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AUTOMOBILE WHEEL RIM ANALYSIS BASED ON TYRE INFLATION PRESSURE AND RADIAL LOAD USING ANSYS

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ABSTRACT: Over the years a lot of work has done and is still continuing with great effort to save weight and cost of applications. The current trend is to provide weight/cost effective products which meet the stringent requirements. The aim of this paper is to study Automobile Wheel Rim Design, Materials and its various Considerations for best design.Analysis is done w.r.t. different tyre inflation pressure along with radial loading on the vehicle.
Keyword: Wheel Rim, Tyre inflation, Ansys.

I. INTRODUCTION

1.1 Background

Automotive wheels have evolved over the decades from early spoke designs ofwood and steel, carryovers from wagon and bicycle technology, to flat steel discs and finally to the stamped metal configurations and modern cast and forged aluminum alloysrims of today's modern vehicles. Historically, successful designs arrived after years of experience and extensive field testing. Since the 1970's several innovative methods of testing well aided with experimental stress measurements have been initiated. In recent years, the procedures have been improved by a variety of experimental and analytical methods for structural analysis (strain gauge and finite element methods).Within the past 10 years, durability analysis (fatigue life predication) and reliability methods for dealing with the variations inherent in engineering structure have been applied to the automotive wheel.

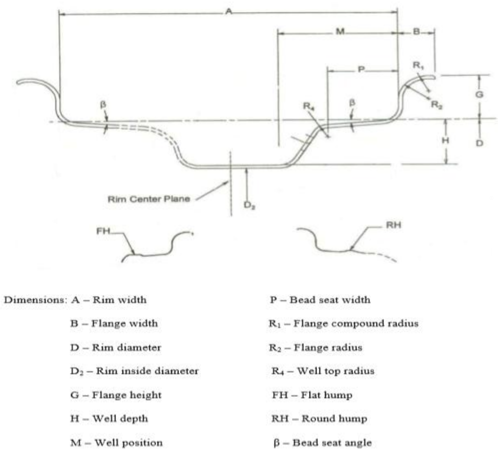

Fig 1:Rim Tyre side profile Nomenclature

1.2 Stress analysis

The performance of the wheel was evaluated as a function of the rim and disc plate thickness. The theoretical analysis of the stress and fatigue life was in good agreement with the result of a rotary corner fatigue test. In this study, radial loading was assumed to be the function of the cosine of the angle from the point of contact. The bending moment introduced as a result of the radial loading was directly affected by the radius as follows

$$M=4*\int_{0}^{\pi/2} q_0 R^2 cos^2\theta d\theta \quad \_\_\_\_\_\_\_\_\_(1.1)$$

With q_o is the applied load due to weight is the angle from the point load, the maximum moment, M.

1.3 Rim Testing

Wright focused solely on testing methods for rims, providing data on proper loading methods and strain gauge placement to yield accurate results. Static and dynamic testing methods were discussed during vehicle braking and cornering. Wright focused on most current quality control tests based on simple loading methods on accelerated test loading factors and test lives for passenger car and truck wheels. Motorcycle rims were also tested. Wright's quality controlled tests methods addressed the wide divergence of opinions on accelerated load test factors and test lives for passenger cars and truck wheels, except for the curb swipe impact tests where an international standard exists. Wright's publication was based on Motor Industry Research Association (MIRA) standards. MIRA developed British and ISO standards for wheels in the United Kingdom. Several good photographs of testing equipment can be seen in this publication.

1.4 Rim design

Krause described a method of wheel assembly testing by stress analysis as an alternative to fatigue testing of wheel components, for evaluating the serviceability of wheel components, as well as, optimized wheel design. The results of stress analysis were compared with material fatigue properties. The loads applied in this stress analysis and in the material fatigue testing were derived from stress cumulative occurring in the actual vehicle service. This stress analysis was of the experimental type and was performed on a specially built slow rolling test bench. Distribution of the force was a function of the cosine angle about the applied load, and the loading equation can be expressed as

$$P = \sum_{i=1}^{n} Pi * cos\,\theta i$$

This relationship is similar in many papers cited. The load fell to zero at 90 degrees. Stresses at the interface of the disc and the rim were the critical area of concern. At the point of contact with the ground, the angle of zero, the stress level at the interface of the disk and rim is in compression. At about 30 degrees rotation the stress level dropped to zero and continued in tension and peaking at the 90 degrees angle.

