International Journal for Ignited Minds (IJIMIINDS)

Structural Analysis and Shape Optimization of Two Wheeler Wheel Spokes

Mr Jnanesh K[a], Imran Ali M R[b] & Zahoor Ahmed Shariff[c]

[a]*Research Engineer, Think and Ink Education and Research Foundation Bangalore, Karnataka, India.*
[b,c]*Asst. Prof, Dept of Mechanical Engineering, H.M.S.I.T, Tumkur, Karnataka, India.*

ABSTRACT

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 un-rideable also the hub may break. For the optimization of weight 4 or 5 spokes wheel instead of a 6 spokes wheel can be done but its strength should be optimum. So when we reduce the number of spokes shape optimization of the spokes becomes necessary to meet the strength requirements, on which this project is focused.

Keywords *- Shape Optimization, Two Wheeler, Spokes, Alloy.*

1. INTRODUCTION

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. In the early years wheels were simple wooden disks with a hole for the axle and because of the structure of wood a horizontal slice of a trunk is not suits, because of it does not have the structural strength to support weight without collapsing and a rounded pieces of longitudinal boards are required. So that spoke wheel was invented more recently and allowed the construction of lighter and swifter vehicles. The alloy wheels are automobile wheels which are made from an alloy of aluminum or magnesium metals (or sometimes a mixture of both).

In automotive industries components which are manufactured from cast alloys have been widely utilized, due to its high strength to weight ratio, low cost and better fuel consumption. Now in recent years, aluminum alloy wheels have been significantly used in transport vehicles because they are important safety components in vehicle suspension systems that support static and dynamic loads encountered during vehicle operation.

The automotive wheels have complicated geometry and must satisfy manifold design criteria, such as style, manufacturability, weight, and performance. With the addition of fascinating stylish wheel, wheel design also needs to accomplish a lot of engineering objectives which includes some necessary performance and durability requirements. However, in order to ensure driving comfort and road handling characteristics, the wheel must be as light as possible. So that reduction in wheel weight is a major concern in wheel industry. Hence researches are concentrating on reducing the weight by using composite material.

1.1 Illustration of Alloy Wheels

An illustration of alloy wheel design and development of a new alloy wheel using optimization with linear static and modal analysis. Major dimension of the model is unaltered and the no of spokes are changed in the design optimization load cases. Boundary conditions and loads remains same for all the iterations.

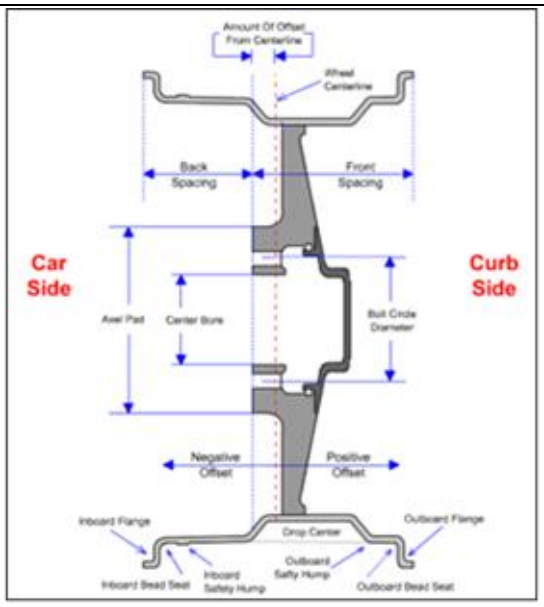

Fig 1: Cross Section of Spokes Wheel

2. LITERATURE SURVEY

Tejas Mulay, Harish Sonawane, Prof. P. Baskar [3], made Design and Analysis of Two Wheeler Front Wheel under Critical Load Conditions. The alloy wheels have always been a subject of interest among the high performance bikers. A lot of research has been going on the different materials and design for the wheels. With the increase in the engine power and hence top speed of the bikes, it has been very important to select a proper wheel. In case of sudden braking or passing over a path hole, large amount of shear forces are generated into the front wheel. Aluminium alloy wheel is the first alloy commercially used for rims. Recently Magnesium alloys have been used widely due to light weight property. The alloy wheels help in increasing the power to weight ratio of the bike. Static-structural analysis of the wheel has become inevitable before doing experimental analysis. This paper deals with the static analysis of a bike front wheel for the various types of loads acting during sudden braking and passing a bump.

