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DESIGN AND ANALYSIS OF ALLOY WHEELS

K. Srinivasa Rao [1], M .Rajesh [2] ,G.Sreedhara Babu [3]

[1,2,3]*Assistant Professors, Dept.of Mechanical Engineering, V.R.Siddhartha Engineering College, Vijayawada, AP, INDIA.*

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Abstract - *The existing car model wheel rim is drawn in the design software Creo 2.0 and various loads and forces are theoretically calculated and applied on the model and analysed through ansys (17.0) software. Initially the static analysis and dynamic analysis is done by giving the corresponding engineering data that consisting of mechanical properties and their related chemical compositions, the vonmises stresses, deformations, and shear stresses are determined for the complex loading that has been applied on rim models. The complex loading includes applying the pressures ie, 90° angle pressure (inflation pressure) on the bead areas, side thrust on rim flange and the tyre pressure on the well area. And the fatigue analysis which includes the product life, the damage factor and safety factors are determined and all this analysis is done by taking three different designs of the same model of car (Volkswagen polo 1.0 TSI) and rim materials (aluminium, A356-T6, magnesium, MgAm60, titanium, 6Al4V) are changed in each case to know the best design and best material for a particular type of loading and later fatigue analysis is also carried for the same cases to know which design and material will be more durable. From the conclusions of the above analysis we came to know that aluminium has less deformation and magnesium has more durable life so we defined a new material which is the alloy of the above two materials, ie, aluminium-magnesium 5000 series alloys. This material had the advantages of both the materials and also economically best. From the results obtained by analysing these two new alloys we have more life and fewer deformations for the same loading conditions for the rim model.*

Key Words: **Wheel Rim, Vonmises stresses, Complex loading, Fatigue analysis**

1.0 INTRODUCTION

The wheel is perhaps the most significant discovery of old times. The wheel has developed from nothing more than an oversized bearing to a fully integral part of any modem transportation vehicle. Wheel is an important structural member of the vehicular suspension system that supports the static and dynamic loads encountered during vehicle operation. A wheel is a circular device that is capable of rotating on its axis, facilitating movement or transportation while supporting a load (mass), or performing labour in machines. Common examples are found in transport applications. A wheel, together with an axle overcomes friction by facilitating motion by rolling. In order for wheels to rotate, a moment needs to be applied to the wheel about its axis, either by way of gravity, or by application of another external force. More generally the term is also used for other circular objects that rotate or turn, such as a ship's wheel, steering wheel and flywheel. Safety and economy are particularly of major concerns when designing a mechanical structure so that the people could use them safely and economically. Style, weight, manufacturability and performance are the four major technical issues related to the design of a new wheel and/or its optimization. The wheels are made of steel, Magnesium alloy and cast/forge Aluminium alloys.

Titanium is also being used in the recent alloy wheel models. Generally we have many wheel designs for the same model, how can we decide one is the better one than the other! So for deciding that we have taken a general case (loading conditions) applied on the particular three random designs.

1.1 PRODUCTION OF ALLOY WHEELS:

Higher cars typically come with alloy wheels rather than basic steel wheels covered with cub hap, called mag wheels because when they are first came out they are made of alloy of magnesium. Today's alloy wheels are made with aluminium alloy, which is more durable. Aluminium alloys wheels are not only more attractive than standard steel wheels; they are also the fraction of their weight. And therefore require less energy to rotate; this contributes to greater fuel efficiency, as well as better handling acceleration and breaking.

Manufacturing begins with high grade aluminium alloy, containing 97%Al. A furnace heats the ingests to 750oC. they liquefy in about 25min. The molten Al then flows directly to a mixer in which they inject argon gas which enables them to remove the hydrogen, this increases the density making the Al less porous when solidified. After adding powder titanium, mg, and other metallic elements to further strengthen the Al they blend in flux, a material which draws aluminium oxide to the surface. They skim off the impurity along with the flux and the liq al is ready for casting.

