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 1.0×10^5 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 constantforce 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 an 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.

MohdZulHazml 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 tests that must be considered before an alloy wheels are ready to enter the market. For this project, static test were choose to analyse on the design of the alloy wheels.

MakkienKeng: In this project presents the new design of cast metal matrix automotive wheel using simulation of low pressure die casting. By using CATIA, a 3-dimensional model of new automotive wheel design is developed as the master pattern. As an approach to simulate the actual casting process, casting simulation tool is used to introduce the cast metal matrix material with composition of aluminum A356 alloy and 20wt% Sic particles into the cast wheel. Then, the finite element model of the wheel is built and solved by using ANSYS.

MohdIzzatFaliqfarhan Bin Baharom: For this project, they used reverse engineering approach to study motorcycle rim, spoke. Due to the confidentiality of the product specifications by the manufacturers, we were unable to obtain the specifications from the manufacturers. Therefore, we disassembled the wheel from a motorcycle and measured the specifications with their knowledge on metrology. Design of the automotive alloy wheel using Solid Works software product.Simulation data collected by using FEA software. Stress analysis on alloy wheel is carried out.

Liangmo Wang - Yufa Chen - Chenzhi Wang 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 1.0×10^5 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.

Wei-Chan Chang The main purpose of that study is, by using a commercial FEA code (ABAQUS), to investigate the effect of the tire portion on the impact performance of tested aluminum wheels and to find out an effective way of static analysis which can be equivalent to the same impact effect of dynamic loading. A 3-D FEA model of each wheel studied in the present work was constructed on the basis of a wheel design developed at a local aluminum wheel manufacturer.

The problem with MAG wheels in early days:

Magnesium alloy wheels, or mag wheels, are sometimes used on race cars, in place of heavier steel or aluminum wheels, which are heavier than MAG wheelsmost street vehicles. Note that aluminum wheels are often mistakenly called "mag wheels".

Oil consumption reduction and performance enhancement have become the development trend of road vehicles, especially for motorcycles. Due to the nature of high-speed motion and rotation, weight reduction of the wheels is thought of as the most efficient way to reduce the oil consumption, improve the accelerating and braking performance, and enhance the riding comfort of a road vehicle. Naturally, use of lightweight materials on the wheels is the most straightforward way to achieve the goal.

So recent developed Magnesium alloys are considered as the most promising metal material in the 21st century, which possesses the attractive properties desired by motorcycles in comparison with steel and Al alloy, such as low density, low cost, higher specific strength, good casting properties, and outstanding damping capability. When used as wheel material, Mg alloys are not only able to reduce the wheel mass and save oil, but also facilitate absorbing vibration and damping the noise emission, enhancing accelerating and braking performance, thus improving the resultant riding comfort. From steel wheel to Al wheel, lightweight Mg alloys have become the first candidate material of wheels.

However, the service states of road wheels are complicated due to the influence of the loads during service, like torsion, impact, vibration, and so on. At present, Mg alloy application on motorcycle wheels lacks theoretic guide because structural design for most of the road wheels available on the market are, nevertheless, based on Al alloys. To promote a scientific understanding of the effect of material substitution and structural features of wheel in service, numerical analyses of stress distribution in wheels of both 356 Al alloy and AM60B Mg alloy under the same service condition were carried out, and the AM60B Mg wheel structure was redesigned and optimized with finite element method.

Why MAGwheels only?

Magnesium is best known for its light weight but italso 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, 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:

Hub Diameter	145 mm	Rim thickness	6mm
Hub thickness	8 mm	Rim outer diameter	500 mm
Spoke Length	155 mm	Number of spokes	6 to 4
Spoke fillet radii	✓ at hub 4R ✓ at outer rim 8R & 13R		

Modeling &Fem Analysis of Alloy Wheel:

In computer-aided design, geometric modeling is concerned with the computer compatiblemathematical description of the geometry of an object. The mathematical description allows the model of theobject to be displayed and manipulated on a graphics terminal through signals from the CPU of the CADsystem. The software that provides geometric modeling capabilities must be designed for efficient use both bythe computer and the human designer.To use geometric modeling, the designer constructs the graphical model of the object on the CRTscreen of the ICG system by inputting three types of commands to the computer. The first type of commandgenerates basic geometric elements such as points, lines, and circles. The second type command is used toaccomplish scaling, rotation, or other transformations of these elements. The third type of command causes thevarious elements to be joined into the desired shape of the object being created on the ICG system. During thisgeometric process, the computer converts the commands into a mathematical model, stores it in the computerdata files, and displays it as an image on the CRT screen. The model can subsequently be called from the datafiles for review, analysis, or alteration. The most advanced method of geometric modeling is solid modeling inthree dimensions.

