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Design and optimization of Aluminium alloy wheel used in automobiles

Lakhan Suryawanshi
lakhansuryawanshi96@gmail.com
Sinhgad Institute of Technology, Lonavala, Maharashtra

Gaikwad S. M.
hodmech.sit@sinhgad.edu
Sinhgad Institute of Technology, Lonavala, Maharashtra

Kulkarni P. D.
pdkulkarni.sit@sinhgad.edu
Sinhgad Institute of Technology, Lonavala, Maharashtra

ABSTRACT

Wheels are the main component of the car. The wheels with the tyre provide the better cushioning effect to the car without engine car may be towed but without wheels car cannot be towed. The amin requirement of the vehicle are it must be perfect to perform its all function. Reverse engineering is not method to redesign the old component. The wheels have to pass different test for best performance like static and vibration analysis etc. design is an important manufacturing activity which provide the quality of the product the 3-D model of alloy wheel design using the technology reverse engineering and CATIA V5 software and further it was imported to ANSYS. The static fatigue and dynamic analysis were performed. This was constrained in all degree of freedom at the bolt. Similarly based on the weight, the thickness of the rim and spoke are varied to attain different mos. Also changing the number of spoke wheel model is prepared and analysis is done. From the analysis done in the project, it can be concluded that the wheel made of magnesium alloy are better as compared to Al alloy1 wheels. As the stresses developed in the magnesium wheel are less as well1 as the S-N1 curve of Mg wheel is better under load condition.

Keyword**—** *Alloy wheel, CATIA V5, ANSYS, Stress Analysis, Reverse Engineering*

1. INTRODUCTION

1.1 Function of The Wheel

The wheel is a critical component in the automobile and bears the weight of the car as well as helps the tire to maintain contact between the car and the road. The wheel is exposed to very hazardous environmental conditions. For high and optimal performance, the wheel is designed to meet some safety and engineering criteria. The wheel should be able to withstand the impact of shock and vibrations and be able to bear the weight of the car and the passengers; it should be light in weight but highly durable.

1.2 Failures Experienced by Wheel Rim

Common causes of wheel rim failure are listed below:

- Misuse or Abuse
- Assembly errors
- Manufacturing defects
- Improper maintenance
- Fastener failure
- Design errors
- Improper material
- Improper heat treatments
- Unforeseen operating conditions
- Inadequate quality assurance
- Inadequate environmental protection/control
- Casting discontinuities

2. PROBLEM STATEMENT

2.1 Background

There are significant and addressable advantages moving towards lightweight wheels, the first and the foremost thing being the fuel economy of the vehicle, reduced vehicle un-sprung mass, reduced driver fatigue and from the view of the manufacturer – reduced raw material consumption and reduced cost play a significant role. Data from the field showed that the majority of the failures occur at the nave region of the wheel than the regions near vent holes and other areas. This study focuses on Design change implementation in the region identified to have failure and reduce the material in the regions having lower stress values. This project focuses on the Finite Element Analysis (FEA) of a new design wheel that has increased thickness at the region identified to have higher stress and gradual reduction of material thickness at lower stressed regions.

Table 1: Design Inputs

Specification	Existing Design	New Design Requirements
Wheel Size	Same as existing	Same as existing
Rim Thickness in mm	6	Optional
Rim Material	Rst 37-2	Optional
Bolt hole Numbers	8	Same as existing
Vent hole Numbers	8	Same as existing
Total Ventilation Area in cm^2	144	Minimum 144
Disc Thickness in mm	11	Optional
Disc Material	Yst 38	Yst 38
Wheel Offset	134	134
Wheel Load in Kg	3000	Same as existing
Wheel Weight in Kg	42.4	Target 36

3. OPTIMIZATION OF WHEEL RIM BY FEM:

3.1 Cornering Fatigue Simulations:

3.1.1 Objective: To simulate the cornering effect through FEA and compare the stresses for different loads.

3.1.2 Bending Moment Calculation

$$BM = (R.\ \mu + D) * F * S$$

Table 2: Bending Movement Calculations.