The wheel mould is made of high strength steel; it's actually a set of three moulds. The upper mould which forms the inside face of the wheel, the fore part side mould which forms the wheels edge, and the lower mould which forms the face. It takes 3 to 4 weeks to produce a mould.

The casting machine is designed to fill the mould from the bottom with pressurised injection. Injecting upward rather than from top, reduces the risk of air bubbles which causes defects. Right before casting the molten metal flows through a filter sheet, made of high temperature resistance ceramic. This traps aluminium oxide. Once cast the aluminium takes about 7 to 10min to solidify. Then the mould automatically opens, releasing the newly cast wheel.Workers submerge it in luke worm water for few min, this cools it down to be handled. The wheel undergoes a complex heat treatment process that takes 12hr to fnish.first they heat the wheel to 500 C. this rearrange the molecular structure strengthening the metal. Then they submerge the wheel in 80C water for 30 seconds in the process of quenching. Then they reheat the wheel, ie, to180C for 9hrs for further stabilising the metal.

The wheel does not come out of the mould in perfect condition. The edges are rough. So it is mounted on the computer guided lathe and refines it to the technical drawings. And for more intrikit face of the wheel, the worker manually trims the edges with a blade.

The shape is now finalised, it's time to test the wheel to make sure its air tight. While pumping air into the wheel they submerge it into the water to determine any pin holes. No air bubbles, the wheel is forwarded for painting to avoid corrosion. The factory test randomly 2 or 3 for wear out of all the produced castings.

2.0 LITERATURE SURVEY:

2.1. INTRODUCTION:

The chapter deals with the review of literature on design and analysis of alloy wheels. Some theoretical and computational investigations are included under the following headings. Also the references of study over four design namely, simple, basic, centrifugal and pentagonal shaped rims.

2.2. Literatures:

J. Stearns, T.S. Srivatsan, A. Prakash, P.C. Lam, Department of Mechanical Engineering, The University of Akron, Akron, OH 44325-3903, USA received 10 April 2003; received in revised form 1 August 2003observed and concluded as potential methods of applying the radial load have been established and most take on a cosine function form. Application of the cosine function is dependent on tire construction. Influence of inflation pressure is modeled as an equivalent load on the bead seat flange. Inflation pressure does seem to have a direct effect on the state of stress in an automobile rim under the influence of a load of the maximum tire rating. Under the influence of a radial load, the rim tends to ovalize about the point of contact with maximum displacement occurring at the location of the bead seat. Loading method and angle greatly influences the state of stress in the wheel. Experimental evidence indicates that the standard cosine bearing load at a loading angle of 45◦ best matches experimental data. The inside bead seat reveals the greatest deflection and is concurrently prone to loss of air pressure due to dislodgment of the tire on the rim.

Gaurav Machave, Pote Susheel Sambhaji, Prof. R.A.Kathar, ISSN:2277-9655 Scientific Journal Impact Factor: 3.449 (ISRA), Impact Factor: 2.114, most commonly used considerations in the design of the rotating body is elucidated. A potentially viable technique for finite element modelling of wheel, subjected to loading, is highlighted. Inflation pressure does have a direct effect on the state of stress in an automobile rim under the influence of a load of the maximum tire rating. Under a radial load, the rim tends to valise about the point of contact, with a maximum displacement occurring at location of the bead seat. The inside bead seat deflects the highest and is prone to loss of air pressure as a result of dislodgement of the tire on the rim. The stresses are much higher in the rim than in the disk. The critical design areas of the wheel are the inboard bead seat and the well.

P. Meghashyam, S. Girivardhan Naidu and N. Sayed Baba observed the results of both static and modal analysis obtained forged steel is suggested as best material and came to a conclusion that Aluminium wheel rim is subjected to more stress compared to Forged steel. In both cases von-mises stresses are less than ultimate strength. Deflections in aluminium are more when compared to forged steel. Since in both the cases von-mises stresses is less than the ultimate strength, talking deflections into account, forged steel is preferred as best material for designed wheel rim.

