Structural and Fatigue Analysis of Two Wheeler Lighter Weight Alloy Wheel

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Abstract: Importance of wheel in the automobile is obvious. The vehicle may be towed without the engine but at the same time even that is also not possible without the wheels, the wheels along the tire has to carry the vehicle load, provide cushioning effect and cope with the steering control. Generally wheel spokes are the supports consisting of a radial member of a wheel joining the hub to the rim. The most commonly used materials for making Wheel spokes are with features of excellent lightness, thermal conductivity, corrosion resistance, characteristics of casting, low temperature, high damping property, machine processing and recycling, etc. This metal 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. Spokes make vehicles look great but at the same time they require attention in maintenance. To perform their functions best, the spokes must be kept under the right amount of tension. The two main types of motorcycle rims are solid wheels, in which case the rim and spokes are all cast as one unit and the other spoke wheels, where the motorcycle rims are laced with spokes. These types of wheels require unusually high spoke tension, since the load is carried by fewer spokes. If a spoke does break, the wheel generally becomes instantly unridable also the hub may break. Presently, for motor-cycles Aluminium alloy wheels are used, currently now replacing by new magnesium alloy due its better properties than Al-alloy. An important implication of this paper or the problem stated here is to “analyse the stress and the displacement distribution comparing the results obtained”. In addition, this work extends Proper analysis of the wheel plays an important role for the safety of the rider. This paper deals with the static & fatigue analysis of the wheel. The present work attempts to analyse the safe load of the alloy wheel, which will indicate the safe drive is possible.

A typical alloy wheel configuration of Suzuki GS150R commercial vehicle is chosen for study. Finite element analysis has been carried out to determine the safe stresses and pay loads.

Keywords: Motorcycle, Geometric modeling and Designing, lightweight alloy-wheel, Rim, Alloy-spokes, fatigue analysis, Al & MAG wheels, Mg Y Zn, Lightweight & Anti-fatigue design.

I. Introduction

History

The wheel is a device that enables efficient movement of an object across a surface where there is a force pressing the object to the surface. Early wheels were simple wooden disks with a hole for the axle. Because of the structure of wood a horizontal slice of a trunk is not suitable, as it does not have the structural strength to support weight without collapsing; rounded pieces of longitudinal boards are required. The spoke wheel was invented more recently, and allowed the construction of lighter and swifter vehicles. Alloy wheels are automobile wheels which are made from an alloy of aluminum or magnesium metals (or sometimes a mixture of both). Alloy wheels differ from normal steel wheels because of their lighter weight, which improves the steering and the speed of the vehicle, however some alloy wheels are heavier than the equivalent size steel wheel. Alloy wheels are also better heat conductors than steel wheels, improving heat dissipation from the brakes, which reduces the chance of brake failure in more demanding driving conditions. Over the years, achieving success in mechanical design has been made possible only after years of experience coupled with rigorous field-testing. Recently the procedures have significantly improved with the emergence of innovative method on experimental and analytical analysis.

Lighter wheels can improve handling by reducing unsprung mass , allowing suspension to follow the terrain more closely and thus improve grip, however not all alloy wheels are lighter than their steel equivalents. Reduction in overall vehicle mass can also help to reduce fuel consumption.
II. Objective

To create simulations of various alloy wheel designs that focus on reducing the mass of the current design and selecting better material. The new designs include reducing the number of spokes, modifying the fillet radius at the intersection of the spoke and the hub.

III. Literature Survey

A wheel rim is a highly stressed component in an automobile that is subjected to loads. Because of the long life and high stresses, as well as the need for weight reduction, material and manufacturing process selection is important in rim design. There are competitions among materials and manufacturing processes, due to cost performance, and weight. This is a direct result of industry demand for components that are lighter, to increase efficiency, and cheaper to produce, while at the same time maintaining fatigue strength and other functional requirements.

A paper published in the year 2009, which is about the fatigue analysis of aluminium wheel rim by Liangmo Wang - Yufa Chen - Chenzhi Wang - Qingzheng Wang School of Mechanical Engineering, Nanjing University of Science & Technology, China.

To improve the quality of aluminum wheels, a new method for evaluating the fatigue life of aluminum wheels is proposed in that paper. The ABAQUS software was used to build the static load finite element model of aluminum wheels for rotary fatigue test. Using the method proposed in this paper, the wheel life cycle was improved to over $1.0 \times 10^5$ and satisfied the design requirement. The results indicated that the proposed method of integrating finite element analysis and nominal stress method was a good and efficient method to predict the fatigue life of aluminum 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.