1.5 Objectives and Scope

To investigate the effects of tyre air pressure in conjunction with the radial load on the Stress and Displacement in tyre rims, through Finite Element Analysis.

The scope of the loading analysis will be limited to the load due to the weight of the bike and inflation pressure only.

II. WHEEL RIM MATERIALS

2.1] Introduction

The predominant wheel material is now steel but the shape; size and method of manufacturing have drastically changed. By 1935 the passenger car wheel diameter has been reduced from 36” to 16” and rim width is increased from 3” to 6” with shrunk in rim diameter from 36” to 44” diameter to 20” to 24” diameter.

2.2] Steel

Rimmed steel in SAE grade 1012 and 1015 were used for the disc because on hot rolled sheet that was very low in alloy content.

SAE Grade	Typical Chemistry (%)	Minimum Typical Properties (KPa)
Rim C1008/1010	C Mn P S 0.10 0.35 0.04 0.05	TYS TS %E 206700 310050 30
Disc C1012/1015	0.13 0.35 0.04 0.05	206700 310050 30

Table 1: Typical Disc wheel materials

2.3] Polycast

An extremely versatile styled manufacturing process consists of permanently molding self skinning polyurethane foam to the face of a steel wheel. The surface of the foam is then painted with urethane paints to accent the molded in styling features. Base coat/clear coat finish system is applied for a deep brilliant, high gloss appearance. The polycast can be molded all the way to the rim flange so no trim is required or a small trim ring can be used to cover the balance weights.

2.4] Aluminum

The most popular casting alloy is A356-T6. Forged truck wheels are usually produced in three or more die operation that involves forging, extruding and hot forming. Forged truck wheels were first introduced in 1948 and in 1973 forged passenger car wheels were introduced. From 1947 to 1966, 2024-T6 aluminum was used but that was replaced with 6061-T6 for improved corrosion resistance and formability at some sacrifice in mechanical properties (Table2).

	2024-T4	**6061-T6**	**5454-0**	**A356-T6**
Tensile strength (kPa)	399620	310050	227370	227370
Tensile yield strength (kPa)	261820	220480	103350	137800
Elongation	8	35	22	8.5
Fatigue strength	20	14	14	11

Table 2: Mechanical properties of Forged, Sheet and Cast Aluminum alloys for wheels

2.5] Magnesium

They typically provide lighter weight and improved performance as well as styling. Corrosion resistance has been an issue with magnesium wheels and they cannot provide the bright machined appearance that aluminum does. Comparison of material properties shows that magnesium is about two third the density of aluminum but has a lower modulus and lower mechanical properties.

2.6] Composite

Fiber reinforced composites using thermoset resins are not new to the list of wheel materials. As early as 1966’s wheel programs were initiated by number of companies worldwide. Michelin produced wheels that were sold as a limited option on the 1971 citroen. More recently work has been done by Firestone, Ford, General motors, Motors, Motor wheel, Owens cornering, Rhodea Incorporated, Volkswagen and others. In 1985 Marsh’s racing tyres marketed a thermoplastic wheel for off road racing applications.

Summary

Since from early 1900’s wood spoke wheel rim to nowadays composite wheel rim materials and high strength steel for rim use are covered. According to the requirement of automobile field and its reliability we are having steel,polycast, Aluminum, Magnesium, composite wheel rim materials available in the market.

