in any of these will be magnified through the fatigue analysis procedure, the fourth box, since this process is logarithmic. A ten percent error in loading magnitude could result in a 100% error in the predicted fatigue life.

The fifth box is the post processing or results evaluation. This can take on the form of color contours on a finite element model or a tabular listing but also quite often leads back into the three inputs to see what effect variations of these inputs will have on the life prediction. This is referred to as a sensitivity or a "what if" study. This is extremely useful at times when you arenot quite sure about the accuracy of one of the inputs. The software denotes this as "optimization" in places.

Benefits:

Analysis using MSC Fatigue significantly reduces costs associated with prototyping and testing by simulating fatigue life early in the design phase. Early simulation shortens time-to-market, improves product reliability, customer confidence and reduces costly recalls or other undesirable consequences of premature product failure.

Usage of MSC Fatigue brings fatigue analysis up front in the design-to-manufacturing process and creates an MCAE environment for integrated durability management.

6.4 Life Estimation Process-

The life estimation process really centers around two major relationships.

- The first relation is that of the loading environment to the stresses and strains in the component or model. This load-strain or load-stress relation is determined using finite element modeling and running linear elastic FE analysis. It is dependent on the characterization of the material properties and in some instances requires that a notch correction procedure take place. For the purposes of this discussion a notch correction is simply a way to compensate for plasticity from a linear FE analysis.

- The second relation is that of the stresses or stains to the life of the component or model. Thisis accomplished by using damage modeling. Each fatigue life method has its own techniques to determine and sum damage which shall be explained as you progress through the example problems.

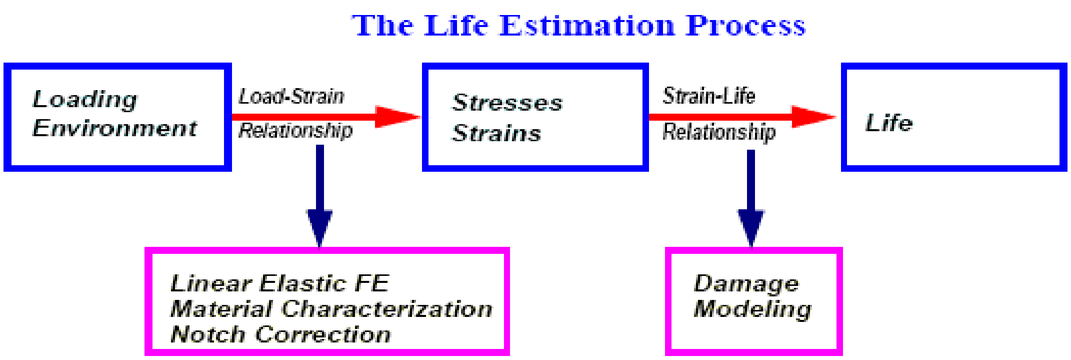

Fig No.6.2 Life Estimation Process

The fatigue analysis is carried out in MSC fatigue tool .The von-misses stresses from ANSYS(.rst file format) is imported to the MSC fatigue and find the number of cycles to failures of crankshaft for forged steel and sintered aluminium.

