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Design Optimization of a Motorcycle Rim, Material Selection and Comparison

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Abstract - *The purpose of this study was to design and analyze the loading of the modified rim strength on the motorcycle. The method used is to use SolidWorks software, loading simulation analysis performed with variations of the rim model and dimensions. Wheel spokes are the supports consisting of a radial member of a wheel joining the hub to the rim with Chrome, Magnesium Alloy, Titanium Alloy and Aluminum Alloy. This study helps us to understand and estimate the stress, factor of safety and displacement of the designed Y-spoke rim. The dimensions were varied from 10mm to 30mm (in increments of 5mm) taken by trial and error method and the number of spokes was varied from 3 to 6. The obtained results were satisfactory and were up to the safety standards of the industry. In comparison with the other models of the rim, the load-bearing capacity of our Y spoke design was satisfactory.*

Key Words: Rim, Motorcycle, Solidworks, Stress analysis, Factor of Safety (FOS).

1. INTRODUCTION

A wheel is a circular device that is capable of rotating on its axis, allowing movement or transportation while supporting a load or mass. A wheel is one of the important parts of any vehicle. The safety aspect is very important to be taken into account in the automobile industry as it involves the lives of passengers. In the automotive field, there have been many accidents caused by plastic deformed (Failure) rims. Rim is the frame of a tire that holds the force and stress due to the weight of the vehicle and the impact from various road conditions. To prevent any accidents due to the failure or deformation of the rim we have carefully considered and increased the safety of the rim. Even the slightest modification will change the load acting on the rim and cause the failure of the structure, hence we need to keep the rim structure as strong and solid as possible. Rims are manufactured in the following ways: Casting, Forging, rolled forging, Die Casting, Welding, Multi-piece rim (assembly). The fastest and the easiest way of manufacturing a rim is by casting. Most of the rims are manufactured by casting.

Structural optimization of various components of automobiles has shown that vehicle performance is greatly affected by components weight, because of the understanding of wheels contribution to the overall vehicle performance, this topic is chosen for the research by the author. To get the best quality of the rim structure various materials and dimensions were checked using the simulation tools. The stress plot, strain plot, deformation plot and the factor of safety plot are shown in this paper.

Sourav Das et.al [2] conducted mass optimization of an aluminium alloy wheel. In this paper, 3 types of loading were used viz. radial load, lateral load and bending load. Radial load due to the weight of the automobile was applied on the rim uniformly as a sector of 36°. Priyanka Abijit Dani et.al [1] investigated the stress concentration on three-spoke pattern with three different materials. Single load was considered in this study, radial force due to tire pressure.

V. Cossalter et.al [3] addresses the decomposition of the motorcycle steering torque in its main components. Influence of the torque on the motorcycle was investigated. So, torque load is also considered in this current study.

2. GEOMETRY

The design parameters are selected based on the standard dimensions of rims used in different bikes. The model includes all the different parts of the rim with different dimensions. The dimensions of the initial design and the part names are shown in the following table (table 1).

Table -1: Dimensions of the initial rim design

Sl. No	Parameters	Dimensions (mm)
1	Hub Diameter (Inner)	80
2	Hub Diameter (Outer)	120
3	Pitch Circle Diameter	400
4	Rim Diameter	460
5	Rim Width	159
6	Rim Thickness	20
7	No. of Spokes	5

The 2-dimensional sketch of the rim structure is shown in figure 1 with all the required dimensions in mm. Figure 1 shows the central hub of the rim at the bottom and the outer part of the rim in the top. The L-shaped curves on the top of the figure are present to accommodate the tire and to prevent the loss of air pressure from the inside of the tire.

