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Optimization of Two Wheeler Rim Using Finite Element Analysis

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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.*

Keywords *– Al alloy, Steel alloy, Mg alloy, Geometric Modeling, FEA, Stress Analysis, Cornering Fatigue Test.*

Introduction

Cornering Fatigue Test and Radial Fatigue Test are performed on any road wheel. It is observed that the FEA result of the above two tests shows that the maximum stress being induced in the wheel is much less than the allowable stress of aluminumalloy. Here comes the scope for further optimization of these wheels. Structural optimization is aimed at to minimize the mass of wheel without compromising the strength of wheel. In many instances, the results of equivalent stress, equivalent elastic strain and total deformation are found

similar to the results before optimization.Thus with some modifications in spoke design, mass of wheel can be decreased maintaining the characteristic behavior of the wheel intact. Finally, the ultimate goal of this project is to reduce the mass of wheel, thereby reducing the cost of wheel.[2]

Problem Statement

Currently, weight and strength of any product is considered as the most vital part in its manufacturing. Since every product or machine requires ample amount of strength for its fluent functioning. Strength of any product can be increased by making it bulky but this increases its weight resulting in decrement of its efficiency. Hence every engineer from each R&D is now trying to reduce its weight taking into account, its strength.

Same is the case for two wheeler vehicle system. Along with engine and frame, Wheels weight plays a key role in deciding bike's efficiency. Because if the weight of wheel is more, bike will not achieve required speed. So, more fuel will get consumed to overcome frictional losses. Also, wear and tear of tire occurs.Heavy vibrations are experienced due to heavy components which are mounted of wheel viz. Wheel ribs, Breaking system which includes either shoe brake arrangement like in old vehicles or disk breaking arrangement like in modern two wheeler vehicles, then tire's weight also contributes to heavy

weight of wheel. Along with it, wheel rims and rib's weight carries the major part of total weight of wheel. For change in design of wheel rim, new roller has to be designed and manufactured which is not economical. The problem stated here is to analyze the fatigue failure of an alloy wheel. The load has to be distributed on the hub diameter surface Even due to gyroscopic effect, it becomes difficult for rider to take turn due to rigidity in handle. Hence, to avoid this, we are trying to provide an optimum solution by deciding wheel's rim material and its rib's design.

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.[1]

Methodology

I) Introduction To Optimization

Finite element-based optimization techniques were first developed by UCLA Professor, Lucien Schmitt in the1960s (Schmitt 1960). Schmitt recognized the potential of combining optimization techniques with finite element analysis (FEA) for structural design. Today, three types of finite element based optimization approaches are available within commercial FEA software's:

i. Parameter optimization.
ii. Shape optimization.
iii. Topology optimization.

Shape optimization is done by removing the material from rim hub where stresses are minimum.[3]

Ii) Static Analysis

Static analysis is carried out using two loads in each loading condition namely radial load, lateral load and bending load. The stress and displacement on the wheel at each loading condition were found out.It may be noted that the stress value is well below the yield stress of the Al alloy.[4]

Iii) Fatigue Analysis

Fatigue is one of the important material properties where the component subjected to cyclic loading. Due to cyclic loading, the materials undergone stress and nucleate micro cracks essentially on the surface of the component. It is understood that tensile stress is always assisted in nucleation and propagation of cracks and leads to failure [4].

Iv) Damage Analysis

The development of micro-cracks on the wheel and damage under the stress factors which deform the material has been found out by FE analysis. It is noted that the probability of damage of the wheel is around the flange as shown by FE analysis. In order to safe guard the failure of material one should look into the design aspects and also the strength properties.[4]

V) Structural Analysis Procedure

The procedure for a static analysis consists of these tasks:

i. Build the model
ii. Set solution control
iii. Set additional solution options
iv. Apply the loads
v. Solve the analysis
vi. Review the results

Following points in mind when doing a static analysis:

i. You can use both linear and non-linear structural elements.
ii. Material properties can be linear or non-linear, isotropic or orthotropic and constant or temperature dependent.
iii. You must define stiffness in some form (for example, young's modulus, hyper elastic coefficients and so on).
iv. For inertia loads (such as gravity), you must define the data required for mass calculations, such as density.
v. For thermal loads (temperatures), you must define the coefficient of thermal

EXPANSION.