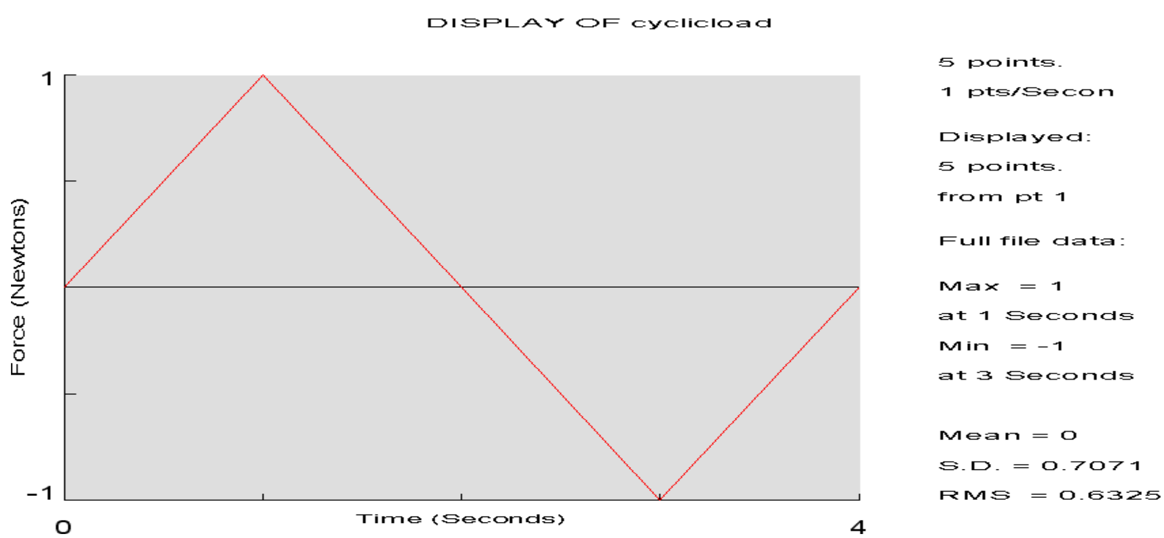

Fig 6.3 Type Of Fatigue Load Inputting

6.5Fatigue Plots - **Steel Alloy :** Fatigue strength of Steel Alloy 2.17*10^5 cycles