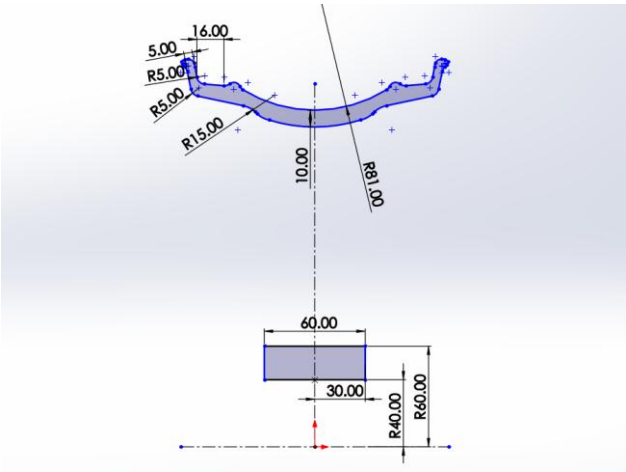

Fig -1: a 2-D sketch of rim structure

The Y spoke design is made to keep more surface of contact on the outer part of the rim and less contact surface on the hub. The dimensions of the solid Y spoke are based on a few different models of bike rim. The angle between the 'V' in the 'Y' is 90° and the remaining part connecting to the hub of the wheel is tapered. Figure 2 gives a better understanding of the dimensions.

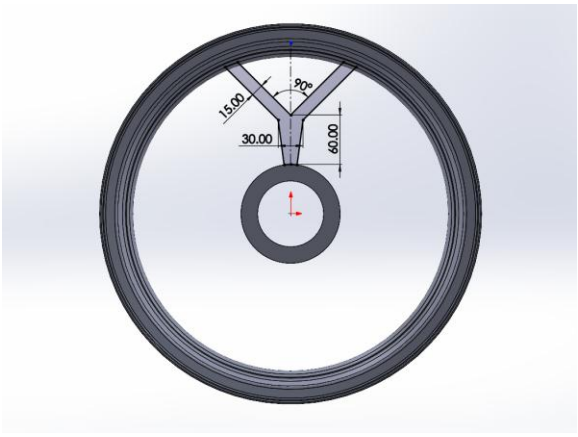

Fig -2: Solid Y spoke design

The selection of the solid Y spoke design was made considering the strength and load-bearing capacity of the design. All the sharp edges and sharp contact points are removed by fillets. The reason behind the addition of fillets is to decrease the stress concentration on the design and to add an aesthetic look to the rim. The initial design of the study can be observed in figure 3.

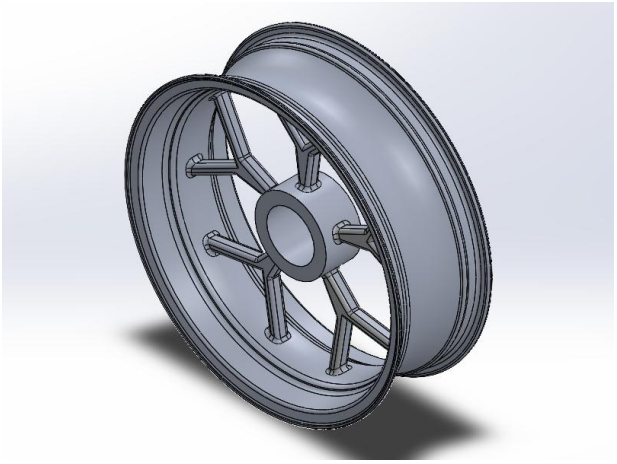

Fig 3: Isometric view of the designed rim

3. ANALYSIS SETUP

The finite element method (FEM) is the most widely used method for solving problems of engineering and mathematical models. To solve a problem, the FEM subdivides a large system into smaller parts which are called finite elements. This process is called meshing.

The figure below (fig 4) shows the fine mesh done in Solidworks by maintaining a small element size. A fine mesh is necessary to obtain accurate simulation results.