III. CAD MODELING OF RIM

1. Disk Drawing:

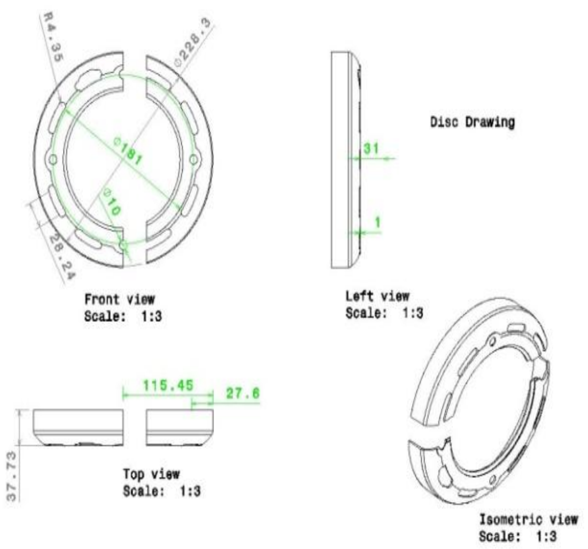

Fig 2: Disc drawing

2. Rim Structure drawing

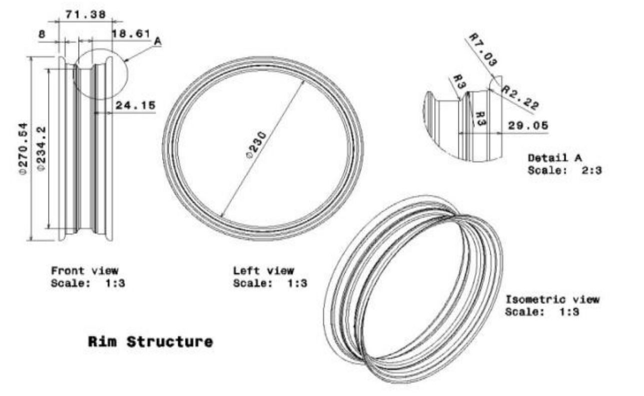

Fig 3: Rim drawing

Fig. 3D Model of Wheel Rim:- (Exploded View of Rim and Disc)

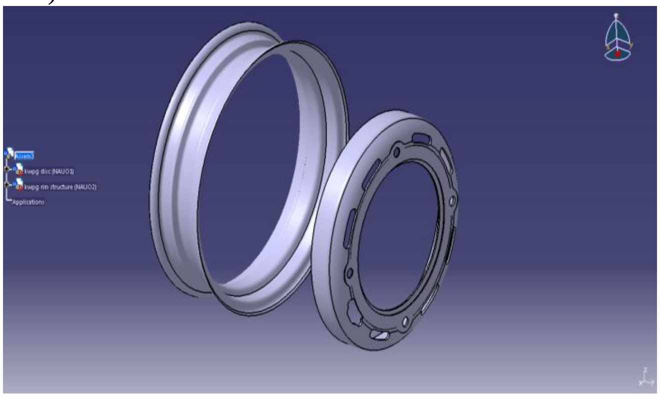

Fig 4: Cad model Rim and Disc

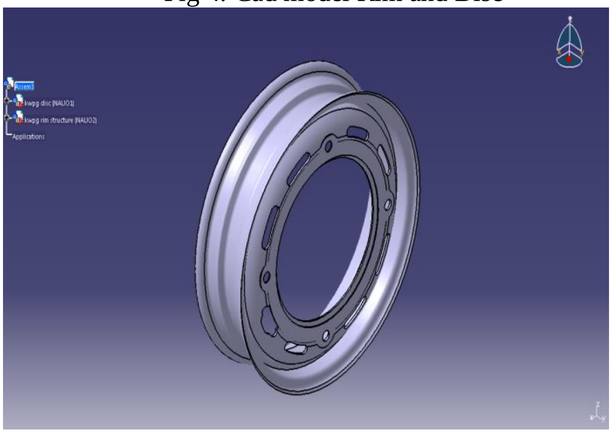

Fig 5: Assembled View of Rim and Disc

IV. ANALYSIS OF THE RIM

4.1 Analysis with tyre inflation pressure:

In order to evaluate the effect of inflation pressure the analysis of rim carried out with three values of tyre inflation pressures-

- 275.79 kPa being maximum operating pressure,
- 227.53 kPa being normal operating pressure,
- 193.05 kPa being minimum operating pressure,