Wheel Rim Inset– D	0.123 m		
Static Loaded Radius – R	0.486 m		
Co-efficient of friction - µ	0.7		
Acceleration Factor – S	1.1		
Wheel Load – F	2300	2650	3000
Bending Moment – BM in Nm	11495	13244	14994

3.1.3 FEA of New Design

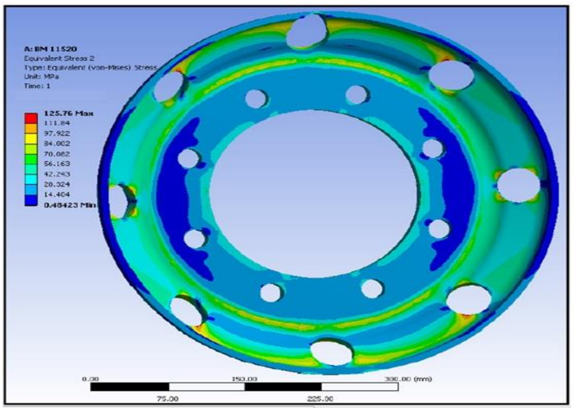


Fig. 1: Stress plot at 2300kg

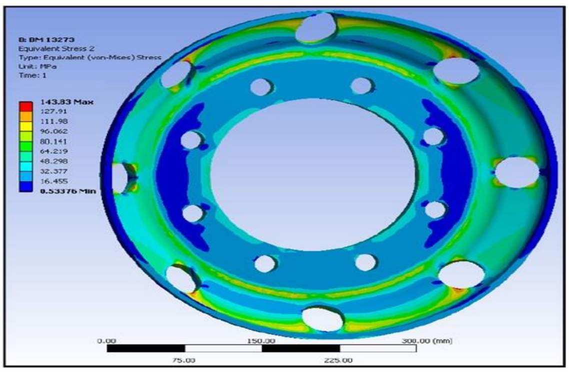


Fig. 2: Stress Plot at 2600 kg

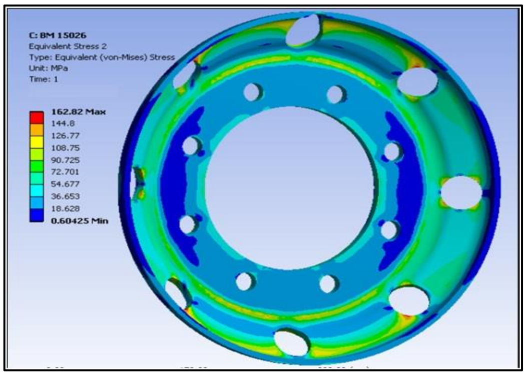


Fig. 3: Stress Plot at 3000 kg

3.1.4 Cornering Fatigue Simulation Results

The following table shows the induced stress values on to the wheel at the regions of interest and maximum stress levels against the material yield strength

Table 3: Comparison of FEA Results

Vonmises stress (Mpa)	2300 kg	2600 kg	3000 kg	Yield strength
Existing design	130	150	170	380
New design	125	143	162	380

3.1.5 Biaxial Fatigue Simulation

The tools of the numeric simulation of the hub/wheel/tire system get completed by LBF Wheel Strength. With interfaces to the world's most used FEM Codes, this software for numeric structural durability analysis of wheels and hubs can be integrated at existing CAE environments and offers efficient features, e.g. physical tire transmission function or the automatic calculation of the required fatigue strength (RFS) for each node of the simulation model.

Objective

To compute the Required Fatigue Strength (RFS) for Existing Design & New Design Wheel with under biaxial Load.

Boundary Condition

Bolt hole considered as rigid.
Pre-stress was not considered.
Thinning was not considered.
Solved and the results are viewed in the post processor.

Input Data

Biaxial Fatigue Simulation Result:

Maximum RFS (MPa) value from simulation					
DISC		VENT HOLE REGION		BOLT HOLE REGION	
UNIFORM DISC THICKNESS	VARIABLE DISC THICKNESS	UNIFORM DISC THICKNESS	VARIABLE DISC THICKNESS	UNIFORM DISC THICKNESS	VARIABLE DISC THICKNESS
120.6	104.9	95.6	83.6	88.6	92.1

Wheel Load in Kg	3000kg
Tyre Size	8.25R20
Inflation Pressure	825 KPa
Design Life	1000000 Km