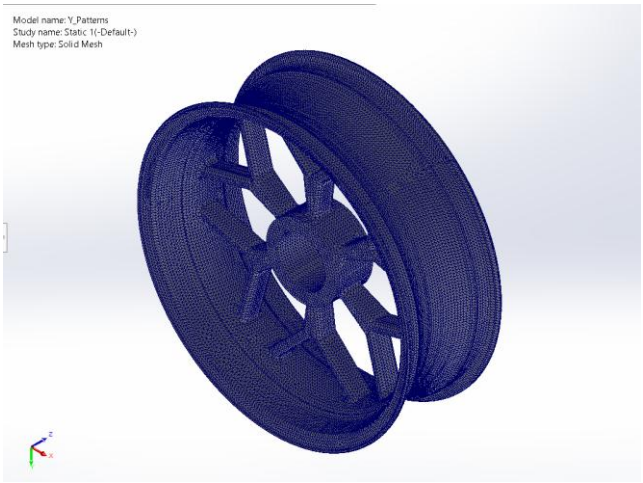

Fig 4: Meshed rim

The surface of the centre hub of the rim is used as a fixture which can be seen in figure 5. The fixture is represented with green arrows.

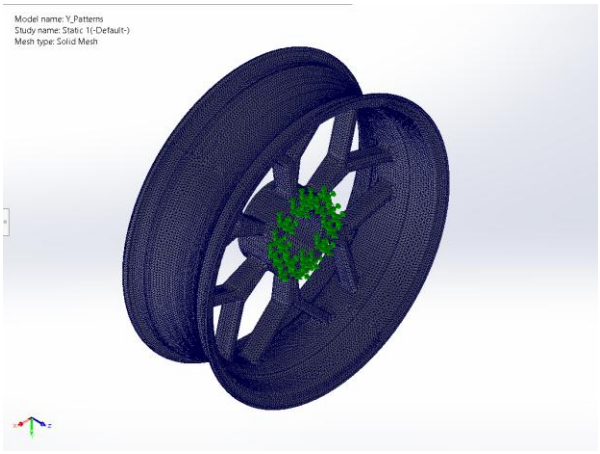

Fig 5: Meshed rim with the hub as a fixture

After meshing and adding a fixture we need to apply load on the component. Figure 6 indicates the different types of loads acting on the rim. The red colour arrow on the centre of the wheel hub indicates the direction of the gravity. The yellow colour arrow indicates the pressure of the tyre which is acting on the rim. The violet colour arrow points out the direction of the torque acting on the rim. This torque represents acceleration or braking effects. All these loads will be acting on a rim on any motorcycle. The values of the loads are given in table 2.

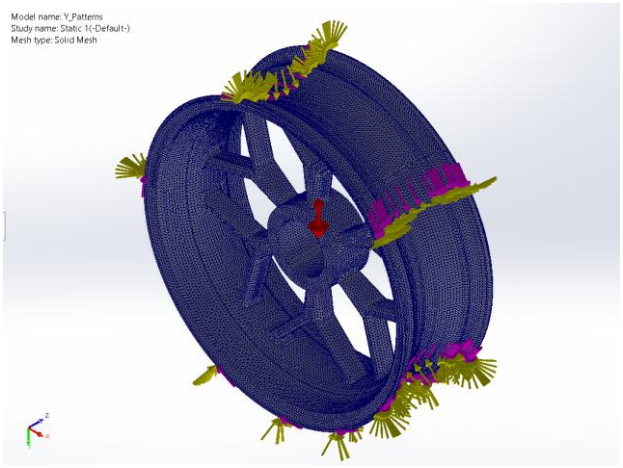

Fig 6: Loads acting on the rim

The force due to mass of the motorcycle and passengers acts on the wheels but not uniformly. In [2] S. Chaitanya, load considered to be acting on a section of the rim. Therefore, force is applied on the rim with a sector with an angle of 36° [2]. The value for all the loads acting on the wheel was obtained from the literature review and considering real-world scenarios, given in Table 3.