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 Fig. The load shaft and wheel were connected by bolts. Due to the main concern being wheel deformation, the load shaft in the FEA analysis was defined as a rigid body, using tie connection with wheel. J area under the wheel rim was under full constraints.

Finite Element Analysis (FEA) was first developed in 1943 by R. Courant, who utilized the Ritz method of numerical analysis and minimization of variation calculus to obtain approximate solutions to vibration systems. Shortly thereafter, a paper published in 1956 by M. J. Turner, R. W. Clough, H. C. Martin, and L. J. Top established a broader definition of numerical analysis. The paper centered on the "stiffness and deflection of complex structures".

N. Satyanarayana&Ch.Sambaiah: During the part of project a static analysis of aluminum alloy wheel A356 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. 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 A.356.2 material. For a wheel maker, reduction in the development time means a reduction in the cost. Hence, to find an effective way of static analysis which can be equivalent to the same impact effect of dynamic loading is an important issue.

G HARINATH GOWD: During the part of project a STATIC ANALYSIS OF LEAF SPRING was carried out using FEA package. The 3 dimensional model of the leaf spring was modeled. Then model was meshed in ANSYS. Analysis found out the total deformation, alternative stress by using FEA software. And also found out the life, safety factor and damage of leaf spring with Material Manganese Silicon Steel.

WU Li-hong1, LONG Si-yuan2, and GUAN Shao-kang: Replacement of A365 with AM60A, service stress distribution in the wheel becomes more uniform, the peak value of the concentrated stress reduced due to low elastic modulus of Mg alloys. The service stress level of redesigned Mg wheel is relaxed further because of its optimized structure by altering the spoke configuration and increasing the fillet between spoke and ring, satisfying the desired reliability with weight saving.

MohdZulHazmi Bin MhdFauzy, Ruzanna Nadia and BintiNisah: During the part of project a static and fatigue analysis of aluminum alloy wheel 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 NAStRAN using the IGES format. We find out the total deformation, alternative stress and shear stress by using FEA software. There are too many
Magnesium is best known for its light weight but it also has some other excellent attributes. Magnesium alloys have excellent strength to weight ratio, good fatigue strength and high damping capacity. Its nonmagnetic, has good thermal and electrical conductivity. Magnesium can be shaped by practically all the known metal working techniques like cast by the sand, investment, permanent mould and die casting, extruded, processed via powder metallurgy technology, can be formed into shapes by forging, drawing, spinning.
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Stamping, impact extrusion and super plastic forming. To further enhance safety, a new generation of wrought and sand casting magnesium alloys has been developed, Eletron 43, 21, and 675, ZK 60 etc. which are inherently flame – resistant even beyond their melting points.

Mg Alloys are well known for the following properties:
1. Ultra-lightness
2. Strength
3. Machinability
4. Cast ability
5. EMI/ RF Radiation shielding
6. Low inertia
7. Creep Resistance
8. Formability
9. Dent Resistance
10. Corrosion Resistance

Forged mag wheels are extremely durable and rigid. The strength of a forged wheel made from magnesium alloy exceeds many times the strength of a cast Al disk. This is achieved by forming a unique fiber structure of the alloy manufactured by the precision 3-D hot forging process in a press with a 20,000 ton capacity.

A forged wheel does not crack; it bends without cracking and can be easily repaired, if necessary. Common casting defects, such as cavities and cracks, are non-existent in forging. So our forged mag wheels are stronger and more durable. Also, all forged mag wheels produced by SMW Engineering undergo strict quality control to comply with road safety requirements.

Forged mag wheels are very lightweight, as much as 1.5 times lighter than aluminum wheels, and 2.2 times lighter than steel wheels. forged magnesium wheels are twice as light compared to cast Al wheels of the same dimensions. Due to lacks of theoretic guide, most of streetbike wheels are of Al-alloy. Wheel weight is a key component in “un-sprung” mass of an automobile (tires, wheels, brake disks, etc.), which directly affects vehicle performance parameters and the lifetime of suspension components. A lighter wheel is much easier to spin and to stop due to a lower momentum of inertia. Forged mag wheels yield shorter breaking distance and faster acceleration, improve manoeuvrability and overall performance and safety, and reduce fuel consumption (by up to 5-7%).

