Design and Failure Analysis of Motorcycle MAG Wheel

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ABSTRACT

The Vehicle Wheels have to carry the vehicle load and also provide the comfort to driving. Therefore the wheels have their own importance as far as any automobile is concerned. The wheel spokes also play a supporting role. These are the radial supports connecting the hub to the rim. The motorcycle business in INDIA is under lot of competition and is diversified. The new product development is an important phase of motorcycle companies to remain in competition. The motorcycle business beats around the fuel efficiency of product as one aspect of customer requirement. Strength and its lightness is a new demand to achieve the good fuel economy. In ordered to achievethis,the vehicle weight should be minimum in comparison with competitor's vehicle. The spoke wheel rim assembly contribute the major weight addition in motorcycle after engine. Hence the light spoke wheel rim plays an important role in overall optimised design of vehicle. A vehicle can be towed without and engine but cannot be the same without the wheels. The motorcycle wheel rim haslots of variation depending upon the location and its respective usage. This often leads to complex car design which needs to be produced and proof tested with a minimum lead time and expenditures. But these new designs and manufacturing technologies must be reliable and efficient, thus the automobile manufacturing is increasingly investigating and developing new design tools to help improve the quality of their products. One promising solution is the use of computer aided engineering to produce a new design. It also helps to improve the quality of the design. In this investigation, computer aided design, finite element analysis and fatigue life prediction are the tools which have been used.. The design of the wheel rim has been optimised using the Finite Element Techniques. CATIA software has been used to develop the three-dimensional structural model of the wheel rim

Keywords: ***Automobile, Spokes, Computer Aided Design, Finite Element Analysis, Fatigue life etc.***

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1. INTRODUCTION

In a vehicle every component is important but some are more critical than others. Components which may fail but will not cause fatal accidents are not catastrophic in failure. The car electrics are an example of this. Wheel, Brakes, Steering or Tyre failure on the other hand, can cause catastrophic accidents is failure. Road wheels are one of the most important safety components from a structural point of view. The wheel is a device that enables efficient movement of an object across a surface. Earlier wheels rims were simple wooden disks with a hole for the axle.

Alloy wheels are wheels that are made from an alloy of aluminium or magnesium. They provide greater strength over pure metals, which are usually much softer and more ductile. Alloys of aluminium or magnesium are typically lighter for the same strength, provide better heat conduction and after produce improved cosmetic appearance over steel wheels. Lighter wheels can improve handling by reducing the spring mass, allowing suspension to follow the terrain more closely and thus improve grip, however not all alloy wheels are lighter than this steel equivalents. Reduction in overall vehicle mass can also help to reduce fuel consumption. This means that it has become necessary to perform more rigorous strength evaluations on new wheel designs. Alloy wheels are prone to galvanic corrosion, which can cause the tyres to leak air if appropriate preventive measures are not taken.

From a design engineer point of view a new or innovative design is a real challenge. In automobile industry, when a new versions of existing vehicle is launched most of the components are quite similar to existing one (scaled proportionately). Innovative kinds of components are not more than 15%. Later the CAE engineer has to sit with design and test engineer to decide

the boundary conditions and then run the analysis. Real work starts only when the Prototype is prepared and test and FEA result correlation process is initialized. After achieving correlation various permutations and combinations could be carried out to make the product better and optimum from cost as well as design point of view.

2. METHODOLOGY

The motorcycle business in INDIA is very big, competitive and diversified. The new product development is very crucial as it determines the position of the organization in the competition. Parts light in weight, stronger and having well aesthetic looks are important and are in demand today. And hence attractive shapes and styling is also given equal importance.

1.1 Profile Evaluation

We gathered the design geometry and specification from actual solid rims. The Surface profile of the outer rims surfaces was obtained from counter tracer device and the vernire callipers. We took rims of Passion Pro, Hero Extreme, KTM Duke, Pulsar As and Rs as the reference rims for our project. The various profiles obtained from the counter tracer are as shown in the following figures.