Samuel Onoriode Igbudu, David Abimbola Fadare concluded that analysis of different loading functions—CLF, BLF and ELF at deferent inflation pressure of 0.3, 0.15 MPa and 0 MPa at specified radial load of 4750N was carried out on a selected aluminium alloy wheel. Von Mises stress was used as a basis for comparison of the different loading functions investigated with the experimental data obtained by Sherwood et al. while the displacement fields (as obtained from the FEM tool) were used as a basis for comparison of the different loading functions as displacement was not covered by Sherwood.

3.0 TYPES OF WHEELS:

3.1 Steel Disc Wheel

This is a rim which practices the steel-made rim and the wheel into one by joining (welding), and it is used mainly for passenger vehicles especially original equipment tires.

3.2 Light Alloy Wheel

These wheels are based on the use of light metals, such as aluminium and magnesium has come to be popular in the market. This wheel rapidly become standard for the original equipment vehicle in Europe in 1960's and for the replacement tire in United States in 1970's. The advantages of each light alloy wheel are explained as below.

3.3 Aluminium Alloy Wheel

Aluminium is a metal with features of excellent lightness, thermal conductivity, rust confrontation, physical characteristics of casting, low heat, machine processing and reutilizing, etc. This metals main advantage is decreased weight, high precision and design choices of the wheel. This metal is useful for energy preservation because it is possible to re-cycle aluminium easily.

3.4 Magnesium Alloy Wheel

Magnesium is about 30% lighter than aluminium and also admirable as for size stability and impact resistance. However, its use is mainly restricted to racing, which needs the features of weightlessness and high strength at the expense of weathering resistance and design choice, etc. compared with aluminum.

3.5 Titanium alloy wheel

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

In the real service conditions, the determination of mechanical behaviour of the wheel is important, but the testing and inspection of the wheels during their development process is time consuming and costly. For economic reasons, it is important to reduce the time spent during the development and testing phase of a new wheel. A 3–D stress analysis of Aluminium wheels of the car involves complicated geometry. Therefore, it is difficult to estimate the stresses by using elementary mechanical approximations. For this purpose, Finite Element Analysis (FEA) is generally used in the design stage of product development to investigate the mechanical performance of prototype designs. FEA simulation of the wheel tests can significantly reduce the time and cost required to finalize the wheel design. Thus, the design modifications could be conducted on a component to examine how the change would influence its performance, without making costly alteration to tooling and equipment in real production.

4.0 WHEEL SPECIFICATIONS:

Model: Volkswagen polo 1.0 TSI
Rim Dia: 15 in (381mm)
Rim Width: 6 in (152.40mm)
Tire pressure: 35psi (0.241N/mm^2)
Aspect ratio: 35-70
Max power: 81KW
Centre bore: 57.1mm
Offset: ET+41
ET- "Einpress Tieffe"(german means offset)
Max Torque: 160 N-m

5.0 RIM NOMENCLATURE:

1. Wheel: Wheel is generally composed of rim and disc.
2. Rim: This is a part where the tire is installed.
3. Disc: It is a part of the rim where it is fixed to the axle hub.
4. Offset: This is a space between wheel mounting surface where it is bolted to hub and centre line of rim.
5. Flange: The flange is a part of rim which holds the both beds of the tire.
6. Bead Seat: Bead seat approaches in contact with the bead face and it is a part of rim which holds the tire in a radial direction.
7. Hump: It is a bump what was put on the bed seat for the bead to prevent the tire from sliding off the rim while the vehicle is moving.
8. Well: This is a part of rim with depth and width to facilitate tire mounting and removal from the rim.