For static structural analysis we import the cad model generated in CATIA into ANSYS software with the (.stp) file format. The model is then assigned with the material properties i.e. aluminum alloy.[3]

Table I. Properties of Material

Sr. no	Property	Al Alloy	Mg Alloy	Steel
1	Elastic modulus (Gpa)	71	45	210
2	Poisson's ration	0.33	0.35	0.30
3	Mass density (kg/m^3)	2800	1700	7872
4	Tensile strength (Mpa)	273	425	340
5	Yield strength (Mpa)	225	382	285
6	Specific heat (J/kg.k)	963	1000	481

Vi) Parameters And Design Of Experiment

Table II. Parameters

Ex. no.	Experimental Parameter		FEA Equivalent Stress (Mpa)
	No. of Spokes	Material	
1.	4 Spokes	Steel Alloy	2.8573
2.	4 Spokes	Al. Alloy	2.8198
3.	4 Spokes	Mg. Alloy	2.805
4.	5 Spokes	Steel Alloy	4.0941
5.	5 Spokes	Al. Alloy	3.945
6.	5 Spokes	Mg. Alloy	4.1372

Calculations

Applied Load :-

Load 0= weight of bike (150 vehicle + 20 extra Kg)
Load 1= (170+75)=245 kg
Load 2 =(170+(2*75))=320 kg
Load 3 = (170+(3*75))=395 kg
Analysis for strength needed :
Mass of bike, dead weight of bike = 150kg Other load = 20 kg
Total gross weight = 150+20=170 kg = 170*9.81 =1667.7 N
Tire and suspension system reduce by 30% load
W_{net} = 170*9.81*0.7 N = 1167.39 N Reaction forces on bike(Nr)= 1167.39 N No. of wheel = 2
But by considering total reaction force on only one wheel (F_T) = 1167.39 N
Rim surface area (6 spokes) = A6 = 48299.69 mm2
Stress on each rim = F_T/A = 1167.39/48299.69 = 0.02416 N/mm^2 Applying Breaking Torque :-
In general acceleration of motorcycle,$(V_f – V_i)/t$ Where,V_f = Final velocity = max of 60 miles in 3.5sec
V_i = Initial velocity = 0 miles =>a – acceleration = 7.6636 m/s^2
Break Force is required to estimate the load on the wheel hub. Now Total force acting on vehicle :-
Mass of the vehicle including rider and other three more persons M =170 + (75*3) = 395kg
F_{Total} = M * a = 395 * 7.6636 = 3027.122 N
Total torque on the hub,
T = F_r * R = (0.5 * 3027.122) *0.27 = 378.39 N-m.

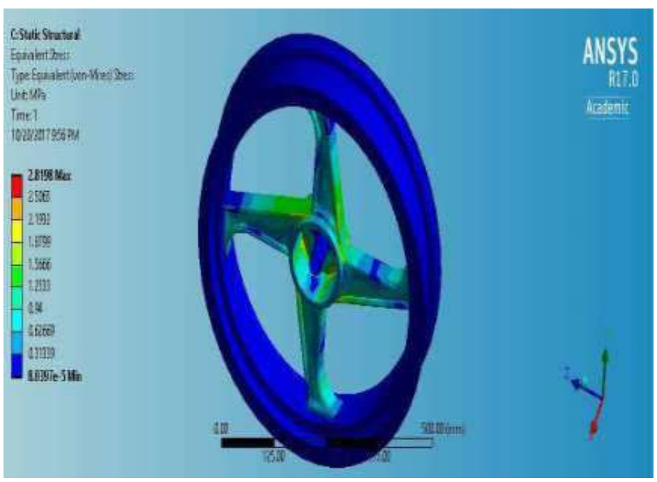

Fig 1(a). Al Alloy (4 Spokes)

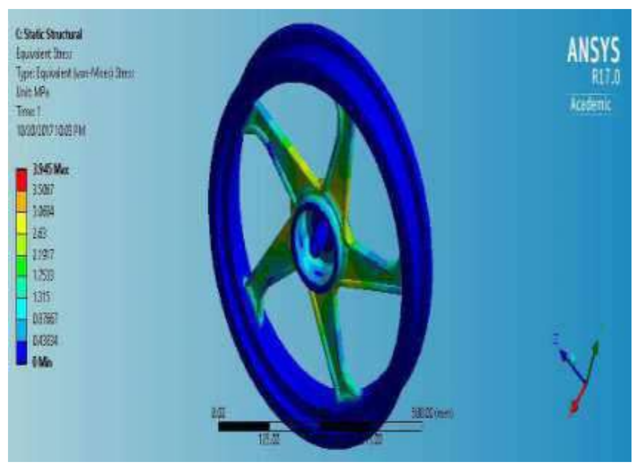

Fig 1(b). Al Alloy (5 Spokes)

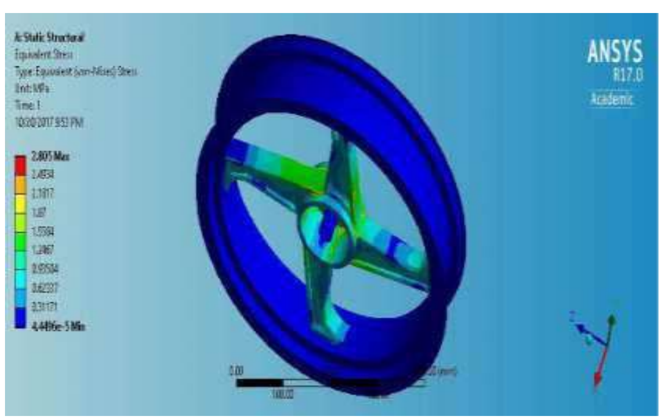

Fig 2(a).Mg Alloy (4 Spokes)