Profiles of Passion pro rim and Duke rim were taken initially with the help of counter tracer and the remaining profiles were based on the two rims. The spokes section and measurement was done with the help of Vernier Calliper.

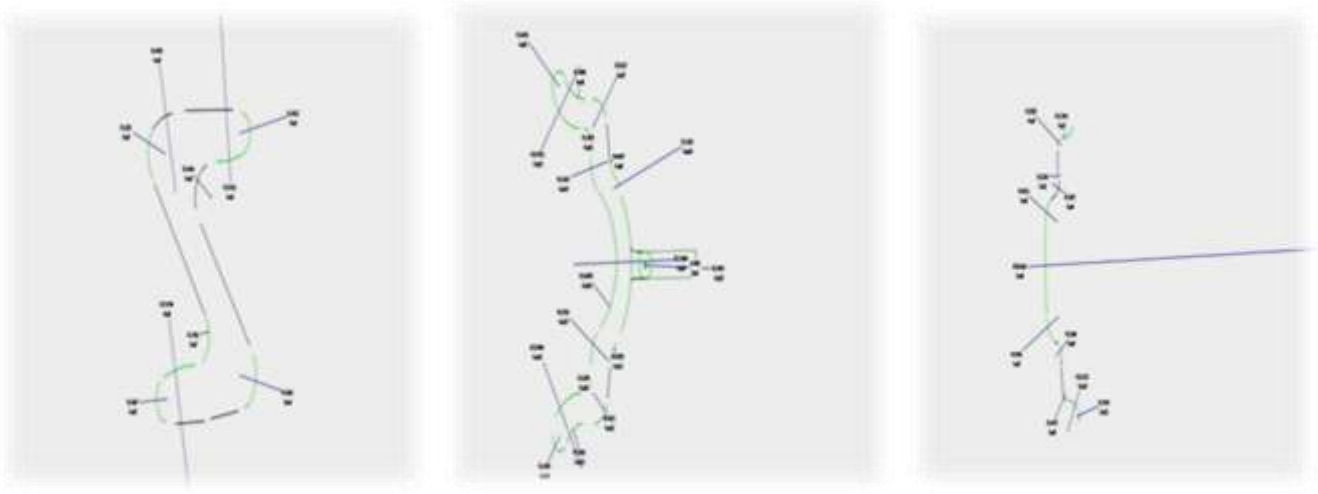

Fig-1: Spoke and Rim profiles

The profiles were taken from the counter tracer to maintain close agreement between the design and actual model. The complex rim profile consisted of many radii and irregular sections. Modelling is done by taking these profile specifications as reference.

2.2 Modelling

Modelling of the rims and spokes was done in CATIA V5 software. During modelling, the multi-section solid operation was used for the modelling of the spokes as they had varying cross sections. The surface was done with the help of shaft command.

The procedure for modelling is as follows:

1. Firstly part modelling was chosen in CATIA V5 Software.
2. In part modelling, sketching was done using the sketcher option for exact profile.
3. The Hub of the rim was created using the PAD command with given radius and thickness.
4. By offsetting one of the planes, base for spoke creation was created. The spoke profile was drawn on the given plane.
5. As we can see from the profile, it is complex and consists of multi sections. By using the multi section command the exact profile of the spoke was created and then extruded by using the PAD command.
6. The above procedure was adopted to design one of the spokes. The remaining spokes were created with the help of circular pattern command.
7. For RIM design, Shaft command was used. The profile of rim is as shown in the figure below. By using shaft command, entire RIM was created.
8. Necessary fillets were given so as to get better results at the stress concentration areas.
9.