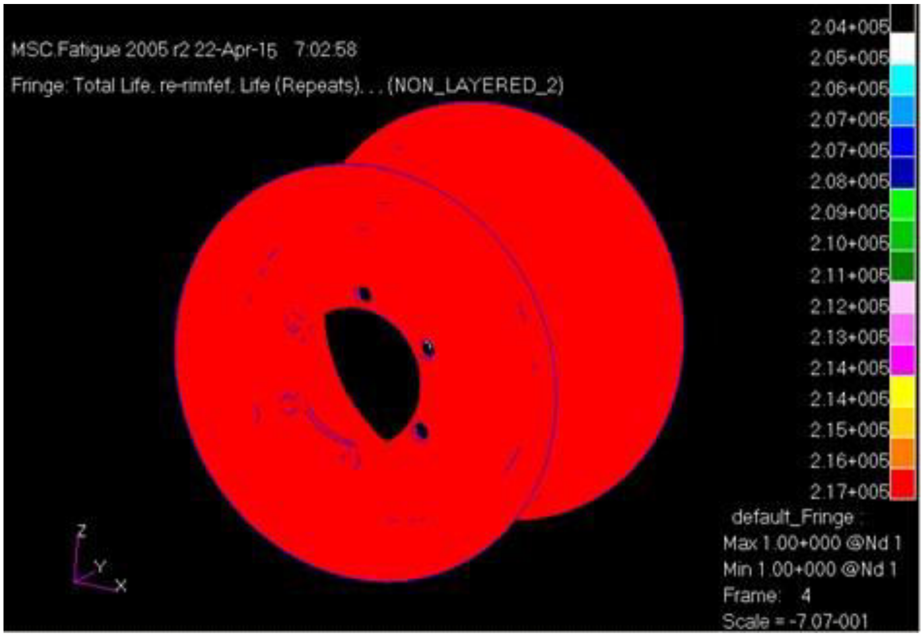

Fig. 6.4 Fatigue strength of Steel Alloy

- **Aluminium Alloy-** Fatigue Strength of Aluminium Alloy 1.32*10^5 Cycles

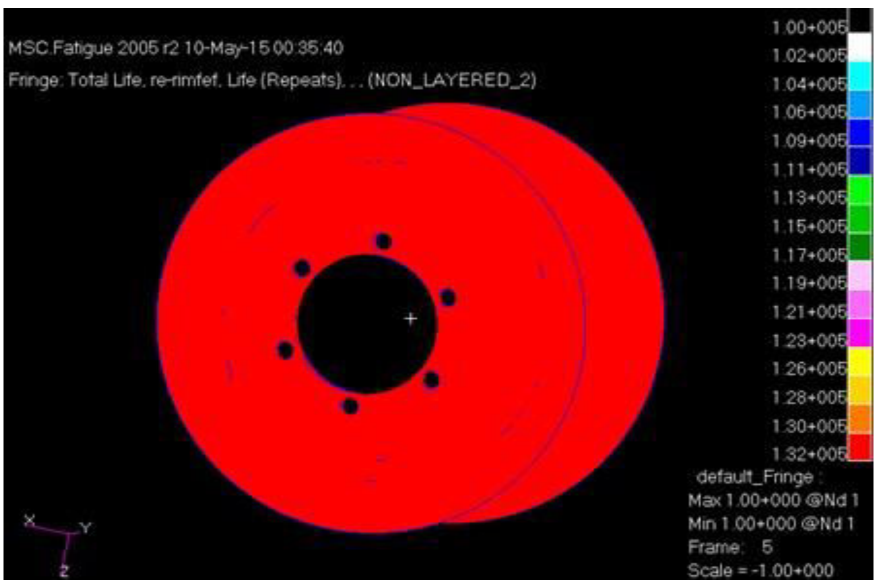

Fig6.5 Fatigue Strength of Aluminium Alloy

- **Magnesium Alloy-** Fatigue Strength of Magnesium Alloy 1.2*10^5 Cycles

Fig6.6 Fatigue Strength of Magnesium Alloy

- **Forged Steel-** Fatigue Strength of Forged Steel $1.97*10^5$ Cycles

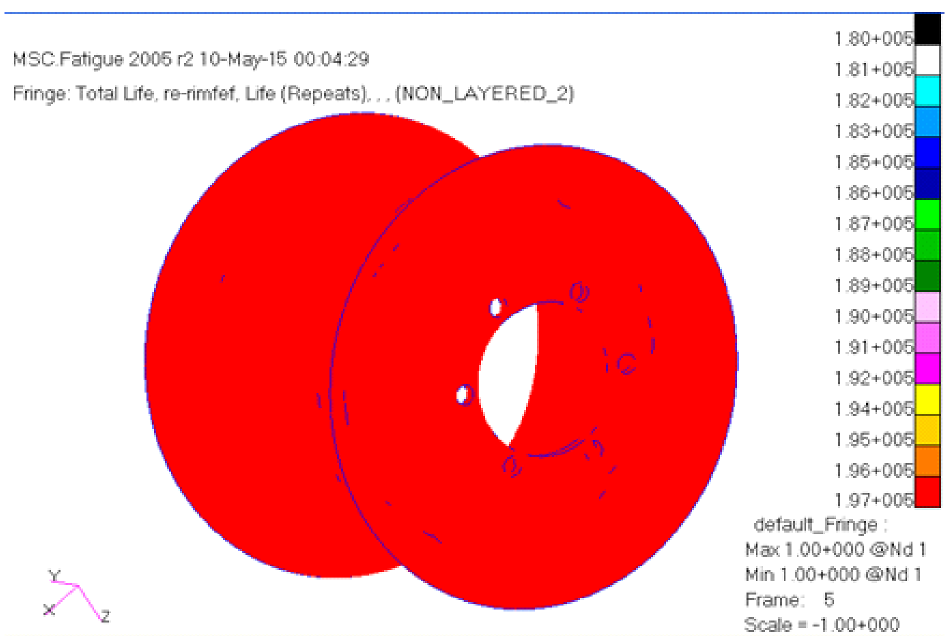

Fig6.7 Fatigue Strength of Forged Steel

- **Composite Wheel-** Fatigue Strength of Composite Wheel $2.57*10^5$ Cycles

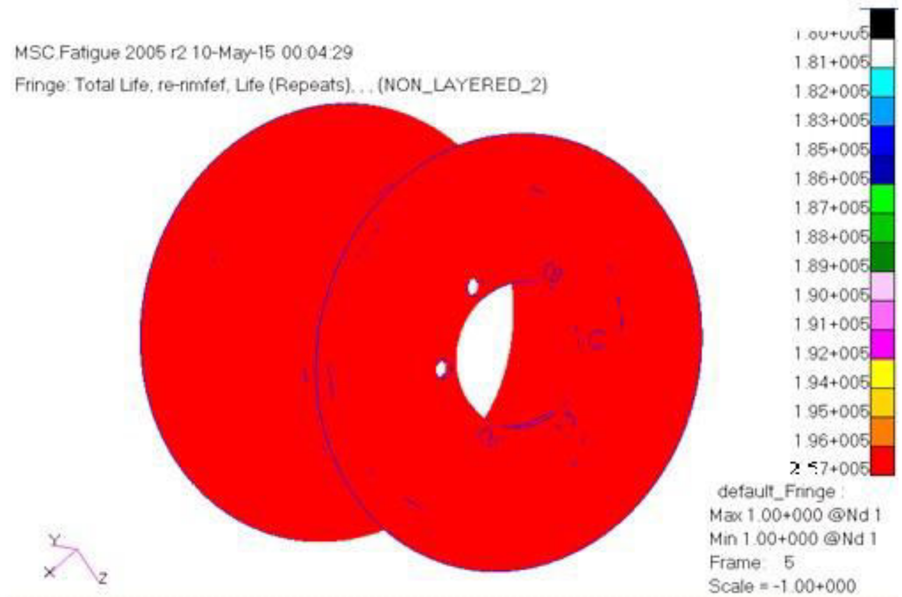

Fig6.8 Fatigue Strength of Composite Wheel

CHAPTER 7
RESULTS AND DISCUSSIONS

7.1 Theoretical Material Properties -

- **Steel alloy:-**

Young's modulus (E) =$2.34*10^5$ N/mm^2

Yield stress=240 N/mm^2

Density =7800kg/m^3

- **Aluminium alloy:-**

Young's modulus (E) =69000 N/mm^{2}Yield stress=130 N/mm^2

Density =2685kg/m^3

- **Magnesium alloy:-**

Young's modulus (E) =45000N/mm^2

Yield stress=130 N/mm^2

Density =1800kg/m^3

- **Forged steel:-**

Young's modulus (E) =210000N/mm^2

Yield stress=220 N/mm^2

Density =7600kg/m^3

- **Composite wheel:-**

Young's modulus (E) =190000N/mm^2

Yield stress=570 N/mm^2

Density =4300kg/m^3

7.2 Results Obtained From Software-

- **Steel Alloy :-**

Von misses stress (σ_v) =140.056 N/mm^2

Number of cycles to failure (N_f)=2.17*10^{5}Cycles

- **Aluminium Alloy :-**

Von misses stress (σ_v) =48.326 N/mm^2

Number of cycles to failure (N_f) =1.32*10^{5}Cycles

- **Magnesium Alloy :-**

Von misses stress (σ_v) =32.204 N/mm^2

Number of cycles to failure (N_f) =1.2*10^{5}Cycles

- **Forged Steel :-**

Von misses stress (σ_v) =135.931 N/mm^2

Number of cycles to failure (N_f) =1.97*10^{5}Cycles

- **Composite Whel-**

Von misses stress (σ_v) =14.21 N/mm^2

Number of cycles to failure (N_f) =2.57*10^{5}Cycles

7.3 Results Comparison From Software And Experiment-

Material	Displacement (mm)	Vonmises Stress (MPa)	Fatigue Strength(Software) (Cycles)	Experimental Results
Steel Alloy	0.1663	140.056	2.17*10^5	1.97*10^5
Aluminium Alloy	0.204	48.326	1.32*10^5	1.02*10^5