275.79 kPa being maximum operating pressure,

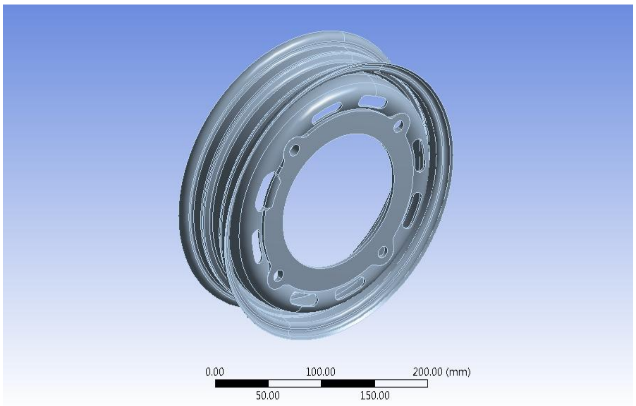

Fig 6: CAD model imported in ANSYS

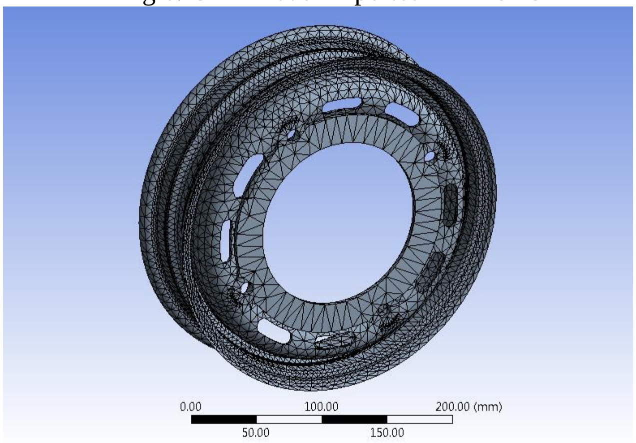

Fig 7: Mesh of Rim

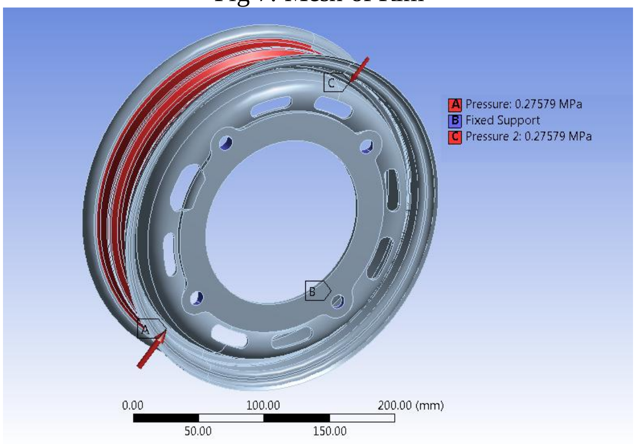

Fig 8: Boundary conditions

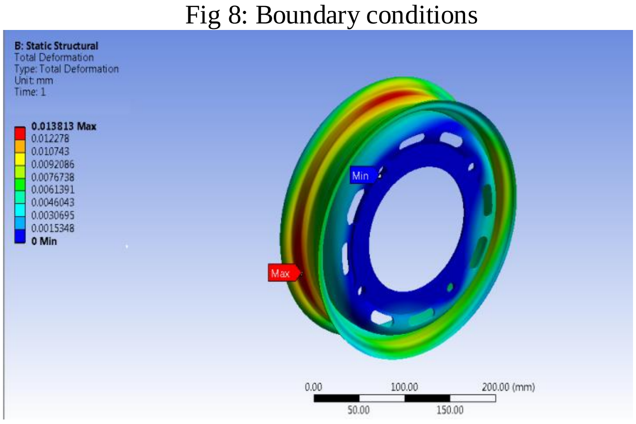

Fig 9: Deflection of 0.013813 mm

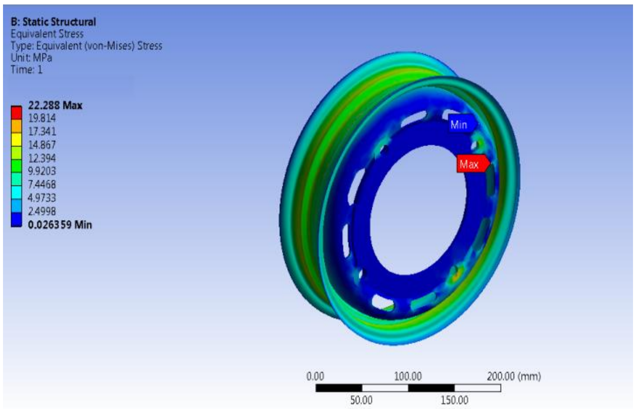

Fig 10: Generated Stress 22.288 MPa

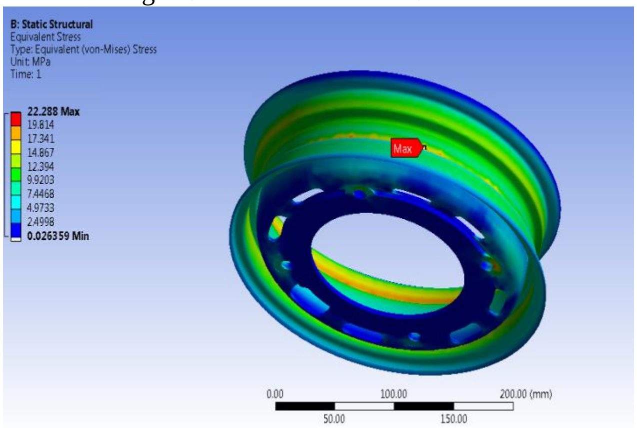

Fig 11: Max stress location

2. 227.53 kPa being normal operating pressure

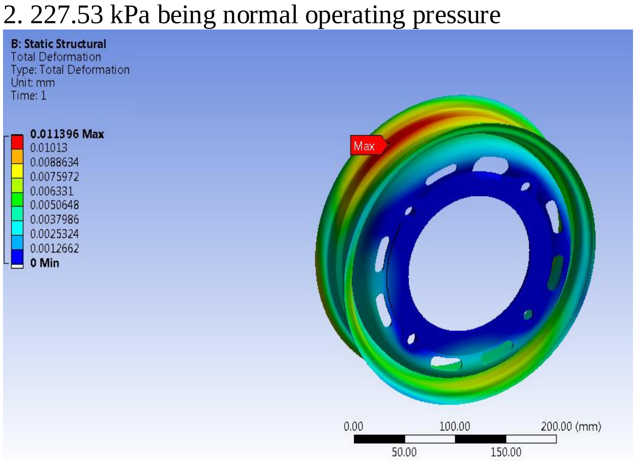

Fig 12: Deflection of 0.011396 mm