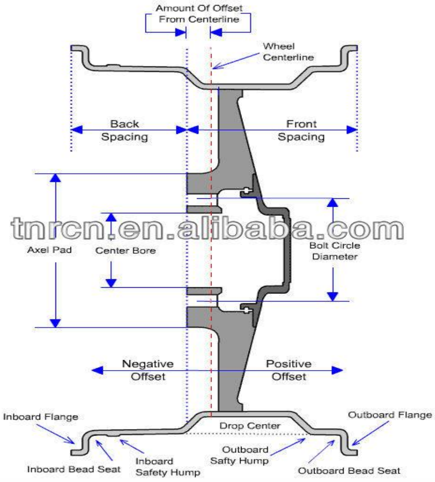
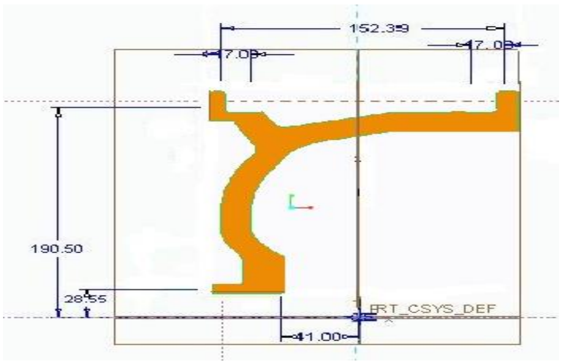


Fig 1: Rim Nomenclature

6.0 DESIGN AND MODELLING

Initially the section diagram of existing car model Volkswagen polo 1.0 TSI wheel rim is drawn in the sketcher as per company specified dimensions in the sketch CREO 2.0 (designing software) as shown in the figure



Later this is revolved using horizontal axis, here figure 2, and fig3 represents the design model and meshed model.

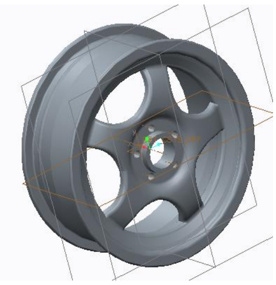


Fig.2

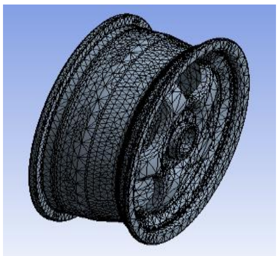


Fig.3

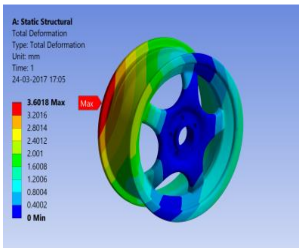
7.0. Meshing

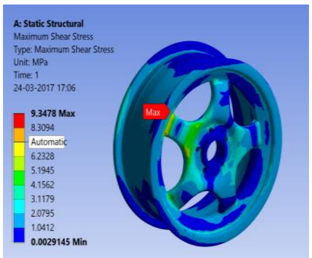
Very fine mesh is used in the analysis and element size of 30mm is used for meshing whole the model No of nodes: 1479796 , No of elements: 877612

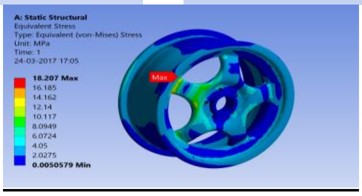
8.0 ANSYS MODELS:

Basic Design:

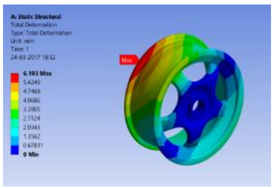
8.1 Aluminium Alloy (A356):

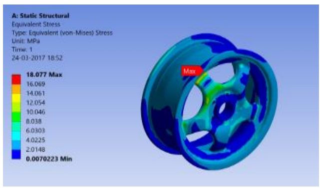


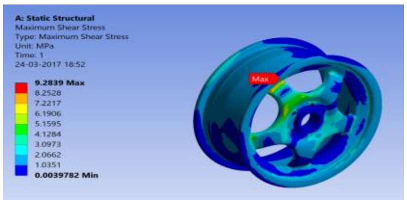




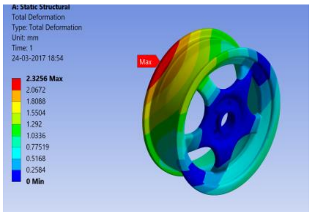
8.2 Magnesium Alloy (AM60):

