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A Comprehensive and Novel Approach to Design of Carbon Reinforced Alloy Wheel with Material Selection

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Abstract- Main objective is to selection of material, analyze the reason of failures of the rim. Mainly the cracks on the surface, bending due to impact loading. Vibration and the hold pressure of the tire can damage the rim. The damage such as rust, dents, etc. which results in increased vibration while running, loss of air pressure and even sometimes the complete structural failure. This can damage the rims which could result in failure of the Rim during running conditions. Changes can be made to a rim and visible damage could lead to greater damage which can't be seen by naked eye, so a repaired rim will never be structurally sound as original rim. There are some more causes of failure, this project will discuss about these failures which can arise in rim. This project is all about the design, analysis and calculation of von-mises stresses and deflections with the help of CATIA and ANOVA method. The part which is under maximum stress as well as respective deformation value can be easily detected.

Keywords- Cracks, Vibration, Air pressure, von-mises stresses, ANOVA.

I. INTRODUCTION

In this theory, we have discussed an automotive wheel; the wheels are designed in the earlier time generally with woods and steels, with time wheels are built with the metal configuration and rim are made with forged aluminium alloys. Today in modern vehicles, wheels are made for aesthetic and for better durability. In the 1970s, numerous innovative techniques of testing well support the wheel with stress measurement have been introduced. In recent years, a series of steps have been improved by the experiment's quality and an analytical method developed for doing a structural analysis of the wheel. Wheels are the crucial parts of vehicles; it handles all the weight of vehicles.

Therefore, the design of the wheel is a prime consideration. For better safety and long life, it is necessary to study the fatigue life cycle of the wheel. Basically, steel, an alloy of aluminium, and magnesium are used in making the wheel. Alloy wheels different from base steel; Alloys are the better choice because of their lighter weight, which helps to increase fuel efficiency and also enhances the efficiency of the engine.

II. ABOUT WHEEL

In its primitive form, it is a circular frame of hard material that can be solid, brittle, ductile or spoked and is capable of turning or rotating on an axle. Whose centre has a bored hole through which axle bearing is placed, about which wheel rotates, when Torque is applied to the wheel about its Axis. The wheel and axle assembly is considered as the sixth simple machine; when it placed vertically under a load-bearing case, the wheel turning or rotating on a horizontal axle make it possible to transport heavy loads. It can also used to control the direction of a vehicle; when connected to a crankshaft or engine, a vehicle can release, store or transmit energy [1-10].

III. MATERIAL SELECTION

A fiber reinforced plastic was selected as the base material for the rim because they are generally considered to have a high specific strength over many metals. There are several different options for the fiber reinforcement material including glass, carbon, and kevlar. A comparison of the tensile modulus can be seen in the accompanying chart. Carbon fiber was eventually chosen over glass and Kevlar, not only for its high specific strength, but because of the significant previous experience in the design and fabrication of carbon fiber components as well as the resources available to produce it. Another consideration when selecting the material is the weave.

The weave of the fabric influences the strength of the fabric in the different directions. The main directions of the fabric that are most commonly referenced when describing the strength are the wrap and fill, or the 1and 2 direction. The wrap fibers run along the length of the fabric and are considered the primary, or 0 degree direction. The fill runs parallel with the width of the fabrics and is considered the secondary or 90 degree direction. Generally carbon fiber is commercially available in three different formats: unidirectional, woven, and braided sleeves. For this project a woven fabric will be

used. Braided sleeve was ruled out due to the specialty item cost of such a large diameter, as well as the difficulty in keeping the weave aligned while pulling the sock over the mold. Unidirectional was also ruled out due to the difficulty of handling the fabric during fabrication. A balance between commercial availability and handling during fabrication was found in 3k twill.

The specific fabric selected also was a Zyvex© Arovex prepreg, meaning it comes pre impregnated with resin that allows for a better resin consistency and work time than that of a dry fabric. The Arovex also has the additional feature of having its' resin reinforced with carbon nana tubes, which Zyvex© claims gives a 30% increase in toughness and increased resistance to fatigue. This is ideal in a wheel rim application. The material selection is very crucial part especially when we are talking about the topic like analysis for strength test or finite element test, etc.

There are several materials we have considering for making wheel rim are following:

1. Composite Materials:

A composite material is also known as composition material or sometimes also called as shortened to composite. They are mainly produced from two or more constituent materials, and the resultant material is developed with high strength and durability. These constituent materials have dissimilar properties from their base material and are merged to create a material with desired properties. Within the resulted structure, the individual elements remain distinct and separate. There are many types of composite materials like UD, woven, wet, prepreg, etc [11].