IV. MODELING OF ALLOY WHEEL USING PRO-E

Top 10 reasons for choosing Pro/ENGINEER Wildfire:

1. More Powerful, Mature Functionality in an Affordable Entry-Level Package
2. More Complete Set of Tools—On a Single Native Architecture
3. Geometry Constrained from the Outset
4. Auto build—Much More Than a 2D-to-3D Conversion Tool
5. Advanced Surfacing Tools
6. Large Assembly Management Tools
7. Design Quality Assurance Tools—Model CHECK
8. Powerful Connections to Third-Party CAD Data
9. Web Connectivity and Web-based Design Conferencing
10. Room to Expand into a Complete Product Development System.

Modeling Procedure for:

Creating the Spoke of the wheelto 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.

Fig.2 Full model of alloy wheel with six spokes

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 tofind the maximum safe stress and the corresponding pay load.

After geometric modeling of the alloy wheel withgiven specifications it is subjected to analysis. The Analysis involves the following discretization calledmeshing, 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 possess.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:

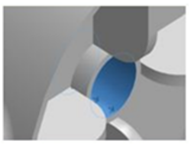
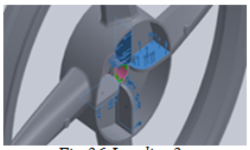
Meshing involves division of the entire of model into small pieces called elements. This is done bymeshing. It is convenient to select the Standard mesh because of wheel structures, so that shape of theobject will not alter.

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 163kg and the maximum allowable Load 6. The tyre used is a common version with inner tube filled to gas pressure 0.28Mpa, 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*	 *Fig.26 Loading1*	 *Fig.26 Loading2*
Entities: 1 Face *Type: Fixed geometry*	*Entities: 1 Face* *Type: Fixed geometry* *Type: Apply pressure,* *Value: pressures of LOAD 0-6*	*Load name: Torque-1,* *Load Details* *Entities: 4 faces, Reference: Face 1* *Type: Apply torque, Value:529 N•m*