Ravi Lidoriya, SanjayChaudhary and Anil Kumar Mohopatra [4], made Design and Analysis of Aluminium Alloy Wheel using PEEK Material Design and Analysis of Aluminium Alloy Wheel using PEEK Material. In the design of automobile, the industry is exploring polymeric material in order to obtain reduction of weight without significant decrease in vehicle quality and reliability. This is due to the fact that the reduction of weight of a vehicle directly impacts its fuel consumption. Particularly in city driving, the reduction of weight is almost directly proportional to fuel consumption of the vehicle. Thus in this project work the entire wheel design of two wheeler was chosen and analyzed by applying different load and redesign the wheel again to minimize the deformation and material will be changed from Aluminium to PEEK (polyether ether ketone) The following materials were chosen: - Aluminium Alloy PEEK (Polyether ether ketone) PEEK with 30% Glass fiber PEEK-90 HMF 20 PEEK-90 HMF 40 The whole design is made by using NX 7.5. The whole design has been made as per original equipment manufacturer (OEM'S) requirement. Analysis has been done by Ansys13.0 software to determine the various stresses, strain and fatigue life of the wheel. The software has helped us really to achieve our goal. As the whole analysis is done by the means of software therefore result and observation are trustworthy and meet with our expectation.

3. OBJECTIVES

The main objectives of this project are listed as bellows:

- To study the existing design of the 5 Spokes Aluminum Alloy Wheel from journal/research papers.
- To design the Aluminum Alloy Wheel of 5, 4 & 3 spokes.
- To conduct structural analysis to understand its behavior for 5, 4 & 3 spokes Wheel.
- Finally compare the obtained results with valid journals.

The objective of the study also involves obtaining the stresses and displacement plots of Aluminum Alloy Wheel for 5, 4 & 3 Spokes Wheel.

4. RESULTS AND DISCUSSIONS

4.1 Geometry of the 5 Spokes Wheel

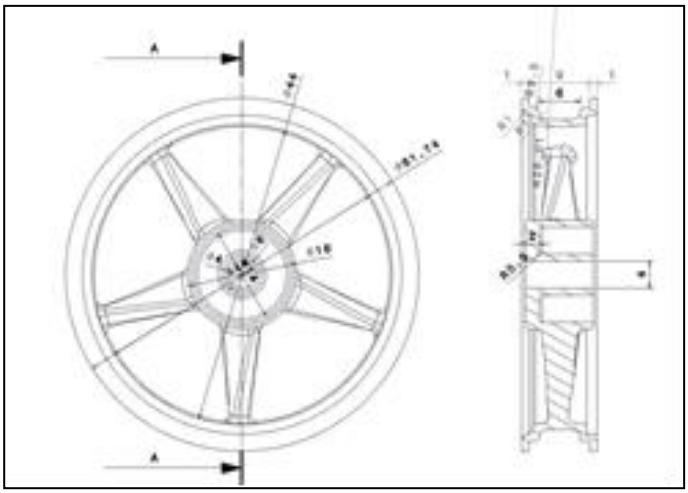

Fig 2: Geometry of the 5 spokes wheel.

Specifications:

- Rim diameter : 51.74mm
- Spokes H=14mm, W=11mm
- Hub Diameter 16mm

4.2 3D Model/Design of Alloy/Mag Wheel

The CAD model considered for the analysis is shown below.