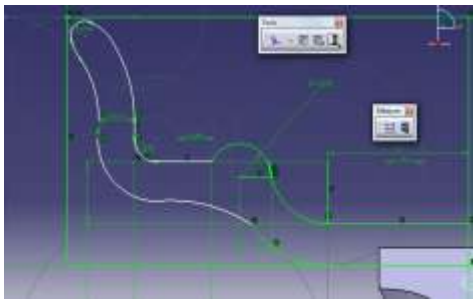

Fig-2: Rim Sketch in CATIA V5

The Modelled Rims of passion pro (5 and 6 spoke), KTM Duke and Hero Extreme respectively are as shown in the following figures

Fig-3: Modelled Rims CATIA V5

3. ANALYSIS

FEA is gaining popularity day by day and is a sought after dream career for mechanical engineers. Enthusiastic engineers and managers who want to refresh or update the knowledge on FEA are encountered with volumes of published books.

There are three methods to solve any FEA problem. These are : Analytical, numerical and experimental.
In our project we have done analysis using Numerical method.

3.1 Numerical Method

The characteristics of Numerical Method are: Mathematical representation, approximate assumptions, applicable even if physical prototype not available, real life complicated problems can be solved. Results obtained are verified by experimental methods or by hand calculations.

The different Numerical Methods are:

3.1.1Finite Element Method

FEMis the most popular numerical method. Applications of FEM are: Linear, Non-Linear, Buckling, Thermal,Dynamic and Fatigue analysis. FEM is also known as FEA (Finite Element Analysis), FMEA (Failure Mode Effect Analysis).

3.1.2Boundary Element Method

BEM is a very powerful and different technique to solve acoustics or NVH problems. Similar to FEM it requires nodes and elements but as the name suggests only the outer boundary of the domain is considered.

3.1.3Finite Volume Method

FVM is a method in which Volume is considered as a key factor (similar to element in FEM). Variable properties at the nodes such as pressure, area, mass are considered. It is based on Navier-Stokes equation.

3.1.3Finite Difference Method

FDM is a method for solving differential equations. It uses Taylor's series to convert differential equation to algebraic equation. It is used in combination of BEM or FVM to solve thermal and CFD coupled problems.

3.2 Analysis Procedure

Linear Static analysis, Modal analysis and Fatigue analysis was carried out on different types of rims. For design and material optimization point of view, we have compared rims of Passion Pro for different number of spokes and by using different types of materials. Following are the materials used and their respective properties:

3.2.1 Material Properties

Material	Young's Modulus E (Mpa)	Poisson's Ratio	Yield Strength (Mpa)
Structural Steel	2.1e5	0.3	250
Aluminium Alloy	71000	0.33	280
Magnesium Alloy	45000	0.35	193

Table-2: Material Properties

3.3.1 Meshing and Load application

Basic theme of FEA is to make calculations at only limited number of points and then interpolate the results for entire domain (surface or volume). There are basically 3 types of elements in FEA meshing: 1D, 2D, 3D elements. For our project we have used 3D element as in the models all the dimensions are comparable. Element shape used is: tetra, penta and hex. Element type is solid. Due to time and space constraints Auto mesh was employed. At the edges where region of stress concentration exists, number of divisions of meshing was increased by applying the bias factor.

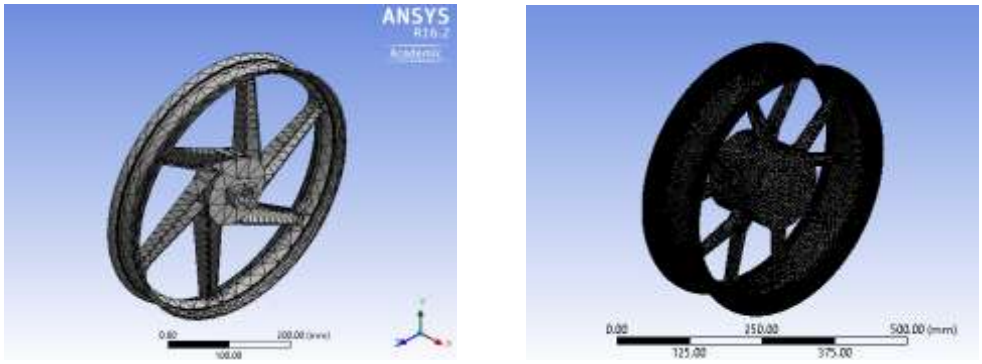

Fig-4: Meshing of models in Ansys 16

The Loads calculated are applied as shown. The hub and shaft part mating region is **FIXED**.