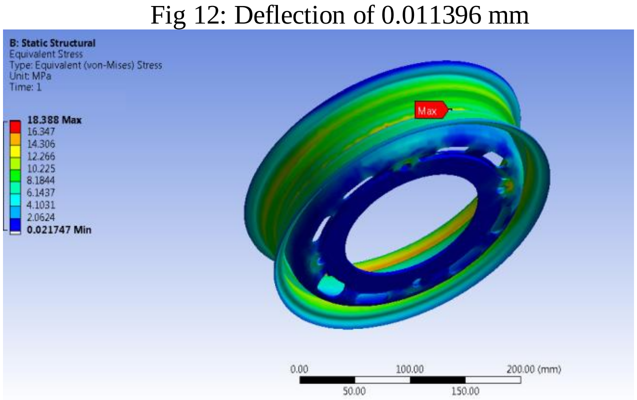

Fig 13: Generated Stress 18.388 MPa

193.05 kPa being minimum operating pressure,

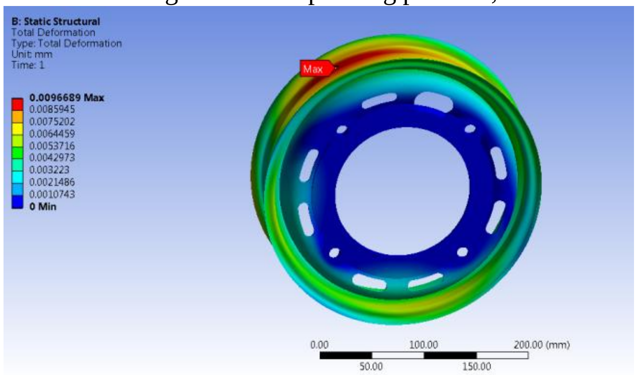

Fig 14: Deflection of 0.0096689 mm

4.2 Analysis with constant tyre inflation pressure (275.79 kPa) and Variation in radial load applied on rim.

Mass of Bike,
Dead Weight of Bike = 120 kg,
Other Loads = 20 Kg
Total Gross Weight = 120 + 20 = 140 Kg
Considering worst case of weight on vehicle:
Mass of the vehicle including rider and other four more persons,
M = 140 + 65 x 4
= 140 + 260
= 400 kg
Hence, maximum average weight on each wheel is 200 kg.