2. Carbon Fibres:

Sometimes, it is also written as carbon fibres, which are fibres that size about five to ten micrometres in diameter, and the main constituent is the carbon atom. High tensile strength, low weight to strength ratio, high stiffness, high temperature, etc. are some of the advantages of Carbon fibres. These properties have made carbon fibre very popular in mechanical engineering, military, aerospace, along with other fields like sports. However, they are expensive when compared with similar fibres. To create the intended composite, carbon fibres are mixed with additional materials such as polymers, epoxy, and so on.

To make carbon fibre, it is first permeated with a plastic resin and then baked, after which the resulting material develops a very high strength-toweight ratio and is extremely rigid but a little bit brittle. When Carbon fibres are composited with other materials like graphite, its resultant product is reinforced carboncarbon composites. Carbon-carbon composite has high heat tolerance.

3. Aluminium alloy:

Al alloys is the predominant metal and most popular non-ferrous metal to be used in construction, engineering, and industry. The alloys containing elements like : copper, magnesium, silicon, tin and zin. The desirable work seeks to reduce the weight of an item (ex- aeroplanes) but not in terms of strength.

4. Boundaries:

The project has aims to complete but also frontiers so that the purposes will not be lost. These ones are:

- The tire for the wheel is already selected so it will be out of the study.
- The shaft that connects the wheel with the vehicle's body is already dimensioned and it is one of the limits of the design as well as the break system [12].

IV. ANALYSIS METHOD-FEM

The description of the laws of physics for space- and time-dependent problems is usually expressed in terms of partial differential equations (PDEs). For the vast majority of geometries and problems, these PDEs cannot be solved with analytical methods. Instead, an approximation of the equations can be constructed, typically based upon different types of discretizations. These discretization methods approximate the PDEs with numerical model equations, which can be solved using numerical methods. The solution to the numerical model equations are, in turn, an approximation of the real solution to the PDEs. The finite element method (FEM) is used to compute such approximations.

The last method we will study is by far the most commonly used method in numerical analysis. This method is referred to as finite element method (FEM). It was originally developed for solving problems in solid-state mechanics (plate-bending problems to be more precise), but it has since found wide application in all areas of computational physics and engineering, as well as in CFD. FEM is by far the most flexible method of all methods we have studied so far, and it can be adapted to a wide range of numerical problems. This makes FEM a universal tool for solving differential equations numerically [13].

The basic concept of FEM can be thought of as splitting the computational domain into individual small patches and finding local solutions that satisfy the differential equation within the boundary of this patch. By stitching the individual solutions on these patches back together, a global solution can be obtained.

V. PROPOSED METHODOLOGY FOR STRETCH DEFORMATION-ANOVA

"A common approach to figure out a reliable treatment method would be to analyse the days it took the patients to

be cured. We can use a statistical technique which can compare these three treatment samples and depict how different these samples are from one another. Such a technique, which compares the samples on the basis of their means, is called ANOVA [14-15].

Analysis of variance (ANOVA) is a statistical technique that is used to check if the means of two or more groups are significantly different from each other. ANOVA checks the impact of one or more factors by comparing the means of different samples.

Analysis of variance (ANOVA) is an analysis tool used in statistics that splits an observed aggregate variability found inside a data set into two parts: systematic factors and random factors. The systematic factors have a statistical influence on the given data set, while the random factors do not. Analysts use the ANOVA test to determine the influence that independent variables have on the dependent variable in a regression study.

The t- and z-test methods developed in the 20th century were used for statistical analysis until 1918, when Ronald Fisher created the analysis of variance method.[12] ANOVA is also called the Fisher analysis of variance, and it is the extension of the t- and z-tests. The term became well-known in 1925, after appearing in Fisher's book, "Statistical Methods for Research Workers."[3] It was employed in experimental psychology and later expanded to subjects that were more complex.

Analysis of variance (**ANOVA**) is a collection of statistical models and their associated estimation procedures (such as the "variation" among and between groups) used to analyze the differences among group means in a sample. ANOVA was developed by the statistician Ronald Fisher. The ANOVA is based on the law of total variance, where the observed variance in a particular variable is partitioned into components attributable to different sources of variation. In its simplest form, ANOVA provides a statistical test of whether two or more population means are equal, and therefore generalizes the t-test beyond two means.