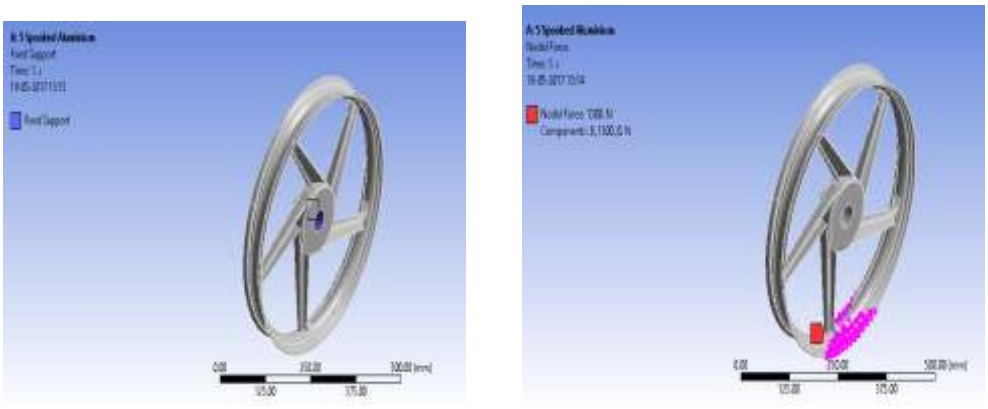

Fig-5: Applying Structural Loads

3.3.2 Comparison of Results

5- Spooked Rim 6- Spooked Rim

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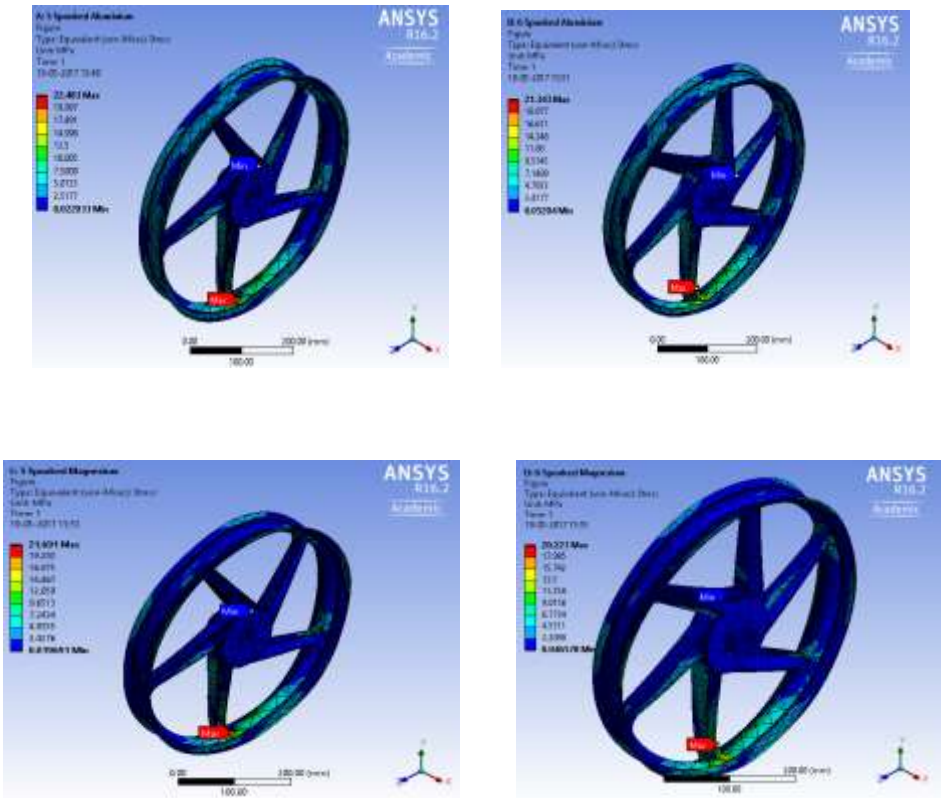