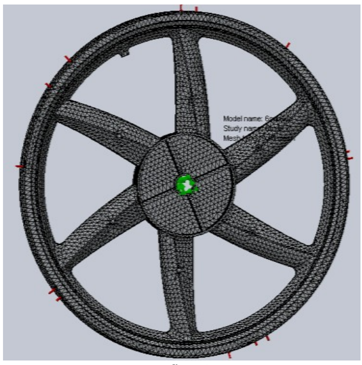
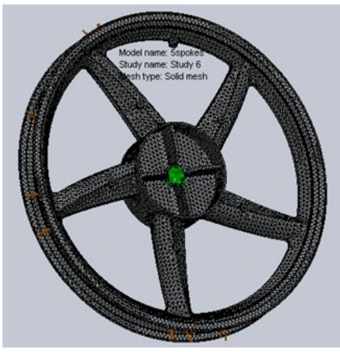
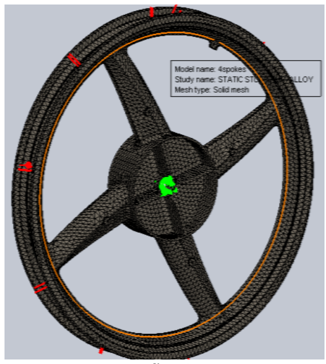
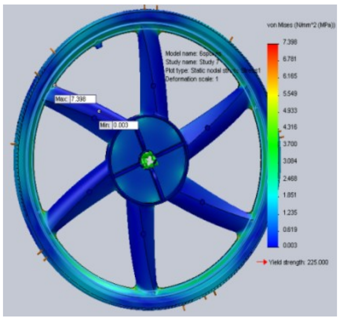
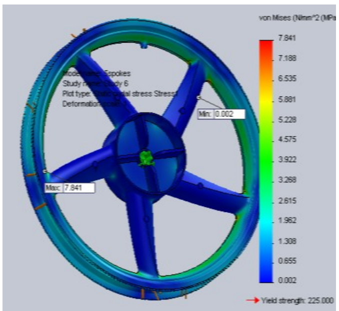
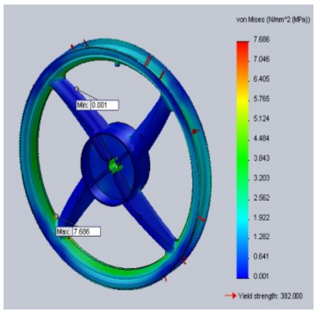
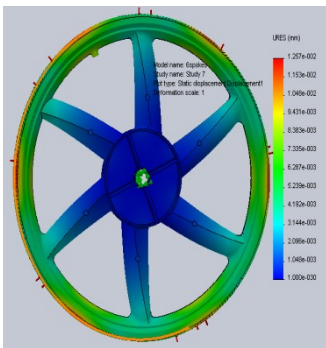
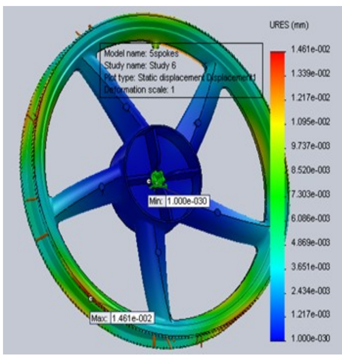
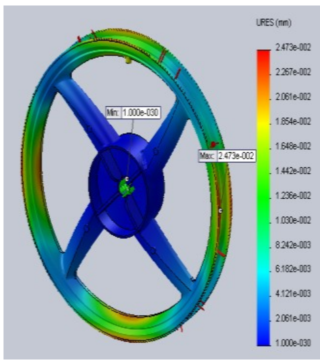
The following are the material properties of the given alloy wheel. Type of model is Linear Elastic Isotropic.