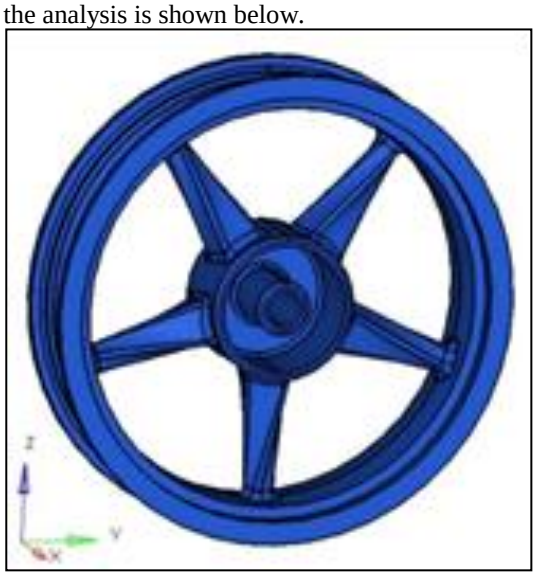

Fig 3: 3D Model/Design of alloy

4.3 FE Model

The Finite element model of the spokes is shown below. The FE model is created using second order tetrahedral element (SOLID 187) with element size of 1mm.

Since elements size play an important role in convergence and results variation. Element size is maintained same for all the iterations so as to minimize the results variation due to element size.

Fig 4: 3D FE Model (Solid 187).

4.4 Material Property

In general the wheel is made of aluminium alloy, hence for the analysis aluminium alloys is used for the analysis and the properties are shown below.

Name	**Young's Modulus (Gpa)**	**Poisson's Ratio**	**Density (Kg/m^3)**	**Yield Strength (MPa)**
Aluminum Alloy	70	0.33	2700	270

Table 1: Material Properties Used in the Model.

4.5 Boundary Conditions

The model is constrained for all 6 DOF at the axle mounting hole as shown below.

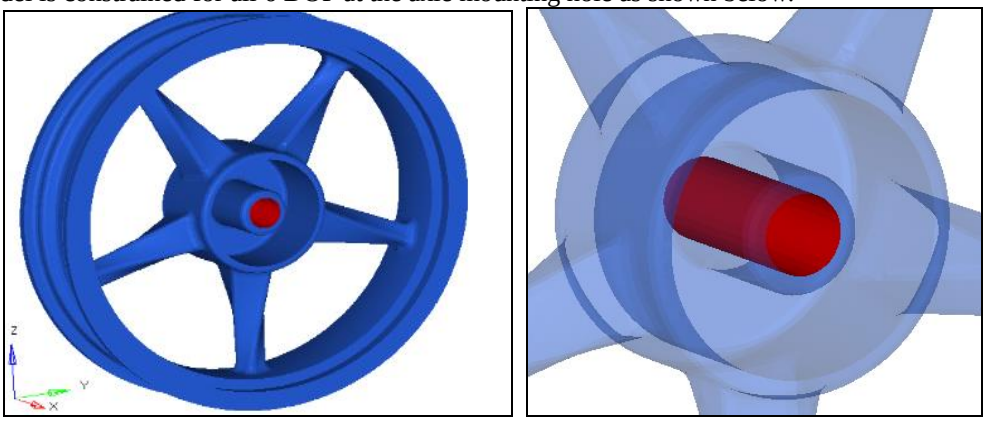

Fig 5: Boundary Conditions.