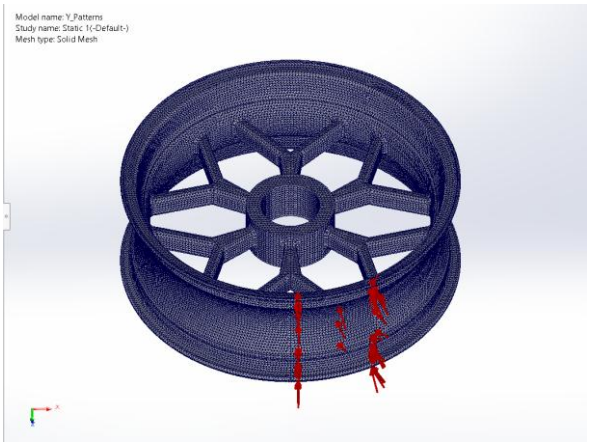

Fig 7: Point load distribution to the rim

Table 2: Loading conditions of all the rims

Sl. No	Loading	Specification
1	Fixture	Centre hub of the rim
2	Pressure (along the entire rim)	32 Psi
3	Torque (along the entire rim)	59 Nm
4	Force (along 36° angle)	1400 N

4. DESIGN STUDY

4.1 Varying Design Parameters

The design parameters were varied are dimensions of the Y spoke which is thickness and number of spokes of the rim. In table 3, the ranges of the varied parameters are given.

Table 3: Design variation

Sl. No	Design parameter	Range (increment)
1	Spoke Thickness	10mm to 30mm (5mm)
2	No. of Spokes	3 to 6 (1)

Table 4: Table of the properties of the four chosen material between design parameters, materials and some currently used rim shapes.

Property	Al-7075-T6	Mg-ZK60A	Ti-6Al-4V	Chrome SS
Density (kg/m3)	2810	1830	4428.784	7800
Young's Modulus (Psi)	10.4×10^6	6.5×10^6	15.2×10^6	29×10^6
Poisson's Ratio	0.33	0.35	0.31	0.28
Shear Modulus (Psi)	3.9×10^6	2.4×10^6	5.9×10^6	11.1×10^6
Yield Strength (Psi)	0.7×10^5	0.44×10^5	1.2×10^5	0.25×10^5
Tensile Strength (Psi)	0.82×10^5	0.52×10^5	1.5×10^5	0.6×10^5

4.2 Material Selection

Aluminium 7075-T6 alloy, Magnesium ZK60A alloy, Titanium alloy (Ti-6Al-4V) and Chrome Stainless Steel were chosen as they are the common materials used in the construction of wheel rim. Properties of these materials are given in table 4.

4.3 Comparison with Standard Rims

The comparison was done with two of the popular motorcycle rim models. The models of Kawasaki Ninja and Honda CB 750 motorcycles were taken to compare with our Y spoke model to check if the design was up to the industrial standards and the safety norms. The dimensions of the rims are the same as the actual model. The same material has been selected for every model which is aluminium alloy.

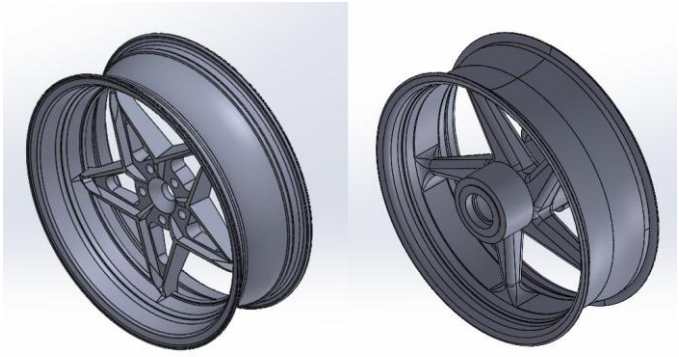

Fig 8: Rim models of Kawasaki Ninja and Honda CB 750

5. RESULTS

The report of the minimum factor of safety, maximum stress and maximum displacement have been presented graphically. This representation aid in comparing the results

5.1 Design variation

By varying the dimensions and the number of spokes of the rim the following plots were obtained which can be seen in fig 9,10,11. The various plots obtained are between the thickness of the Y spoke and the FOS, stress and displacement of the rim for the varying number of spokes. The obtained results were meeting the safety standards.