The dampening ability (the absorption of shocks and vibrations caused by road imperfections) of magnesium alloys is 100 times higher than those made from aluminum and 23 times higher than steel. This promotes increased durability of suspension brackets, smooth and easy motion of the car, and a longer lifetime of the suspension and brakes. The high heat conductivity property of magnesium also means cooler brake disks and brake drums and a longer life for brake pads.

Geometric Properties of alloy wheel:

<table>
<thead>
<tr>
<th></th>
<th>Hub Diameter</th>
<th>Rim thickness</th>
<th>Spoke Length</th>
<th>Number of spokes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hub Diameter</td>
<td>145 mm</td>
<td>6mm</td>
<td>155 mm</td>
<td>6 to 4</td>
</tr>
<tr>
<td>Hub thickness</td>
<td>8 mm</td>
<td>Rim outer diameter 500 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spoke Length</td>
<td>155 mm</td>
<td>Number of spokes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spoke fillet radii</td>
<td>✓ at hub 4R</td>
<td>at outer rim 8R &amp; 13R</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Modeling & FEM Analysis of Alloy Wheel:

In computer-aided design, geometric modeling is concerned with the computer compatible mathematical description of the geometry of an object. The mathematical description allows the model of the object to be displayed and manipulated on a graphics terminal through signals from the CPU of the CAD system. The software that provides geometric modeling capabilities must be designed for efficient use both by the computer and the human designer. To use geometric modeling, the designer constructs the graphical model of the object on the CRT screen of the ICG system by inputting three types of commands to the computer. The first type of command generates basic geometric elements such as points, lines, and circles. The second type command is used to accomplish scaling, rotation, or other transformations of these elements. The third type of command causes the various elements to be joined into the desired shape of the object being created on the ICG system. During this geometric process, the computer converts the commands into a mathematical model, stores it in the computer data files, and displays it as an image on the CRT screen. The model can subsequently be called from the data files for review, analysis, or alteration. The most advanced method of geometric modeling is solid modeling in three dimensions.
IV. MODELING OF ALLOY WHEEL USING PRO-E

**Modeling Procedure for:**

**Creating the Spoke of the wheel**
To draw a spoke profile, select a BLEND tool, where we define the attributes, Section, Direction and Depth.

**Creating Circular Pattern for Spoke**
Select the spoke, which is to have a circular pattern, Select the PATTERN tool from the Sketcher menu.

**Creating the HUB part for wheel**
Select the Extrude tool from the sketcher menu, then right click on mouse to get an internal sketch option, choose it. Select the plane on which the hub profile has to draw, and then create a HUB profile using circle option.

**Creating the Rim Part of wheel**
Select the plane, on which the Rim profile has to draw, then choose the Revolve option, by right clicking the mouse on window will get an internal sketch option, select it. Draw the Rim profile as per the dimensions required, then choose an axis to which the profile has to revolve, using the revolve dash board on the window screen. Then the required shape of the Rim will get.

**Creating the Ribs for Hub part**
Select the plane on which the rib profile has to draw, using the sketcher menu, draw the required shape of the rib, Ribs are used for stiffness of the wheel. Using the Extrude tool, specify the height and width of the rib.

**Creating the round edges at corners**
Select the round tool from the menu bar. Select the edges that are required to smoothen, with different radii.

**Creating the air nipple**
Select the datum plane tool from the menu bar, choose the plane to which, the created datum plane should be.

Define the placement for created datum plane. Select the Extrude tool from the sketcher menu, then right click on mouse to get an internal sketch option, choose it. Select the plane on which the profile of Air Nipple has to draw. Using the extrude dash board options; enter the required depth and thickness for the profile.

V. ANALYSIS

Designers and engineers primarily use structural simulation to determine the strength and stiffness of a product by reporting component stress and deformations. The type of structural analysis performs depends on the product being tested, the nature of the loads, and the expected failure mode:

- A short/stocky structure will most likely fail due to material failure (that is, the yield stress is exceeded).

For the given below specification of the allow wheel, the static analysis is performed using solid works to find the maximum safe stress and the corresponding pay load.

After geometric modeling of the alloy wheel with given specifications it is subjected to analysis. The Analysis involves the following discretization called meshing, boundary conditions and loading.