Fig-6: Rims under stress

Material	Equivalent Stress (Max.)Mpa (5 spooked Rim)	Equivalent Stress (Max.)Mpa (6 spooked Rim)	Deformation (Max.)mm (5 spooked Rim)	Deformation (Max.)mm (6 spooked Rim)
Structural Steel	24.866	23.922	0.044	0.045
Aluminium Alloy	22.483	21.343	0.110	0.121
Magnesium Alloy	21.691	20.277	0.178	0.180

Table-3: Analysis Results

MODAL ANALYSIS

Modal Analysis was carried out in order to determine the natural frequency and mode shapes of vibration .

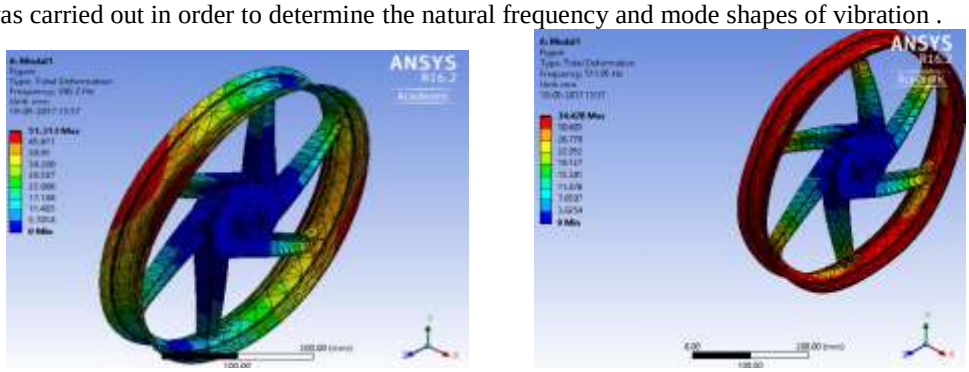

Fig-7: Modal Analysis

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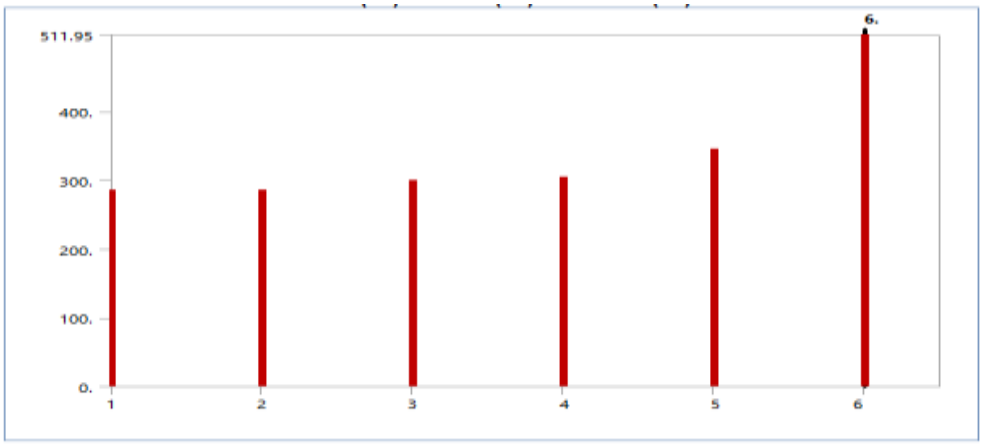

Fig-8: Graphical representation of Modal analysis

4. CONCLUSION

Maximum and Minimum Von mises stresses were calculated for the static load case which represent the working load-condition. The mechanism of load transfer from the wheel rim was studied in detail and suggestions were made to how to optimise the FEM's model load cases. It was found that the wheels stress level in the critical areas was below the materials allowable fatigue stress level. Finally, a procedure for the fatigue stress level prediction of the wheel was developed to verify that the actual lifetime of the wheel was greater than, or at least equal to the required lifetime.