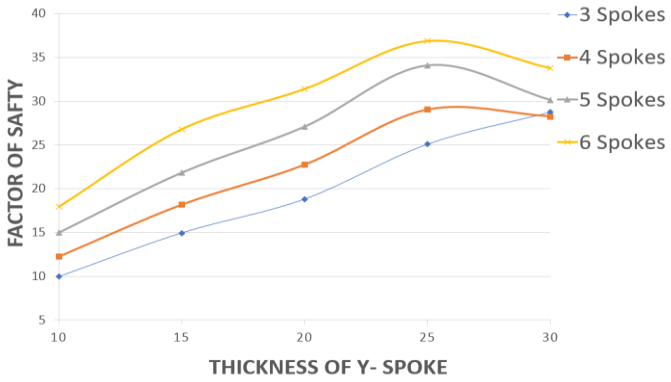

Chart 9: Thickness of Y spoke vs FOS

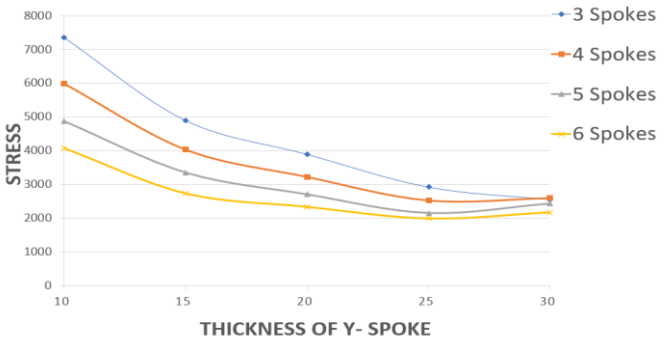

Chart 10: Thickness of Y spoke vs Stress (Psi)

From figure 9 and 10, the maximum factor of safety and minimum stress is at 25mm thickness and 6 spokes. While the lowest displacement is at 30mm thickness and 6 spokes, the difference is insignificant. Therefore, the optimal design is 6 Y spokes with 25mm of thickness.

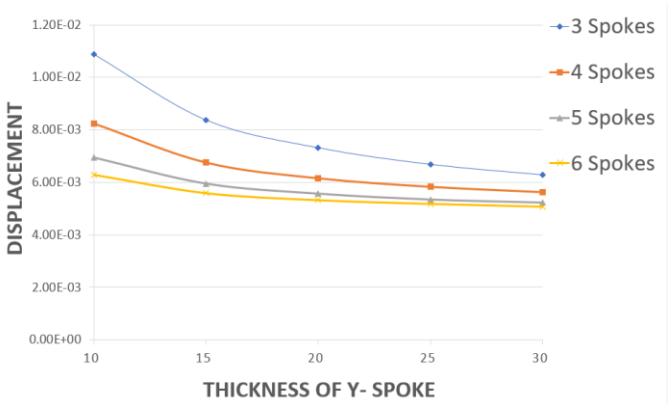

Chart 11: Thickness of Y spoke vs displacement

5.2 Material Selection

By running tests on the 25mm thick 6 spoke model with different materials, the best material for the model was identified as Al-7075-T6. Even though the performance for titanium alloy was good the cost was very high. The feasibility to use the material was not so satisfactory, hence the material was not the perfect choice for the modelled rim. Therefore, by considering all the factors, the best material selection for the modelled rim would be the aluminium alloy (Al-7075-T6).

Table 4: Comparison with different materials

Material	Al-7075-T6	Mg-ZK60A	Ti-6Al-4V	Chrome SS
Stress (psi)	1972.1	1982.6	1960.2	1938.6
Strain ($\times 10^{-4}$)	1.38	2.25	0.93	0.48
Displacement (mm)	0.0518	0.0834	0.0355	0.0184
Factor of Safety	37.14	22.31	61.21	12.89

5.3 Comparison with Standard Rims

The table below shows the results obtained after the comparison of the modelled rim with both the motorcycle rim models. The plots below will show the stress concentration on each of the 3 models of the rims.