As tyre inflation pressure is one of the constant force acting on rim throughout its working conditions, while the radial load acting on rim is variable. In order to evaluate the performance of rim for different radial load, analysis carried out with constant tyre inflation pressure of 275.79 kPa and different radial load employed on each rim as follows:

- 150 kg – Low load
- 175 kg – Average Load
- 200 kg – High Load

Tyre pressure 275.79 kPa with Radial Load of 150 kg (1500 N) on rim

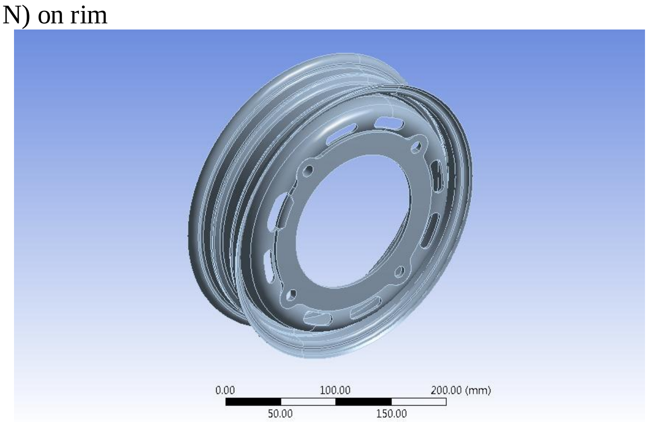

Fig 15: CAD model imported in ANSYS

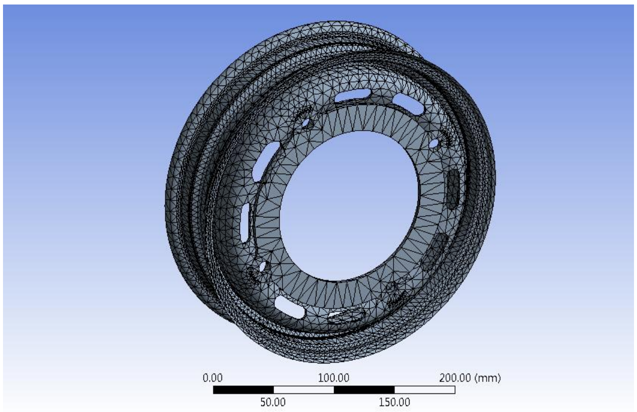

Fig 16: Mesh of Rim

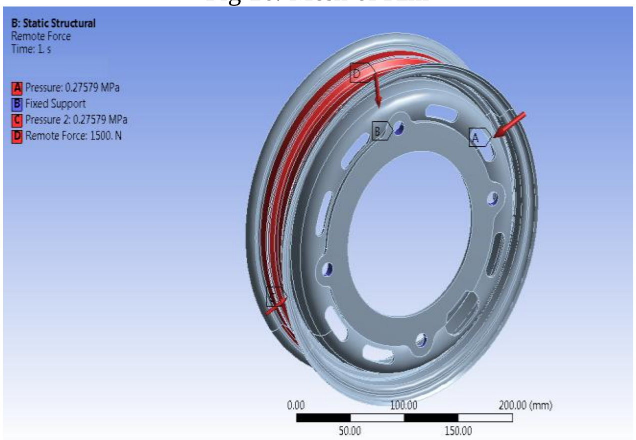

Fig 17: Boundary conditions

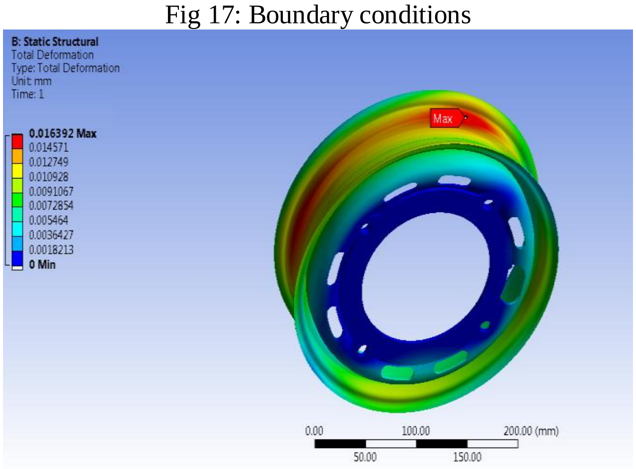

Fig 18: Deflection of 0.016392 mm

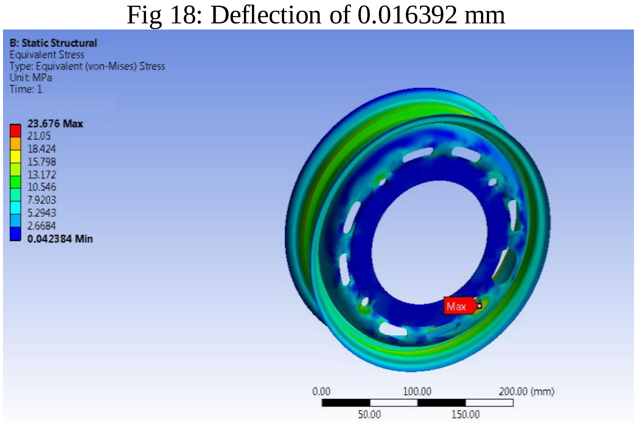

Fig19: Generated Stress 23.676 MPa

Tyre pressure 275.79 kPa with Radial Load of 175 kg (1750 N) on rim

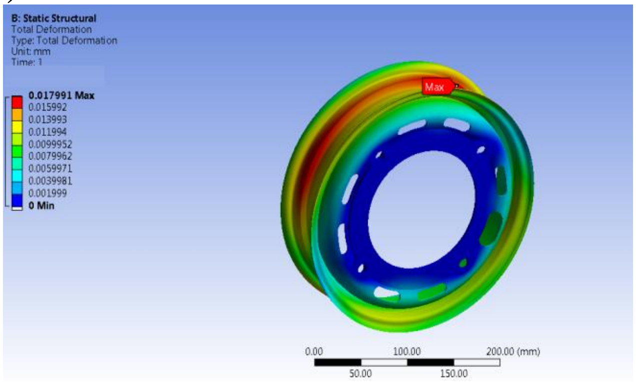

Fig 20: Deflection of 0.017991 mm

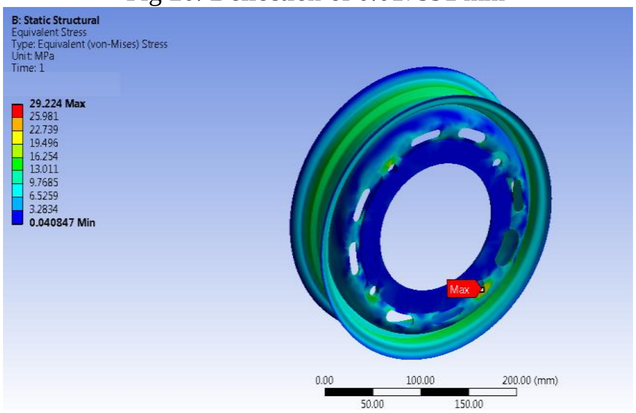

Fig 21: Generated Stress 29.224 MPa

Tyre pressure 275.79 kPa with Radial Load of 200 kg (2000 N) on rim

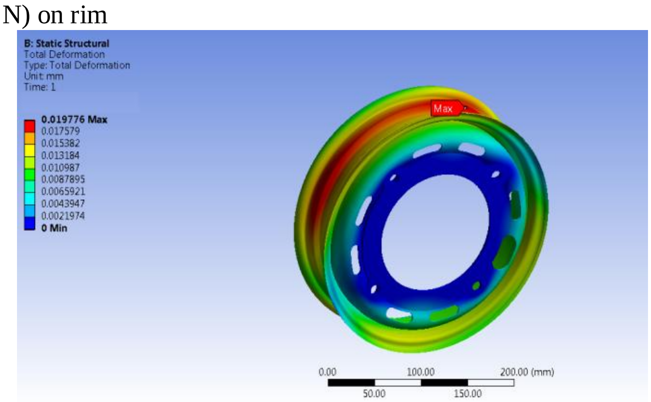