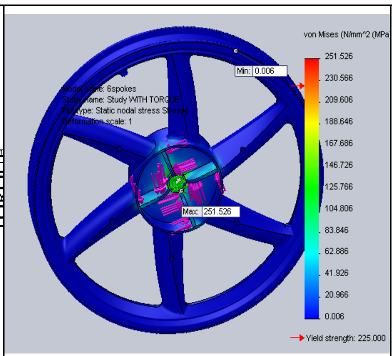
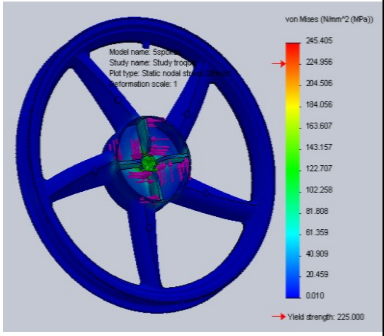
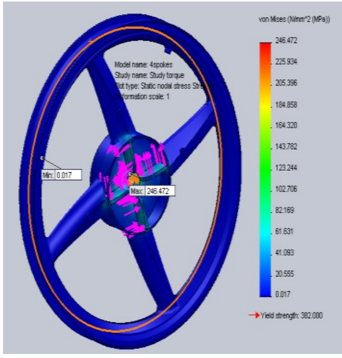
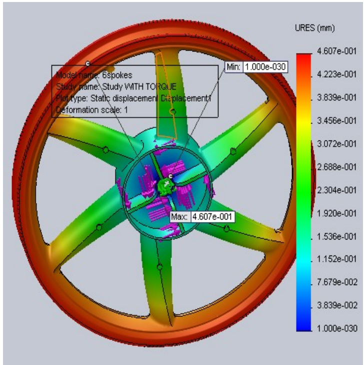
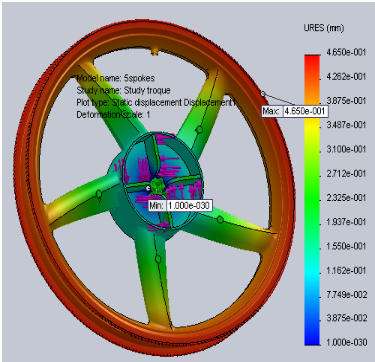
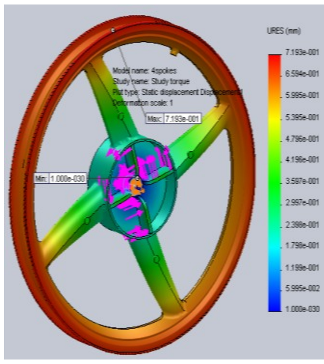
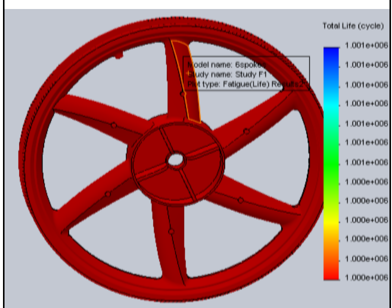
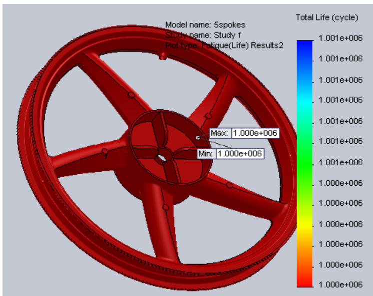
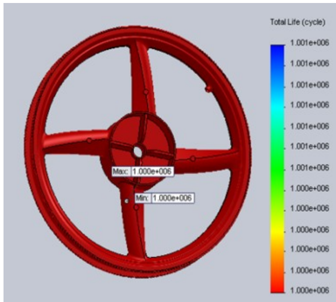
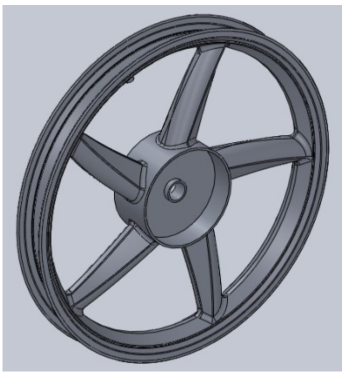
S. No	PROPERTY	Al Alloy 201.0-T43 Insulated Mold Casting (SS)	Mg Alloy ZK60*
1	**Elastic Modulus(GPa)**	71	**45**
2	**Poisson's Ration**	0.33	**0.35**
4	**Mass Density (kg/m3)**	2800	**1700**
5	**Tensile Strength (MPa)**	273	**425**
7	**Yield Strength (MPa)**	225	**382**
8	Thermal Expansion Coefficient(/K)	1.9e-005	1.9e-005
9	Thermal Conductivity W/(m. K)	121	**160**
10	Specific Heat J/(kg.K)	963	**1000**

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.

Mesh type	Solid Mesh		
Mesher Used:	Standard mesh		
Jacobian points	4 Points		
TYPE OF WHEEL MODEL	**With 6 Spokes**	**With 5 Spokes**	**With 4 Spokes**
Element Size	6 mm	6 mm	6 mm
Tolerance	0.3 mm	0.3 mm	0.3 mm
Mesh Quality	High	High	High
Total Nodes	138283	129933	121024
Total Elements	77485	72121	66289
Maximum Aspect Ratio	27.471	27.339	27.337
% of elements with Aspect Ratio < 3	76.2	74.2	72.8
% of elements with Aspect Ratio > 10	0.246	0.326	0.291
% of distorted elements(Jacobian)	0	0	0
Time to complete mesh*(hh;mm;ss):	00:02:00	00:01:59	00:01:56

TABLE : SIMULATION RESULT DETAILS			
	With 6 Spokes **Al alloy**	**With 5 Spokes Al alloy**	**With 4 Spokes Mg alloy**
MESHED MODELS	 fig. 1	 fig. 8	 fig. 15
STRESS ANALYSIS	 fig. 2	 fig. 9	 fig. 16
DISPLACEMENT ANALYSIS	 fig. 3	 fig. 10	 fig. 17