Table 5: Comparison with Standard models

Rim Design / Parameters	Y Spoke Design	Kawasaki Ninja	Honda CB 750
Stress (psi)	1972.5	3053	1846.3
Strain ($\times 10^{-4}$)	1.38	2.438	1.435
Displacement (mm)	0.0518	0.0617	0.0515
Factor of Safety	37.14	23.99	39.66

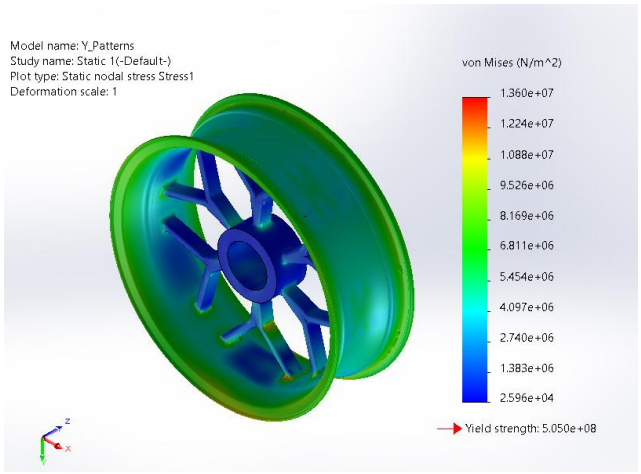

Fig 12: Stress concentration on Y spoke model

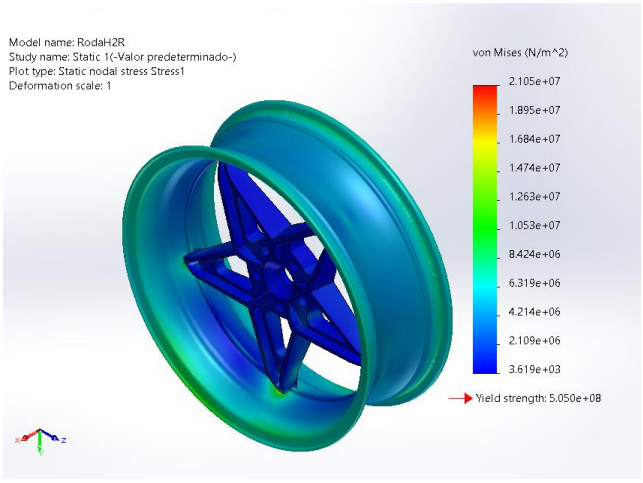

Fig 13: Stress concentration on Kawasaki ninja model

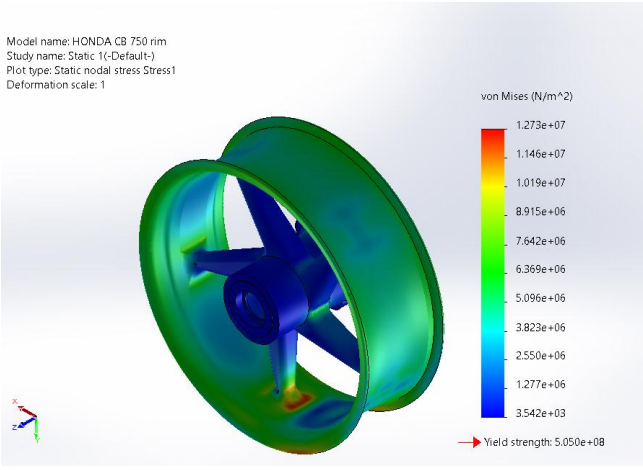

Fig 14: Stress concentration on Honda CB 750 model

6. CONCLUSIONS

A comparative study of different spoke number, dimensions of Y spoke, materials and comparison with standard models have been carried out. The evaluation report in terms of stress, strain and displacement is generated and presented.

1. The regions of stress concentration on individual models have been identified.
2. The best results for dimensions of the Y spoke were for 25mm thickness with 6 number of spokes.
3. The best material to be used is Al-7075-T6 after considering all the factors.

In comparison with the other models of the rim, the load-bearing capacity of our Y spoke design was satisfactory

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