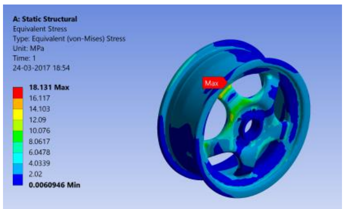


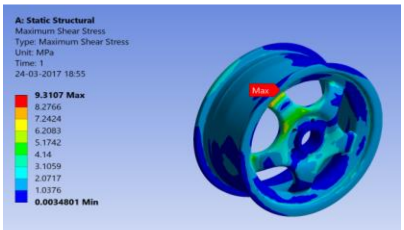




8.2Titanium Alloy:

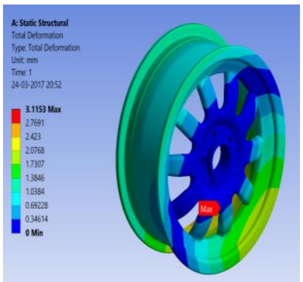


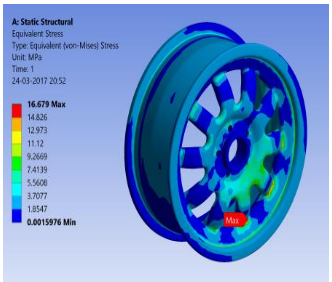


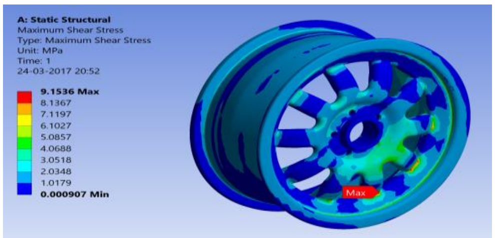


Simple Model:

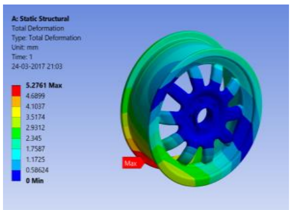
8.3 Aluminium Alloy (A356):

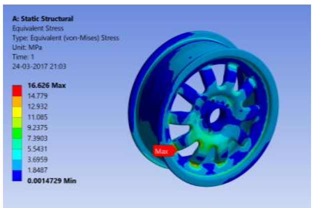


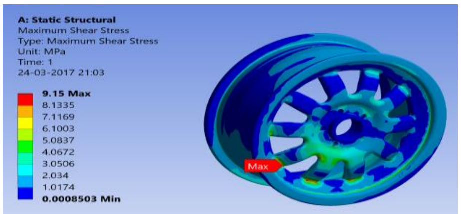




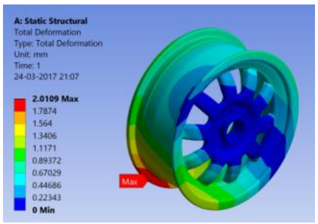
8.4 Magnesium Alloy (AM60):

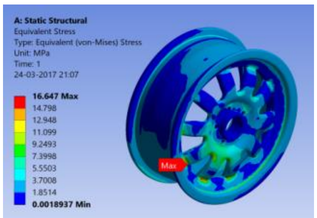


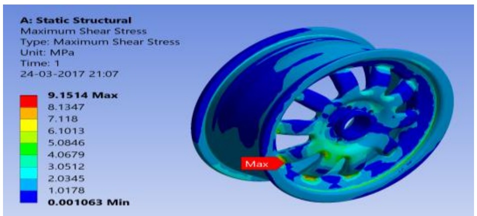




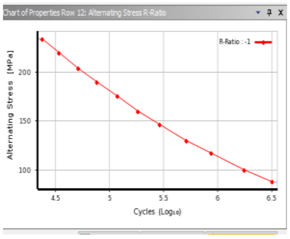
8.5 Titanium Alloy:

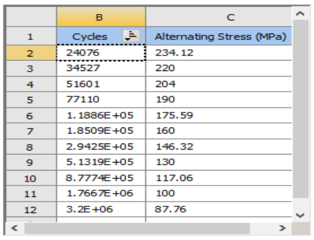




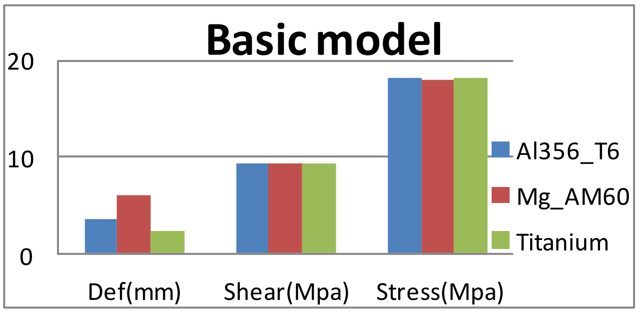


8.6Graphical Representation of Static Analysis: Aluminium Alloy (A356):





	B	C
1	Cycles	Alternating Stress (MPa)
2	24076	234.12
3	34527	220
4	51601	204
5	77110	190
6	1.1886E+05	175.59
7	1.8509E+05	160
8	2.9425E+05	146.32
9	5.1319E+05	130
10	8.7774E+05	117.06
11	1.7667E+06	100
12	3.2E+06	87.76



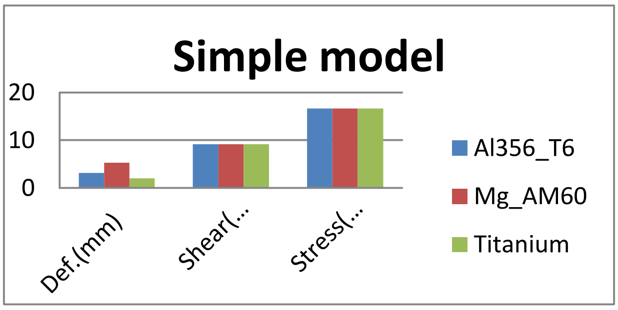
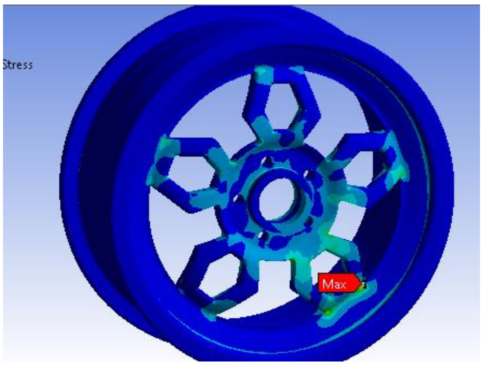


Fig.Dynamic loading

9.0 PRACTICAL FAILURE CASES:

Comparing the theoretically most stressed areas of wheel rim (obtained from ansys software) with practical failed cases



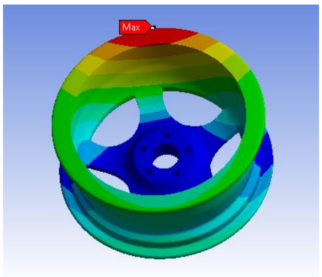


Figure showing Max deformed area where when there will be air leakage (tube less tyres) from the tyres

CONCLUSIONS:

From the analysis we came to know that all the three designs are safe and are within the standard limits

Among the three designs simple rim design is more promising than centrifugal rim Followed by pentagonal rim

Among the three materials steel alloy is the best material followed by aluminium and magnesium