STRESS ANALYSIS FOR BREAKING TORQUE	 fig. 4	 fig. 11	 fig. 18
DISPLACEMENT ANALYSIS FOR BREAKING TORQUE	 fig. 5	 fig. 12	 fig. 19
FATIGUE LIFE ANALYSIS	 fig. 6	 fig. 13	 fig. 20
ISOMETRIC VIEWS OF MODELS	 fig. 7	 fig. 14	 fig. 21

Applied Loads

Load 0 = weight of Bike (143 vehicle +20extra 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

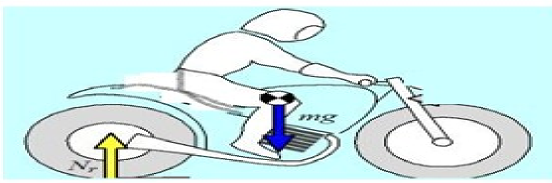


Fig. 22 Forces and normal reactions

Analysis for strength needed:

Mass of Bike, Dead Weight of Bike =143kg
Other Loads = 20 Kg
Total Gross Weight =143 + 20 = 163 Kg
= 163X 9.81 N
Tires and Suspension system reduced by 30% of Loads
W_{net} = 163 X 9.81 X 0.7 N = 1119.32N
Reaction Forces On Bike=N_r = 1119.32N
Number of Wheels: 2
But by considering total Reaction Force on only one wheel F_T=1119.32N
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 = 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 0.011945MPa pressure simulationsnormal 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:a = (v_f - v_i) / t
v_f- *final velocity= max of 60miles in 3.5sec*
v_i- *initial velocity = 0 miles,*
=>a - acceleration= 7.6636m/s²
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 M= 163+65X6
F_{total} =M X a = 4237.9 N

Torque on the hub:
T = F_r X R in N.m (hereF_r is the force on the each wheel= 0.5F_{total} & is R radius of the rim = 0.25m)
T = 2119X0.25 = 529 N.m

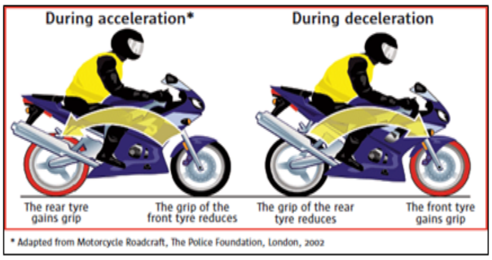


Fig. 23 Braking torque effecting wheels

VI. RESULTS AND DISCUSSIONS:

Stress analysis values for 6,5-Spokes Al-alloy and 4 spoke Mg-alloy

S.NO	LOADING		Stresses In the Alloy Wheel in MPa		
	Description	load (N)	With 6 Spoke Al Alloy	with 5 Spokes Al Alloy	With 4 Spokes Mg Alloy
1	Motorcycle Load	1119.321	2.182	2.312	2.269
2	with 1 Man	1565.676	3.044	3.323	3.169
3	with 3 Men	2012.031	3.925	4.154	4.078
4	with 4 Men	2458.386	5.054	5.075	4.978
5	with 5 Men	2904.741	5.655	6.002	5.877
6	with 6 Men	3351.096	6.532	6.924	6.788
7	with 7 Men	3797.451	7.398	7.841	7.686

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:

No. of spokes	**Mg**	**Al**	% of weight saving
6 spokes	24.3911	40.1294	60.78
5 spokes	21.8042	35.8761	60.77
4 spokes	19.1728	31.608	60.66

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

in 6 spoke Al-alloy wheel	251.526 > yield stress
in 4 spoke Al-alloy wheel	250.148> yield stress
in 4 spoke Mg-alloy wheel	246.472< yield stress (safe stresses)

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 higherFOS 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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REFERENCES

[1]. Cuixia, Z. (2006). “Design and structural analysis of aluminum alloy wheel”, Ph.D Dissertation, Zhejiang University, Zhejiang.

[2]. Angmo Wang - Yufa Chen - Chenzhi Wang - Qingzheng Wang (2009),Fatigue Life Analysis of Aluminum Wheels by Simulation of Rotary Fatigue Test thesis in School of Mech Engineering, Nanjing University of Science & Technology, China.