Magnesium Alloy	0.2136	32.29	1.2*10^5	0.9*10^5
Forged Steel	0.1923	135.931	1.97*10^5	1.67*10^5
Composite Wheel	0.21357	14.21	2.57*10^5	2.27*10^5

Table 7.1 Results Comparison From Software And Experiment

CHAPTER 8

CONCLUSIONS

- The von misses stresses developed in steel alloy during static analysis is 140.056 N/mm^2 at load 21.3KN the stress is below yield stress of material for these stress range we have to find at what number of cycles the component is yielding or crack is going to initiates
- During fatigue analysis of steel alloy the crack is initiating at N_f=2.17*10^{5}Cycles.
- The von misses stresses developed in Aluminium alloy during static analysis is 48.326 N/mm^2

at load 21.3KN the stress is below yield stress of material for these stress range we have to find at what number of cycles the component is yielding or crack is going to initiates

- During fatigue analysis of Aluminium alloy the crack is initiating at N_f=1.32*10^5Cycles.
- The von misses stresses developed in Magnesium alloy during static analysis is 32.294 N/mm^2 at load 21.3KN the stress is below yield stress of material for these stress range we have to find at what number of cycles the component is yielding or crack is going to initiates.
- During fatigue analysis of Magnesium alloy the crack is initiating atN_f

  =1.2*10^5Cycles.
- The von misses stresses developed in Forged steel during static analysis is 135.931 N/mm^2 at load 21.3KN the stress is below yield stress of material for these stress range we have to find at what number of cycles the component is yielding or crack is going to initiates
- During fatigue analysis of Forged steel the crack is initiating atN_f

  =1.97*10^5Cycles.
- From results we can make out, in steel alloy and composite alloy have the Number of cycles to failure (N_f)= 2.17*10^5 and 2.27*10^5 Cycles is greater than Aluminium, Magnesium, Forged steel. Hence Steel alloy and composite alloy are more feasible to use than Aluminium and other .
- Hence composite alloy and steel alloy have more life and durability compared to Aluminium and other alloy wheels

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