Analysis of Variance (ANOVA) is a parametric statistical technique used to compare datasets. This technique was invented by R.A. Fisher, and is thus often referred to as Fisher's ANOVA, as well. It is similar in application to techniques such as t-test and z-test, in that it is used to compare means and the relative variance between them. However, analysis of variance (ANOVA) is best applied where more than 2 populations or samples are meant to be compared.

Statistics Solutions is the country's leader in Analysis of Variance (ANOVA) and dissertation statistics. The use of this parametric statistical technique involves certain key assumptions, including the following:

1. Independence of case:
Independence of case assumption means that the case of the dependent variable should be independent or the sample should be selected randomly. There should not be any pattern in the selection of the sample.

2. Normality:
Distribution of each group should be normal. The Kolmogorov-Smirnov or the Shapiro-Wilk test may be used to confirm normality of the group.

3. Homogeneity:
Homogeneity means variance between the groups should be the same. Levene's test is used to test the homogeneity between groups. If particular data follows the above assumptions, then the analysis of variance (ANOVA) is the best technique to compare the means of two, or more, populations".

VI. RESULT AND ANALYSIS

"CATIA is the product design software developed and created by Dassault Systemes. This is a multinational software company based in France. It is a globally and widely used software that delivers 3D design, Computer-aided engineering solutions, PLM, and Computer-aided manufacturing solutions. The software is commonly used in manufacturing industries and Original Equipment Manufacturers (OEMs) to increase designing, analyzing, and managing new products.

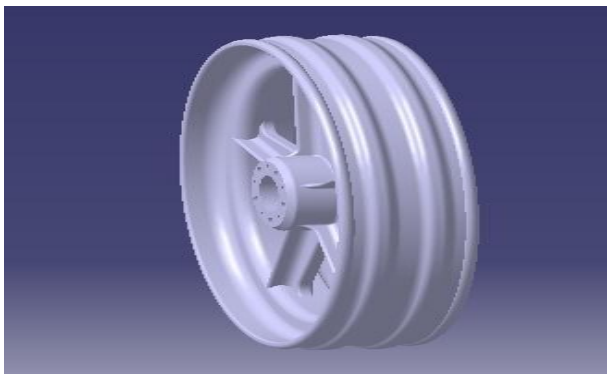

Fig 1. View allocation.

- Regularly alluded to as 3D Product Lifecycle Management programming suite, CATIA bolsters different phases of item advancement (CAx), from conceptualization, plan (CAD), fabricating (CAM), and building (CAE). CATIA encourages community building crosswise over controls, including surfacing and shape outline, mechanical designing, hardware and frameworks designing.
- CATIA gives a suite of surfacing, figuring out, and perception answers for make, adjust, and approve complex imaginative shapes. From subdivision, styling, and Class A surfaces to mechanical useful surfaces.

- CATIA empowers the making of 3D sections, from 3D outlines, sheet metal, composites, and shaped, manufactured or tooling parts up to the meaning of mechanical congregations. It gives devices to finish item definition, including useful resiliences, and in addition kinematics definition.

1. Anova Optimization:

Table 1. Stretch and Aspect Ratio.

Stretch	Aspect Ratio
99.89	83.72
0.11	16.28
0	0
0.208	5.341
0.584	2.067

Table 2. Summary output.

SUMMARY OUTPUT	
Regression Statistics	
Multiple R	0.979869
R Square	0.960143
Adjusted R Square	0.710143
Standard Error	9.971269
Observations	5

Table 3. ANOVA Residual.

ANOVA

	df	SS
Regression	1	9580.704
Residual	4	397.7048
Total	5	9978.409

	Coefficients	Standard Error	Lower 95.0%	Upper 95.0%
Intercept	0	#N/A	#N/A	#N/A
Aspect Ratio	1.145072	0.11665	0.8212	1.468944

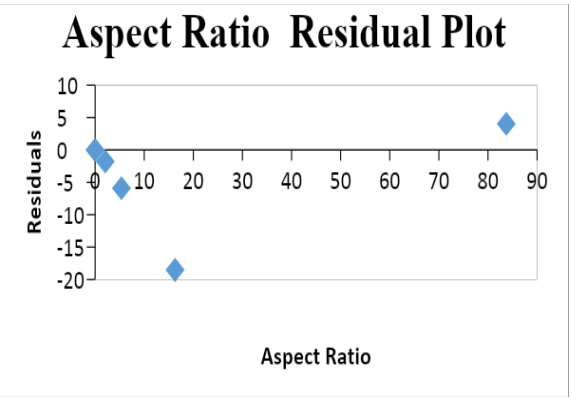

Fig 2. Aspect Ratio Residual Plot.