[3]. RamamurtyRaju, P., Satyanarayana, B., Ramji, K., Suresh Badu, K. (2007), “Evaluation of fatigue life of aluminum alloy wheels under radial loads”. Journal Engineering Failure Analysis.

[4]. Wei-Chan Chang (2008), “Modeling for Impact Test of Aluminum Wheels”, Department of Mechanical Engineering National Central University Jhong-Li 32001, Taiwan, R.O.C

[5]. M.Riesner and R. I. DeVries, “Finite Element Analysis and Structural Optimization of Vehicle Wheels”, in Proceedings of International Congress & Exposition - SAE, Detroit, MI, 1993.

[6]. Chan, “Analysis of Impact Test for Aluminum Alloy Wheel,”(2006) National Yunlin University of Science & Technology

[7]. N.Satyanarayana&Ch.Sambaiah (2012), “Fatigue Analysis of Aluminum Alloy Wheel Under Radial Load”, (IJMIE), ISSN No. 2231 –6477, Vol-2, Issue-1, 2012

[8]. WU Li-hong1, LONG Si-yuan2, GUAN Shao-kang1 (2009),“Verification of Applying Mg-Alloy AM60B to Motorcycle Wheels with FEM”, College of Materials Science and Engineering, Chongqing University, China.

[9]. Wu Lihong, Long Siyuan, Guan Shaokang. “Study on structural optimum technology of motorcycle Mg-alloy wheel” Machinery Design & Manufacture, 2006, (9):85-87

[10]. Wu Lihong, Long Siyuan, Xu Shao-yong, et al. “Influences of Mg alloy and Al alloy on service stress in motorcycle wheel”. Materials Science and Technology, 2007, 15(3): 397-100.

[11]. Cleginaldo Pereira de Carvalho (2002), “Wheels – An Approach for Structural Analysis and Fatigue Life Prediction”,Journal of Mechanical Engineering

[12]. Msc. ShaymaaMahmood (2011), Engineering Materials. National Instruments (2009), Static and Fatigue Structural Test Tutorial.

[13]. MOHD ZUL HAZMI BIN MHD FAUZY (2008), “Finite Element Analysis Of Car Alloy Wheel”, thesis in UNIVERSITI TEKNIKAL MALAYSIA MELAKA.

[14]. Lawerence and Miller, P., "Wheel materials," SAE technical publication #880697, 1988.

[15]. The Automotive Research Association of India (2007), “Automotive Vehicles Wheel Rims for Two and Three Wheeled Vehicles - Light Alloy Wheel Rims – Method of Test and Requirements” Ministry of Shipping, Road Transport &highways Government of India.

[16]. Wei, D., "Rim section fatigue results of Aluminum and Steel wheels,", SAE Report 01612, 1992.

[17]. Wright, D, "Test Methods for Automotive Wheels," I Mech E Conference Publications.

[18]. S Vikranth Deepak, C Naresh and Syed AltafHussain (2012), “Modelling and Analysis Of Alloy Wheel For Four Wheeler Vehicle”, ISSN 2278-0149

[19]. D.Apelian (2009), “Aluminum cast Alloys; For Enabling Tool and Improved Performance”, North American Die Casting Association, Wheeling