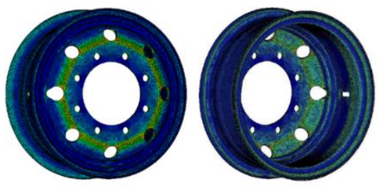


Fig 4.7 (a): Bi-Axial Stress distribution in Uniform thickness Disc design

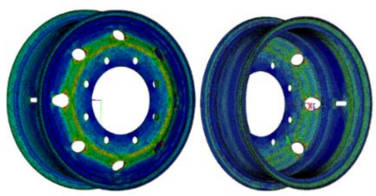
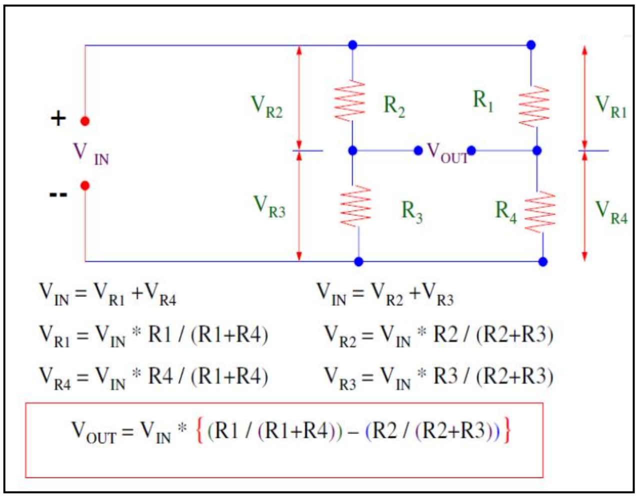


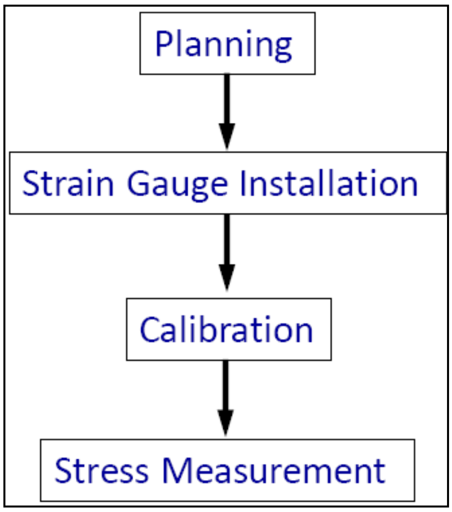
Fig 4.7(b): Bi-Axial Stress distribution in variable Thickness Disc Design

4. EXPERIMENTAL STRESS ANALYSIS

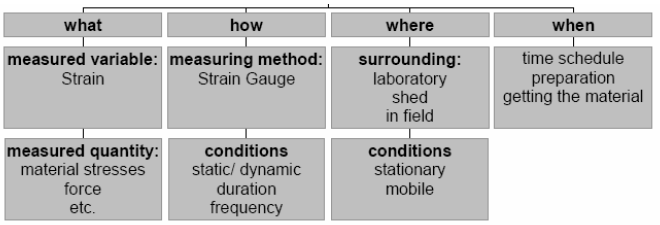
Experimental stress analysis aids in measuring stress occurring in the components / products. This is the direct prerequisite for an optimal design of the components. Strain gauges are the principal measuring instrument used in this context. Strain gauge is an electrical conductor whose resistance change as it is strained. Strain is the elongation ratio of deformed length to the original length. The strain gauge used is of universal general-purpose type (CEA-06-062UW-350).



4.1 Procedure



4.2 Planning



4.3 Stress Result Discussion

MAX. RFS Value (MPa) Comparison						
	DISC		VENT HOLE REGION		BOLT HOLE REGION	
	UNIFORM	VARIABLE	UNIFORM	VARIABLE	UNIFORM	VARIABLE
ESA	117.5	108.8	89.3	79.6	73.2	65.2
FEA	120.6	104.9	95.6	83.6	88.6	92.1

From the results of ESA & FEA, it was observed that the RFS value of the Wheel with the variable thickness (VT) disc design would perform as intended and will further facilitate increased loading application. From all the major peaks stress region it is revealed that the proposed design has RFS value much lower than their endurance limit.

5. CONCLUSION

The stress values for the wheel with the variable thickness disc design were much lower (5-10%) when compared to the earlier design. The design was hence successful in reducing the stress acting on wheels. FEA using road load data and tire model closely predict the experimental stress and the fatigue performance of the product. FEA results & ESA results were in good agreement to each other. It was found that Stress in the variable thickness disc is comparable with the uniform thickness disc. But in variable thickness disc will improve strength in nave region, vent hole region & Bolt hole region with reducing the weight & cost of Wheel rim. In this design 15% weight reduction achieved without compromising the performance of wheel rim.

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