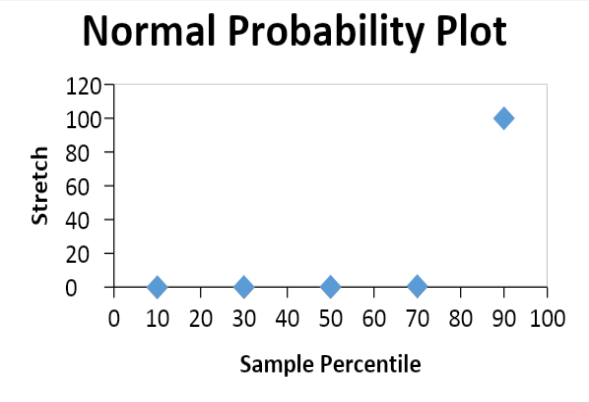

Fig 3. Normal Probability Plot.

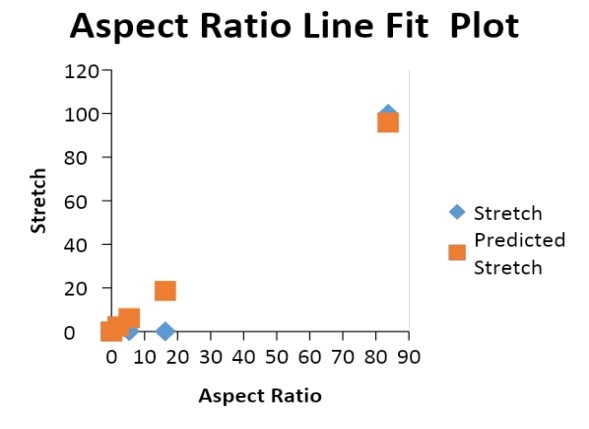

Fig 4. Aspect Ratio Line Fit Plot.

Table 4. Probability output.

PROBABILITY OUTPUT	
Percentile	Stretch
10	0
30	0.11
50	0.208
70	0.584
90	99.89

VII. CONCLUSION AND FUTURE

In order to improve the ride comfort and reduce the weight of automotive vehicles, we designed a magnesium alloy wheel based on structural optimization and dynamic impact performance. In summary of the detailed research, the results of the simulations and experiments led to the following conclusions:

Study of the damping properties of the materials showed favorable damping properties for the magnesium alloy material. Based on the findings of structural optimization and dynamic impact theory, magnesium alloy wheels were designed and manufactured. Compared with the aluminum alloy wheel, the magnesium alloy wheel design can reduce the stress by 99.8.

The designed wheels meet the lightweight requirements in comparison with aluminum wheels, which is expected to increase ride comfort by reducing vibrations.

Damping test methods for the magnesium alloy sample were designed to obtain the damping performance parameters of the magnesium alloy material. Finite element analysis models of the magnesium alloy wheels were established with certain boundary conditions and constraints. The applicability of the model was verified by the free modal experiments on the wheel. Dynamic impact simulation analysis of the designed wheels was carried out, and the dynamic speed response of magnesium alloy wheels under the impact of a dynamic load on the road surface was obtained.

By defining the structural parameters of the magnesium alloy wheel and taking the acceleration and shock response of the wheel as the output, structural design optimization of the wheel was carried out to obtain the optimal magnesium alloy wheel structural parameters. The target of lightweight and high dynamic impact performance magnesium alloy wheels was achieved through optimization.

Our study opens avenues for the next generation of wheel design. This technique can be applied to a multitude of machine components to enhance various structure vibration performance values. We believe that our analysis can also be used to enhance the response of vibration reduction and lightweight wheel design. We hope that our results will instigate a resurgence of interest in the application of damping material for wheels and motivate future exploration of the effect of other types of structures on wheel vibration behavior.

VIII. FUTURE SCOPE

In future we will analyze the performance of this two wheeler rim by varying the material or modifying the current design of wheel rim includes reducing the number of spokes, modifying the fillet radius at the intersection of the spoke and the hub in the present design and that modified design will be analyzed and compared under the same loading conditions. We believe this proposed design would anticipate further advances in future.

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