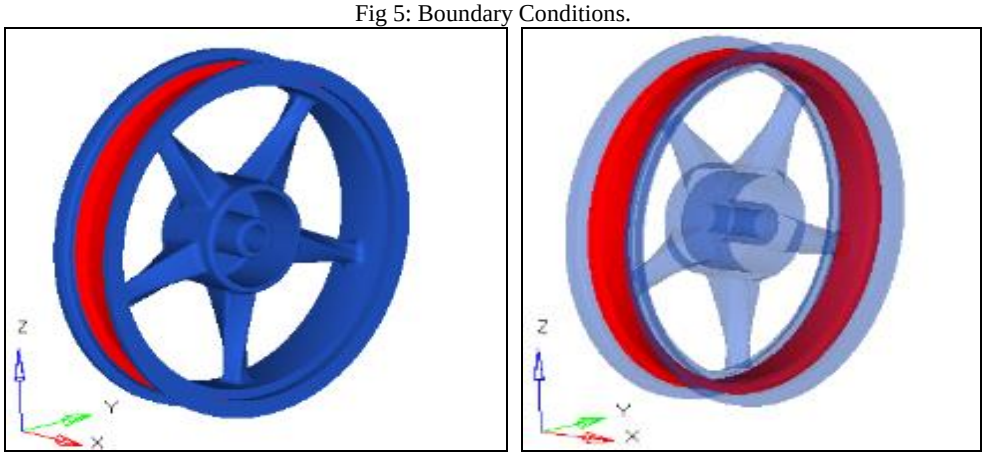

Fig 6: Air Pressure.

The air pressure of 28 PSI (0.19 MPa) is at the tire mounting location as shown below
The radial load of 2649 N is applied at the tire rim as shown below.
Radial load acting on the wheel
Radial load = total load (weight of the vehicle + weight of the rider & co rider)
= 150 + 60 +60
= 270*9.81
Radial load = 2649 N
It is assumed that the entire load is acting on the wheel without any losses.