**About analysis with Solid Works:**

Solid Works Simulation Xpress is design analysis software that is fully integrated in solid Works. SolidWorks Simulation Xpress simulates the testing of your part’s prototype in its working environment. It can help you answer questions like: how safe, efficient, and economical is your design. solid Works Simulation Xpress is used by students, designers, analysts, engineers, and other professionals to produce safe, efficient, and economical designs.

**Fatigue Analysis:**

During design validation, a structure is exposed to both static strength tests and fatigue tests. However, once a structure is deployed, it spends the vast majority of its lifetime being subjected to smaller repeated forces that can cause cumulative damage over time. For this reason, testing the durability of a structure makes up a larger proportion of the tests that are run. Durability is one of the most important attributes that structures can
Fatigue testing measures durability and is defined as the repeated mechanical loading of a structure to determine failure points. It requires complex analysis using the field of fracture mechanics, which is the analysis of material flaws to discover those that are safe and those that are liable to propagate as cracks and cause failure.

Add an event as constant amplitude for a required number of cycles, with zero based condition. Then define S-N curve for the applied material, as log-log graph. The Stress-Life (S-N) or Total Fatigue Life method is widely used for HCF applications. During HCF testing, a material spends the majority of life in a state where the cracks are very small, the growth is controlled, and the structure integrity is retained.

As noted earlier, the applied stress stays within the elastic range of the material. Total Life is determined by running multiple specimen tests at a number of different stresses. The objective is to identify the highest stress that produces a fatigue life beyond 10 million cycles. This stress is also known as the material’s endurance limit.

**Procedural Steps in Solid Work simulation:**
- Import developed Pro-E model into solid works.
- Select the type of analysis require.
- Applying the material
- Fixing the geometry
- Apply the loads
- Create the mesh for the imported model
- Run the analysis

**Meshing:**
Meshing involves division of the entire of model into small pieces called elements. This is done by meshing. It is convenient to select the Standard mesh because of wheel structures, so that shape of the object will not alter.

**Boundary Conditions:**
To ensure the accuracy and reliability of the analysis result, the structural and mechanical model of the rear wheel is established. Fig. 1 shows the existing models fig.7, 14 and redesigned model (fig 21). Net weight of the motorcycle is 163 kg and the maximum allowable load 6. The tyre used is a common version with inner tube filled to gas pressure 0.28 Mpa, uniformly distributed on the exterior ring surface of wheel.

To ensure reliability of the analysis, the sum of motorcycle net weight and maximum allowable load was applied to the rear wheel alone. The sum was considered to be the maximum load, which was distributed on the rim surface. By considering, the maximum load is equal to motorcycle weight including rider and all loads.

**Loads and Fixtures:**
![Fig 25 Fixture](image1)
![Fig 26 Loading 1](image2)
![Fig 26 Loading 2](image3)

The following are the material properties of the given alloy wheel. Type of model is Linear Elastic Isotropic.

<table>
<thead>
<tr>
<th>S. No</th>
<th>PROPERTY</th>
<th>Al Alloy 201.6-T43 Insulated Mold Casting (SS)</th>
<th>Mg Alloy ZK60'</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Elastic Modulus(GPa)</td>
<td>71</td>
<td>45</td>
</tr>
<tr>
<td>2</td>
<td>Poisson’s Ratio</td>
<td>0.33</td>
<td>0.35</td>
</tr>
<tr>
<td>4</td>
<td>Mass Density (kg/m3)</td>
<td>2800</td>
<td>1700</td>
</tr>
<tr>
<td>5</td>
<td>Tensile Strength (MPa)</td>
<td>273</td>
<td>425</td>
</tr>
<tr>
<td>7</td>
<td>Yield Strength (MPa)</td>
<td>225</td>
<td>382</td>
</tr>
<tr>
<td>8</td>
<td>Thermal Expansion Coefficient(K)</td>
<td>1.9e-005</td>
<td>1.9e-005</td>
</tr>
<tr>
<td>9</td>
<td>Thermal Conductivity (W/(m. K))</td>
<td>121</td>
<td>160</td>
</tr>
<tr>
<td>10</td>
<td>Specific Heat (J/(kg.K))</td>
<td>963</td>
<td>1000</td>
</tr>
</tbody>
</table>

Tensile test results of S-RS P/M and RS P/M ZK60 alloys (recent Mg alloy\(^{[20]}\)) at room temperature
Mesh Information and details are represented as in table.