[20]. Zhenya Zhang, HuashunYuy, Shaoqing Wang, Haitao Wang and Guanghui Min- Microstructure and Tensile Properties of ZK60 Alloy Fabricated by Simpli¯ed Rapid Solidi¯cation Powder Metallurgy (S-RS P/M) Process, June 2009
[21]. WU Li-hong1, LONG Si-yuan, GUAN Shao-kang College of Materials Science and Engineering, Chongqing University, Chongqing 400044, China) "Verification of Applying Mg-Alloy AM60B to Motorcycle Wheels with FEM.
[22]. G Harinath Gowd et al. / International Journal of Engineering Science and Technology (IJEST) "STATIC ANALYSIS OF LEAF SPRING"
[23]. Hiroyuki Watanabe1, Koji Moriwaki, Toshiji Mukai1, Tetsu Ohsuna3, Kenji Hiraga3 and Kenji Higashi2 Materials Processing for Structural Stability in a ZK60 Magnesium Alloy, Materials Transactions, Vol. 44, No. 4 (2003) pp. 775 to 781 #2003 The Japan Institute of Metals express regular article.
[24]. G.M.Stoica1, E. A. Payzant2, L. Wu1, H. H. Liao1, J. E. Spruiell1, and P. K. Liaw DEVELOPMENT OF THE MICROSTRUCTURE OF SEVERELYPLASTICALLY DEFORMED Mg ALLOY, ZK60, Materials Science and Engineering Department, The University of Tennessee, Knoxville, TN 37996; Metals and Ceramics Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831, JCPDS-International Centre for Diffraction Data 2006 ISSN 1097-0002.
[25]. Design guide of Magnesium Elektron UK Magnesium Technology Centre Rake Lane Manchester.
[26]. Numerical simulation of AM50A magnesium alloy under large deformation. International Journal of Impact Engineering 30 (2004) 117–142, DOI: 10.1016/S0734-743X(03)00060-5
[27]. Chia-Lung Chang, Shao-Huei Yang Simulation of wheel impact test using finite element method, doi:10.1016/j.engfailanal.2008.12.010
[28]. Text book of Fundamentals of Machine Component Design ROBERT C. JUVINALL Professor of Mechanical Engineering University of Michigan KURT M. MARSHEK Professor of Mechanical Engineering University of Texas at Austin JOHN WILEY & SONS, INC.
[29]. Chen Chunmei, An Jian, Li Rongguang, Wang Baishu (Key Laboratory of Automobile Materials, Ministry of Education, Jilin University, Changchun 130025, China)Investigation of Friction and Wear Behavior of Mg97Zn1Y2 Alloy
[30]. Beginner's Guide to SolidWorks 2013- Parts, Assemblies, Drawings, Simulation Xpress
[31]. Fu-sheng PAN, Su-qin LUO, Ai-tao TANG, Jian PENG,Yun LU Influence of stacking fault energy on formation of long period stacking ordered structures in Mg−Zn−Y−Zr alloys
[32]. Amelia ana dascăl, 2.daniel cărăuleanu, wheels auto modeling using finite element method,university politehnica of timisoara, faculty engineering of hunedoara, Romania
[33]. A. Berg-Pollack a, F.-J. Voellmecke b, C.M. Sonsino Fatigue strength improvement by ultrasonic impact treatment of highly stressed spokes of cast aluminium wheels, www.elsevier.com/locate/ijfatigue
[34]. Z. Yang, J.P. Li, J.X. Zhang, G.W. Lorimer and J. Robson REVIEW ON RESEARCH AND DEVELOPMENT OF MAGNESIUM ALLOYS
[35]. Hisao watarai Trend of research and develop ment for Mg alloys Reducing the Weight, science & techology trends
[36]. 65th Annual World Magnesium Conference proceedings http://www.citysat.com.pl/~omen/2008_World_Mg_Conference_Papers
[37]. **C. Blawert, N. Hort and K.U. Kainer** Center for Magnesium Technology, Institute for Materials Research, AUTOMOTIVE APPLICATIONS OF MAGNESIUM AND ITS ALLOYS, Trans. Indian Inst. Met. Vol.57, No. 4, August 2004, pp. 397-408
[38]. IMA Mg Showcase Issue 11, Winter 2010,
[39]. Use of magnesium alloys in optimizing the weight of automobile: Current trends and opportunities Mutua James, J. M. Kihiu, G. O. Rading, and J. K. Kimotho
[40]. A. Zafer Senalp , Oguz Kayabasi, Hasan Kurtaran Static, dynamic and fatigue behavior of newly designed stem shapes for hip prosthesis using finite element analysis Gebze Institute of Technology, Department of Design and Manufacturing Engineering, Turkey doi:10.1016/j.matdes.2006.02.015
[41]. Design Optimization of Formula One Student Sports Car Upright Using Hypermesh, International Journal of Mechanical and Industrial Engineering (IJMIE), ISSN No. 2231 –6477, Vol-2, Issue-1, 2012
[42]. Alloy rim cracking and failure Department of Natural Resources and Mines, Safety Alert No. 287 | 25 May 2012

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