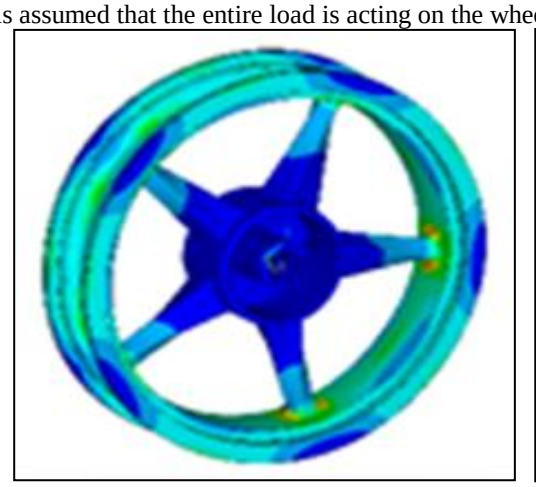

Fig 7: Maximum von-Mises Stress Plot

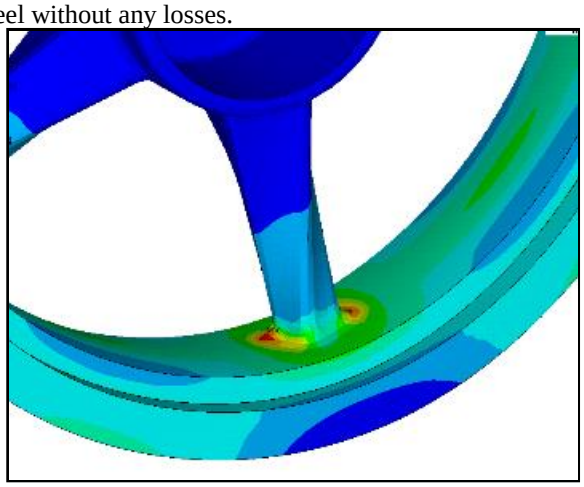

Fig 8: Zoom in view von-Mises Stress Plot

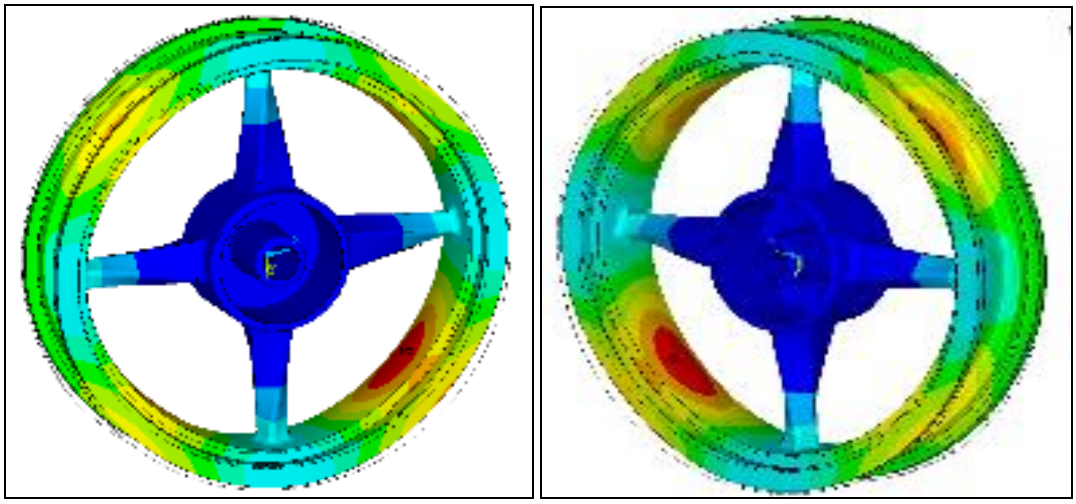

Fig 9: Displacement Plot

From the above fig, Maximum von-Mises stress and displacement is found to be 29Mpa and 0.0049mm.The maximum displacement found in the model (0.0049mm) is very negligible.

Based on the stresses and displacement induced in the wheel, we can try to optimize the wheel by reducing one spokes, this leads to reduce the overall weight of the wheel. Similar to this load case, remaining optimization load cases is carried out with same boundary condition and loads. The model is optimized with 4 & 3 spokes, the obtained model is compared and tabulated as shown in the below table.

Wheel Type	Displacement (mm)	von-Mises Stress (Mpa)	von-Mises Strain	Mass (Kg)
5 Spokes	0.0049	29	5.45E-04	12.5
4 Spokes	0.0091	40	7.40E-04	10
3 Spokes	0.143	53	0.001	7.5

Table 2: Results Summary for all Iterations.

5. CONCLUSION

From the above FE analysis fallowing conclusion can be drawn for all the iterations.

• The von-Mises stress induced in the wheel with 5 spokes is 29MPa.

The von-Mises stress induced in the design iteration 2 is 40MPa, which more than the base line design and below the yield strength of the material.

• The von-Mises stress induced in the design iteration 3 is 53MPa, which more than the base line design and below the yield strength of the material.

• The mass of the wheel is reduced by 2.5 kg i.e. 20% for 4 spokes wheel compared to 5 spokes wheel.

• The mass of the wheel is reduced by 5 kg i.e. 40% for 3 spokes wheel compared to 5 spokes wheel.

• The displacement induced in all three designs are low.

• The von-Mises strain induced in all three design are small and can be neglected.

• The design 2 & 3 are satisfying the strength requirements, hence either design 2 or 3 can be used for the given loading condition.

• From the FE Analysis it is observed that the design 2 or 3 can be successfully replace the base line design.

Reference

1. Priya Udasi, Sanjay Kumbhare, "*Analysis on Design and Analysis of Two Wheelers Wheel with the Replacement of Aluminum Alloy*".
2. M. Saran Theja, M. Vamsi Krishna, "Analysis on Structural and Fatigue Analysis of Two Wheeler Lighter Weight Alloy Wheel".
3. Tejas Mulay, Harish Sonawane, Prof. P. Baskar, "*Design and Analysis of Two Wheeler Front Wheel under Critical Load Conditions*".
4. Ravi Lidoriya, Sanjay Chaudhary and Anil Kumar Mohopatra, made Design and Analysis of Aluminum Alloy wheel using PEEK Material Design and Analysis of Aluminium Alloy Wheel using PEEK Material.
5. Madhu K Sa, Ravi Prakash Mb, & Somashekar H Kc, made Structural Analysis and Optimization of Two Wheeler Alloy Wheel by Using FEA Approach.
6. Rajarethinam P, Periasamy K, made Modification of Design and Analysis of Motor Cycle Wheel Spokes.
7. Mr. Sunil N. Yadav1, Prof. N. S. Hanamapure, "*Design Modification and Analysis of Automobile Wheel Rim Element Analysis*".
8. K Kalyani Radha, G Srinivas Kumar and J Paul Rufus Babu, "*Modeling and Structural Analysis of Alloy Wheel Using COSMOS*."