Magnesium occupies last position as it has more deformation for the same loading condition .from this results we can then why magnesium alloy material is only used for pretty shorter period restricted to racing cars only

From the fatigue analysis aluminium alloy has got more life than that of the steel alloy

Even though the safety factor is almost equal for both the materials aluminium is subjected to less damage compared to steel (for same loading conditions)

From the above results we define a new material (Al-Mg alloy) which is more promising than other two i.e. these has got less deformations like ALUMINIUM and more lifelike magnesium

Under the influence of a radial load, the rim tends to vocalize about the point of contact with maximum displacement occurring at the location of the bead seat.

The inside bead seat reveals the greatest deflection and is concurrently prone to loss of air pressure due to dislodgment of the tire on the rim.

Actually failure of alloy wheel occurs mostly at the areas where there is max stress values occurs (predicted by analysis software)

More deformed areas are also in agreement with theoretical values

REFERENCES:

1.Comparison of Loading Functions in the Modelling of Automobile Aluminium Alloy Wheel under Static Radial Load by Samuel Onoriode Igbudu1, David Abimbola Fadare, Mechanical Engineering Department, Ambrose Alli University, Ekpoma, Nigeria

2.Design and Analysis of Wheel Rim using CATIA & ANSYS by P. Meghashyam1, S. Girivardhan Naidu2 and N. Sayed Baba, ,3Scholar /Department of Mechanical Engineering, JNTUA/Madanapalle Institute of Technology & Science.

3.Fatigue Analysis of Aluminum Alloy Wheel Under Radial Load, International Journal of Mechanical and Industrial Engineering (IJMIE), ISSN No. 2231 –6477, Vol-2, Issue-1, 2012.

4.International journel of Engineering Sciences & Research Technology Study Of Influence Of Pressure And Load On Wheel Rim By Radial Fatigue test by Gaurav Machave, Pote Susheel Sambhaji, Prof. R.A.Kathar, Quality Engineer, Klassic Wheels Pvt.Ltd, Ahmednagar, Maharashtra, India.

5.Impact Analysis of Aluminum Alloy Wheel, by Sivakrishna. V M.Tech Student, (Machine Design), Mechanical Engineering Department, Sarada Institute of Science Technology & Management.

6.Modeling and Analysis of Alloy Wheel for Four Wheel Vehicle by S Vikranth Deepak1, C Naresh and Syed Altaf Hussain.

7.Modeling the mechanical response of an aluminum alloy automotive rim by J. Stearns, T.S. Srivatsan∗, A. Prakash, P.C. Lam, Department of Mechanical Engineering, The University of Akron, Akron, OH 44325-3903, USA.

8.Modification of Design and Analysis of Motor Cycle Wheel Spokes by Rajarethinam P, Periasamy K.

9.Structural and Fatigue Analysis of Two Wheeler Lighter Weight Alloy Wheel by M. Saran Theja1, M. Vamsi Krishna, Mechanical Engineering, (M.Tech) Machine Design,MITS (J.N.T.U.A), Madanapalle, Chittoor (Dist.), A.P., India.

10.Understanding the Influence of Pressure and Radial Loads on Stress and Displacement Response of a Rotating Body: The Automobile Wheel by J.Stearns, T.S.Srivatsan,X.Gao, and P.C.Lam Department of Mechanical Engineering, The University of Akron, Akron, OH 44325-3903, USA

BIOGRAPHIES

K.SrinivasaRao.
Assistant Professor.
Dept of Mechanical Engineering.
V.R.Siddhartha Engineering College,
Vijayawada - 520 007

M. Rajesh..
Assistant Professor
Dept of Mechanical Engineering.
V R Siddhartha Engineering College,
Vijayawada - 520 007

G.Sreedhara Babu.
Assistant Professor
Dept of Mechanical Engineering.
V R Siddhartha Engineering College,
Vijayawada - 520 007