<table>
<thead>
<tr>
<th>Mesh type</th>
<th>Solid Mesh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mesher Used:</td>
<td>Standard mesh</td>
</tr>
<tr>
<td>Jacobian points</td>
<td>4 Points</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TYPE OF WHEEL MODEL</th>
<th>With 6 Spokes</th>
<th>With 5 Spokes</th>
<th>With 4 Spokes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Element Size</td>
<td>6 mm</td>
<td>6 mm</td>
<td>6 mm</td>
</tr>
<tr>
<td>Tolerance</td>
<td>0.3 mm</td>
<td>0.3 mm</td>
<td>0.3 mm</td>
</tr>
<tr>
<td>Mesh Quality</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Total Nodes</td>
<td>138283</td>
<td>129933</td>
<td>121024</td>
</tr>
<tr>
<td>Total Elements</td>
<td>77485</td>
<td>72121</td>
<td>66289</td>
</tr>
<tr>
<td>Maximum Aspect Ratio</td>
<td>27.741</td>
<td>27.339</td>
<td>27.337</td>
</tr>
<tr>
<td>% of elements with Aspect Ratio &lt; 3</td>
<td>76.2%</td>
<td>74.2%</td>
<td>72.8%</td>
</tr>
<tr>
<td>% of elements with Aspect Ratio &gt; 10</td>
<td>0.246%</td>
<td>0.326%</td>
<td>0.291%</td>
</tr>
<tr>
<td>% of distorted elements (Jacobian)</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Time to complete mesh *(hh:mm:ss):</td>
<td>00:02:00</td>
<td>00:01:59</td>
<td>00:01:56</td>
</tr>
</tbody>
</table>

### TABLE : SIMULATION RESULT DETAILS

<table>
<thead>
<tr>
<th>MESHED MODELS</th>
<th>With 6 Spokes Al alloy</th>
<th>With 5 Spokes Al alloy</th>
<th>With 4 Spokes Mg alloy</th>
</tr>
</thead>
<tbody>
<tr>
<td>fig. 1</td>
<td>fig. 8</td>
<td>fig. 15</td>
<td></td>
</tr>
</tbody>
</table>

**STRESS ANALYSIS**

| fig. 2        | fig. 9                 | fig. 16                |

**DISPLACEMENT ANALYSIS**

| fig. 3        | fig. 10                | fig. 17                |
Structural And Fatigue Analysis Of Two Wheeler Lighter Weight Alloy Wheel

Applied Loads
Load 0 = weight of Bike (143 vehicle + 20 extra kg)
Load 1 = (163+65) kg
Load 2 = (163+65X2) kg
Load 3 = (163+65X3) kg
Load 4 = (163+65X4) kg
Load 5 = (163+65X5) kg
Load 6 = (163+65X6) kg
Analysis for strength needed:

Mass of Bike, Dead Weight of Bike = 143 kg
Total Gross Weight = 143 + 20 = 163 kg
Tires and Suspension system reduced by 30% of Loads
W_{net} = 163 \times 9.81 \times 0.7 = 1119.32 N
Reaction Forces On Bike = N_r = 1119.32 N

Number of Wheels: 2
But by considering total Reaction Force on only one wheel F_T = 1119.32 N

Rim surface area which is having 6 spokes:
A_6 = 48299.69 mm^2 (this can be obtained from selecting faces on rim by using measuring tool in solid works)

Stress on the each Rim = \frac{N}{A} = 0.02321 N/mm^2
So pressure on the each rim for load = 0.02321 N/mm^2
It is similarly for different Loads Stress on Each Rim with Loads
Pressure by Load 1 = 0.0324 N/mm^2
Pressure by Load 2 = 0.0417 N/mm^2
Pressure by Load 3 = 0.0509 N/mm^2
Pressure by Load 4 = 0.0601 N/mm^2
Pressure by Load 5 = 0.0694 N/mm^2
Pressure by Load 6 = 0.0786 N/mm^2

Applying Pressures:
Apply 0.011945 MPa pressure simulations normal to the faces as shown in the figure
Again it is similarly for rims with spokes 5 & 4. The simulation results are as shown in figures.