Results And Discussion

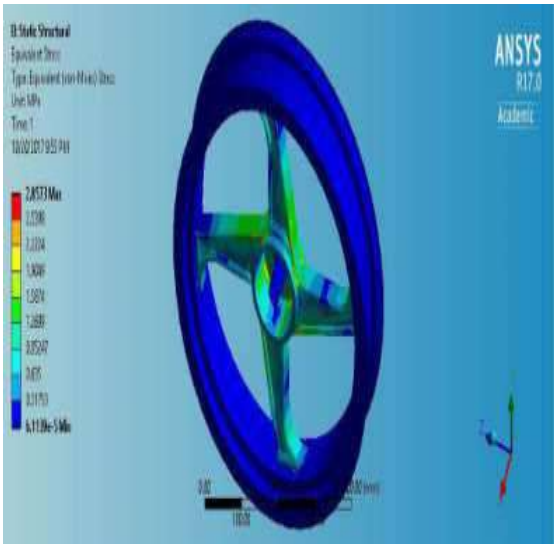

Fig 2(b).Mg Alloy (5 Spokes)

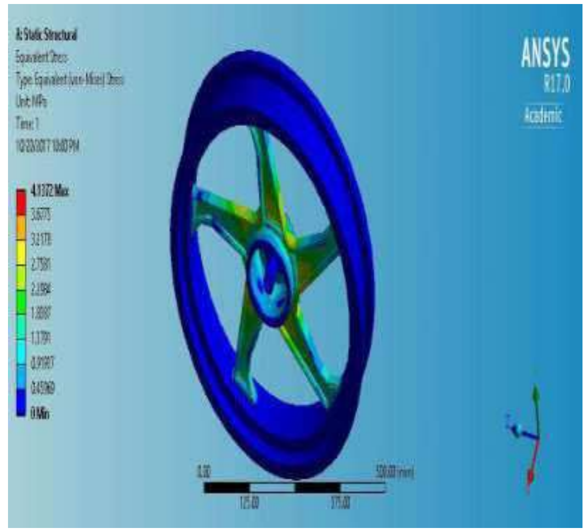

Fig 3(a). Steel (4 Spokes)

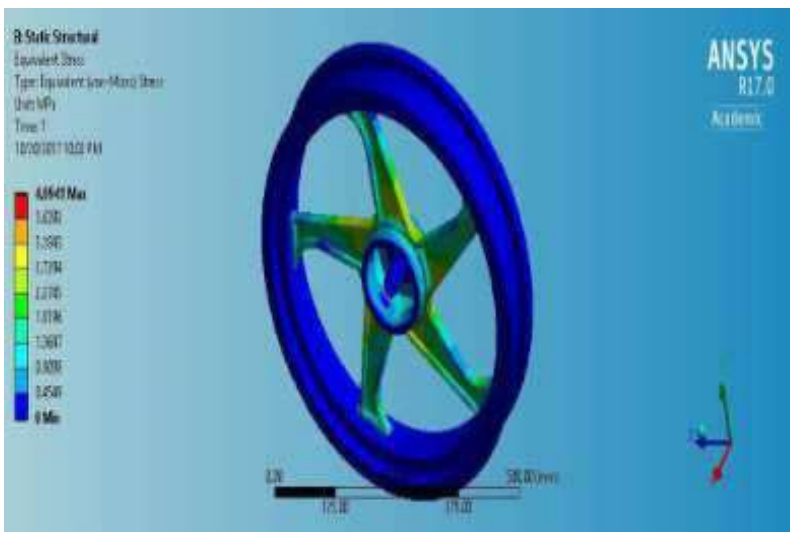

Fig 3(b). Steel (5 Spokes)

Conclusion

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.[1]

i) The maximum stress area was located at Spoke-Rim contact.
ii) Stresses induced in 4-Spokes Alloy wheel are less as compared with Al-Alloy of the 5and 6 Spokes.
iii) The weights of the Mg alloy with 4-Spokes wheel is less as compared with Al-Alloy of the 6,5and 4 Spokes.
iv) Fatigue life cycle is estimated.
v) Fatigue life cycle for the Mg-alloy is more as compared with all Al-alloys materials.
vi) Induced Stress due to braking torque in the 4 Mg-Spoke wheel are lesser than the remaining wheels.

vii) Material reduction can be done by reducing number of Spokes. The objective was to reduce the weight of the alloy wheel has been achieved. The objective was to reduce the weight of the alloy wheel has been achieved. 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.[5]

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