Fig 22: Deflection of 0.019776 mm

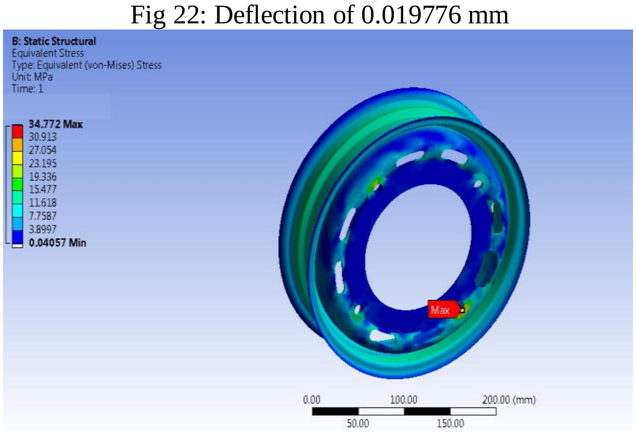

Fig 23: Generated Stress 34.772 MPa

Table 3: Summary of Analysis

Applied load conditions	Max Displacement (mm)	Max Von Mises Stress (N/mm^2)
A] With Different Tyre Inflation Pressure		
275.79 kPa	0.13813	22.288
227.53 kPa	0.011396	18.388
193.05 kPa	0.0096689	15.601
B] With Tyre inflation pressure of 279.75 kPa and different radial load.		
150 kg	0.016392	23.676
175 kg	0.017991	29.224
200 kg	0.019776	34.772

V. CONCLUSION

Following the described objective, the state of stress and mechanical response of aluminum automobile rims has been established, and the effects of inflation pressure are now well understood, in addition to the imposed radial load.

The stresses developed are within allowable limit in all possible cases. And this will lead into the possibilities of the material optimization.

REFERENCES

[1] "A Review on Modeling and Analysis of Car Wheel Rim using CATIA & ANSYS" by T. Siva Prasad,T. Krishnaiah, J. Md. Iliyas, M.Jayapal Reddy at International Journal of Innovative Science and Modern Engineering (IJISME) ISSN: 2319-6386, Volume-2, Issue-6, May 2014