Applying Braking Torque:
In general Acceleration of the street motorcycle:
\begin{align*}
\text{a} &= \frac{\text{vf} - \text{vi}}{\text{t}} \\
\text{vf} &= \text{max of 60 miles in 3.5 sec} \\
\text{vi} &= 0 \\
\text{a} &= \text{7.6636 m/s}^2
\end{align*}
Brake force is required to estimate the load on the wheel hub.
Now Total force acting on the vehicle:
Mass of the vehicle including rider and other five more persons
\begin{align*}
M &= 163 + 65 \times 6 \\
F_{total} &= M \times a = 4237.9 N
\end{align*}

Torque on the hub:
\begin{align*}
T &= F_r \times R \text{ in N.m (here } F_r \text{ is the force on the each wheel= 0.5F_{total} \& is R radius of the rim = 0.25 m) } \\
T &= 2119 \times 0.25 = 529 N.m
\end{align*}

VI. RESULTS AND DISCUSSIONS:
Stress analysis values for 6,5-Spokes Al-alloy and 4 spoke Mg-alloy

<table>
<thead>
<tr>
<th>S.NO</th>
<th>Description</th>
<th>load (N)</th>
<th>With 6 Spoke Al Alloy</th>
<th>with 5 Spokes Al Alloy</th>
<th>With 4 Spokes Mg Alloy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Motorcycle Load</td>
<td>1119.321</td>
<td>2.182</td>
<td>2.312</td>
<td>2.269</td>
</tr>
<tr>
<td>2</td>
<td>with 1 Man</td>
<td>1565.676</td>
<td>3.044</td>
<td>3.323</td>
<td>3.169</td>
</tr>
<tr>
<td>3</td>
<td>with 3 Men</td>
<td>2012.031</td>
<td>3.925</td>
<td>4.154</td>
<td>4.078</td>
</tr>
<tr>
<td>4</td>
<td>with 4 Men</td>
<td>2458.386</td>
<td>5.054</td>
<td>5.075</td>
<td>4.978</td>
</tr>
<tr>
<td>5</td>
<td>with 5 Men</td>
<td>2904.741</td>
<td>5.655</td>
<td>6.002</td>
<td>5.877</td>
</tr>
<tr>
<td>6</td>
<td>with 6 Men</td>
<td>3351.096</td>
<td>6.532</td>
<td>6.924</td>
<td>6.788</td>
</tr>
<tr>
<td>7</td>
<td>with 7 Men</td>
<td>3797.451</td>
<td>7.398</td>
<td>7.841</td>
<td>7.686</td>
</tr>
</tbody>
</table>

The Stresses induced in the 4-Spokes Mg Alloy wheel 7.686 MPa is less as compared with the Stresses induced in the 5-Spokes Al alloy (AM60A), and also nearer to Al-alloys with 6 spokes. So in the 4 spoke model can substitute to the 6 or 5 spoke wheels safely.
Weight (N) reduction in the model:

<table>
<thead>
<tr>
<th>No. of spokes</th>
<th>Mg</th>
<th>Al</th>
<th>% of weight saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 spokes</td>
<td>24.3911</td>
<td>40.1294</td>
<td>60.78</td>
</tr>
<tr>
<td>5 spokes</td>
<td>21.8042</td>
<td>35.8761</td>
<td>60.77</td>
</tr>
<tr>
<td>4 spokes</td>
<td>19.1728</td>
<td>31.608</td>
<td>60.66</td>
</tr>
</tbody>
</table>

Max. Von Mises Stress due to braking torque in the wheel (by considering drum braking):

<table>
<thead>
<tr>
<th>Description</th>
<th>Stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>in 6 spoke Al-alloy wheel</td>
<td>251.526 &gt; yield stress</td>
</tr>
<tr>
<td>in 4 spoke Al-alloy wheel</td>
<td>250.148 &gt; yield stress</td>
</tr>
<tr>
<td>in 4 spoke Mg-alloy wheel</td>
<td>246.472 &lt; yield stress (safe stresses)</td>
</tr>
</tbody>
</table>

VII. CONCLUSIONS

The objective was to reduce the weight of the alloy wheel has been achieved. The current design is 60% lighter than the original design. What more can be done to reduce the weight. In this work the overall dimensions are controlled by reducing number of spokes to the alloy wheel with same functioning stability and less weight. The stress and displacements in 4 spoke alloy wheel are lesser than six and five spokes alloy wheels. And also having higher FOS in the four spoke model design.

SCOPE FOR FUTURE WORK:

1) Further to do optimization of material thickness to reduce the material consumption.
2) Further to improve life of component by using advanced fatigue strain life approach.

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