FINITE ELEMENT ANALYSIS OF COMPOSITE MATERIAL FOR AUTOMOTIVE WHEEL RIM

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ABSTRACT

Composite materials play a major role in weight reduction in automobile industry. Conventional material used for wheel rim is Aluminium alloy. Further weight reduction is achieved by use of magnesium alloy and composites materials. This work, investigated the static analysis of wheel rim using finite element package ANSYS 14.5 software. The dimensions of existing wheel rim of two-wheeler are taken into consideration. The static analysis such as deflection, von-mises stress and strain by using finite element method are done, and it is carried out for conventional aluminium alloy and compared with magnesium alloys and composite materials. Based on the static analysis, the possible replacement of aluminium alloys will be used for wheel rim.

KEYWORDS: Aluminium Alloy, Composite Material, Finite Element Analysis & Deflection, Von-Mises Stress

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INTRODUCTION

Weight reduction, fuel efficiency and energy conservation are always the areas, which automobile manufacturer concentrates while developing a vehicle. All the three areas are connected, so if one of them is taken care of, the others can be easily solved [1]. Material changing trend has been in the automobile industry for a long period of time and it still happens to be the best possible solution, which an automobile manufacturer has in dealing with the above mentioned problems [2]. By introducing better materials and a significant amount of design optimization, weight reduction can be achieved, which in turn, increases the fuel efficiency for IC engine powered vehicles and in the case of electric and hybrid vehicles, the energy is conserved. Ever since the rubber compound has been introduced as the preferred material for the tyre, the rim is the component that is used as the supporting structure for the tyre [3]. Now, this rim has had its fair share of material changes. From steel to aluminium alloy to magnesium alloy, automobile manufacturers have tried and tested various materials, in order to make the rim as lightweight as possible [5]. Composite materials is not a new term for the automobile world and by introducing composite materials as the material for rims, it can truly be the game changer [6]. Composite materials are taken into consideration because of their high strength to weight ratio. Therefore, keeping that in mind, in this paper, we investigate the finite element analysis of a few commonly known composite materials, and whether they can be used as a replacement for traditional metal rims.

METHODOLOGY

First we designed the wheel rim with the exact dimensions of Yamaha FZ using PTC CREO 2.0. In the next step, we imported our design in Ansys 14.5. The first material, which we analyzed is the

traditional Aluminium Alloy (Al 356) with the given load and pressure. The second material we used is, Magnesium alloy (Am60) and compared the results. Then, we see if we can get better results in Composite materials, and the first material which we took into consideration is Kevlar-49 and analyzed using the properties in the given wheel. Last, we analyzed the carbon fiber in the wheel and we compared the total deformation, maximum stress and maximum strain.

About Wheel Rim

The rim is the metal part, on to which, the rubber compound known as the tyre is mounted. Manufacturers for some time now have been looking for weight reduction in this particular area. Conventionally, STEEL was the preferred choice of material with which, the rim was fabricated. Over the years, the manufacturers tested and changed to lightweight materials such as aluminium alloy and magnesium alloy. The use of this new type of lightweight materials significantly improved the weight reduction, and also played a vital part in improving the performance of the vehicle.

About Composite Materials

The combination of two materials is known as composite materials. Composites were previously used only as materials to make the body of the car and to make a few interior of the vehicle. The commonly known composites are Carbon Fiber, Kevlar, Glass Fiber. Manufacturers have now found ways, in which composite materials can be incorporated in the place of conventional metals. Because of their high strength to weight ratio, composites have now found their way into the automobile field, and are here to stay for years to come.

Wheel Dimensions

Outer Radius= 230 mm, Inner hub radius= 71.75 mm

Width of the rim= 84.08 mm

No of spokes= 5

Spoke Length= 130 mm

Modelling of Wheel Rim

Figure 1: Isometric View

Figure 2: Top View

Figure 3: Side View

EXPERIMENT DETAILS

Modelling

Existing specification of wheel rim of Yamaha FZ are taken into consideration. Convert into geometry modelling in CREO. Import into ANSYS for analysis.

Meshing

Three meshing types are given to find out the accurate and converging result for deformation, equivalent stress and strain.

Loading

Calculation of load applied on wheel.

Here, we add the air pressure in the tire in the front wheel, which is 28 psi, which is then converted into Pascal to give the value 193053 Pa

Now, the radial load is applied where we calculate by

Kerb weight = 135 Kg

Seating capacity = 2

Approximate weight of each person= 80 Kg

Total weight = $153 + (2 \times 80) = 295$ Kg

Distribution of weights between the two wheels, $295/2 = 147.5$ Kg

Assuming the worst case scenario to know the breaking point we add to get 200Kg

Maximum vertical load (F) = $200 \times 9.81 = 1962$ N

Radial Load (Fr) = $K \times F$

K- 2.2 with the confirmation from SAE

Fr = $2.2 \times 1962 = 4316.4$ N

Thus, we get the load as 4316.4 N

When applied on the wheel, load will be divided into 2 to distribute the load

So, the load on each side is 2158.2 N

Table 1: Mechanical Properties

Properties	Aluminum	Magnesium	Kevlar-49	Carbon fiber
Density	2770 Kg/m ³	1800Kg/m ³	1400 Kg/m ³	1600 Kg/m ³
Young's Modulus	71 GPa	45GPa	75GPa	135GPa
Poisson's Ratio	0.33	0.35	0.34	0.30
Ultimate Tensile Strength	280Mpa	220Mpa	1300Mpa	1500Mpa

FINITE ELEMENT ANALYSIS OF WHEEL RIM

Aluminium Alloy (Al356)

Figure 4: Equivalent (Von-Mises) Stress

Figure 5: Total Deformation

Figure 6: Equivalent (Von-Mises) Strain

Magnesium Alloy (Am60)

Figure 7: Equivalent (Von-Mises) Stress

Figure 8: Total Deformation

Figure 9: Equivalent (Von-Mises) Strain

Kevlar -49

Figure 10: Equivalent (Von-Mises) Stress

Figure 11: Total Deformation

Figure 12: Equivalent (Von-Mises) Strain

Carbon Fibre

Figure 13: Equivalent (Von-Mises) Stress

Figure 14: Total Deformation

Figure 15: Equivalent (Von-Mises) Strain

Table 2: Analysis Report

	Course	Mid	Fine
Am60 Magnesium			
Total deformation	0.047425	0.048142	0.050374 mm
Max stress	15.044	15.044	13.812 MPa
Max strain	0.00033631	0.00033727	0.00031427
Carbon Fiber			
Total deformation	0.015886	0.01629	0.016881mm
Max stress	15.009	15.009	13.764 MPa
Max strain	0.00011181	0.00011223	0.00010338
Kevlar Fiber			
Total deformation	0.028487	0.028918	0.03026 mm
Max stress	15.034	15.034	13.799 MPa
Max strain	0.00020162	0.00020226	0.00018807
Aluminum alloy (al356)			
Total deformation	0.031219 mm	0.03167 mm	0.03327 mm
Max stress	19.035 Mpa	19.235 Mpa	16.964 Mpa
Max strain	0.00026963	0.00027268	0.0002567

CONCLUSIONS

The static analysis is carried out to find the deformation, stress and strain for four different materials such as Aluminium alloy, magnesium alloy, carbon fiber and kevlar fiber. It is observed that Kevlar-49 and Carbon Fiber have lesser deformation compared to the traditionally used Aluminum alloy. Thus, from this investigation, we can say that composites can definitely be used as a replacement for metal in wheel rims, thus reducing the weight and increasing the fuel economy of the vehicle.

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