[2] "Fatigue Analysis of Aluminum Alloy Wheel Under Radial Load" by N. Satyanarayana&Ch.Sambaiah at International Journal of Mechanical and Industrial Engineering (IJMIE), ISSN No. 2231 –6477, Vol-2, Issue-1, 2012

[3] "Design and Weight Optimization of Aluminum Alloy Wheel" by Sourav Das, (CAE Analyst) Altair Engineering India Pvt Ltd, Bangalore at International Journal of Scientific and Research Publications, Volume 4, Issue 6, June 2014 ISSN 2250-3153

[4] "Computer Aided Design and Simulation of Radial Fatigue Test of Automobile Rim Using ANSYS" by Emmanuel M. Adigio and Ebughni O. Nangi at IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 11, Issue 1 Ver. IV (Feb. 2014), PP 68-73

[5] "Topology Optimization of Aluminum Alloy Wheel" by Ch. P. V. Ravi Kumar1, Prof. R. SatyaMeher at International Journal of Modern Engineering Research (IJMER) Vol. 3, Issue. 3, May-June. 2013 pp-1548-1553 ISSN: 2249-6645

[6] Finite Element Analysis of the Classic Bicycle Wheel" by Andrew D. Hartz at Rose-Hulman Institute of Technology ME522 Finite Element Analysis conference July 18, 2002.

[7] Fatigue Analysis of an Automobile Wheel Rim" Case study

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