Studying Effect of Pressure on Rim

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Abstract: Wheels are clearly safety related components and hence fatigue performance and the state of stress in the rim under various loading conditions are prime concerns. Further, wheels continue to receive a considerable amount of attention as part of industry efforts to reduce weight through material substitution and down gauging. Possible loading conditions on the metal rim are: (a) pressure due to inflation, (b) radial loading on the bead seat resulting from the weight of the automobile, and (c) local bending moments induced on the rim due to an offset. These are directly influenced by the width of the rim. In order to evaluate the effect of rim width on stress the rim is analyzes experimentally with constant inflation pressure and variation in rim width. Location of high stresses in the weld area is of major concern for welded rims. Typically, the disc is welded to the rim at the well area. Residual stress causes addition stress or possible micro structural cracks to the rim.[1]

Key Words: Fatigue Performance, Tyre pressure, Radial load.

Introduction:

The objective of this study is to investigate the effects of tire air pressure in conjunction with the radial load on the stress and displacement in tire rims, through experimental stress analysis and finite element analysis. Effects of providing a hole or opening(square and round geometry's) placed on the rim to allow radio frequencies to pass will also be investigated. Effects of environmental degradation will be investigated through the examination of published literature and observations of many rims. [2]The scope of the loading analysis will be limited to the load due to the weight of the car and inflation pressure only.3 Nonlinear contact analysis of the tire / rim interface will not be considered, as well as the effect of the pressure on the bead seat due to mounting.

Effect of Tyre Air Pressure on Rim:

Tire air pressure is a constant load with no relation to the rotation of the wheel. However, the induced stress on the rim due to inflation pressure only, is comparatively small. In actual wheel usage, the cyclically varying stress due to the bending moment or the radial load is superimposed on the constant stress generated by the tire air pressure. Fig.1 shows schematic forces acting on the rim.

The tire air pressure is applied not only directly to the rim outer side but also indirectly to the rim flange. The later load, which is directed in an axial direction, is generated by the air pressure pressing on the tire side wall. This load varies according to a) the type of tire, b) the aspect ratio of the cross section of the tire and (c) the reinforcement structure of the tire [10].

The axial component Wp which result from the inflation of the tyre is calculated by the following equation [9].

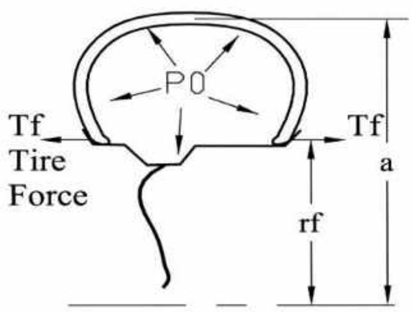

Fig .1 Schematic showing force acting on tyre

Finite Element Analysis of Automobile Wheels:

Stress calculations in automobile rim have usually been restricted to the rim. The method described here has thus far been applied only to the rim; it could be logically applied to entire wheel. The wheel is modeled by a finite element technique enabling representation of complicated shapes by a set of interconnected simple bodies. The stresses calculated within each element describe the stress distribution of material may be determined. Formulation of the stiffness matrix of a constant strain triangular element for axisymmetric problem is given [4].

Analysis with constant inflation pressure

Analysis of wheel rim using Ansys software is carried out with constant tyre inflation pressure (275.79 kPa) and variation in radial load applied on rim.

Wheel rim details used for analysis or case study,

Wheel rim: Rim designation 3.5B X 10

Wheel rim material: as per IS 1079 – HREDD

- Chemical composition :
  1. %C = 0.08 max
  2. %S = 0.03 max
  3. %P = 0.03 max
  4. %Mn = 0.4 max
  5. %Al = 0.02 max
- Mechanical properties :
  1. Mechanical strength = 260 – 330 N/mm^2
  2. Modulus of elasticity = 200 Gpa
  3. Poisson's ratio = 0.3
  4. % of elongation = 32 min.

Tyre inflation pressure is one of the constant force acting on rim, while radial load is varying load.

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

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 o 275.79 Kpa and different radial load employed on rim as follows :

1. 150 kg
2. 175 kg
3. 200 kg

A. Analysis with tyre inflation pressure 275.79 Kpa and radial load of 150 kg.

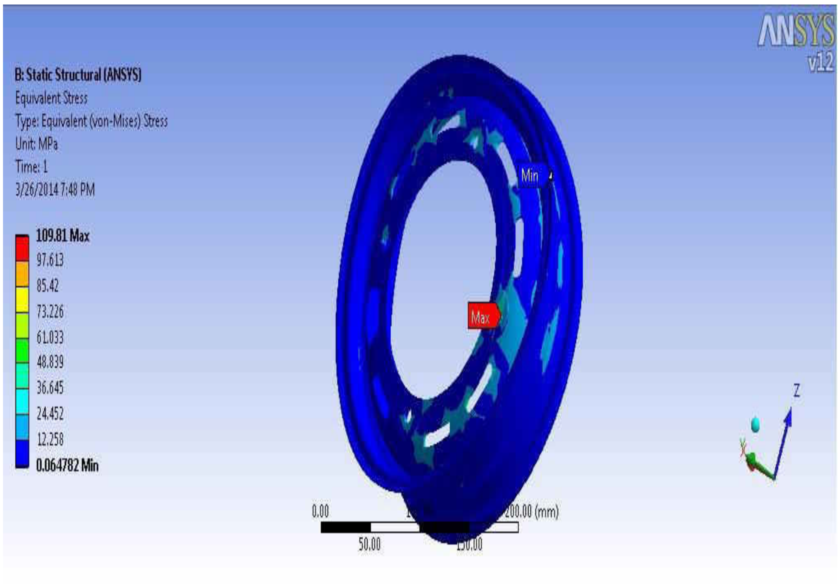

Fig.2.Von Mises Countour plot at 275.79 kpa tyre inflation pressure and radial load of 150 kg.

B.Analysis with tyre inflation pressure 275.79 kpa and radial load of 175 kg.

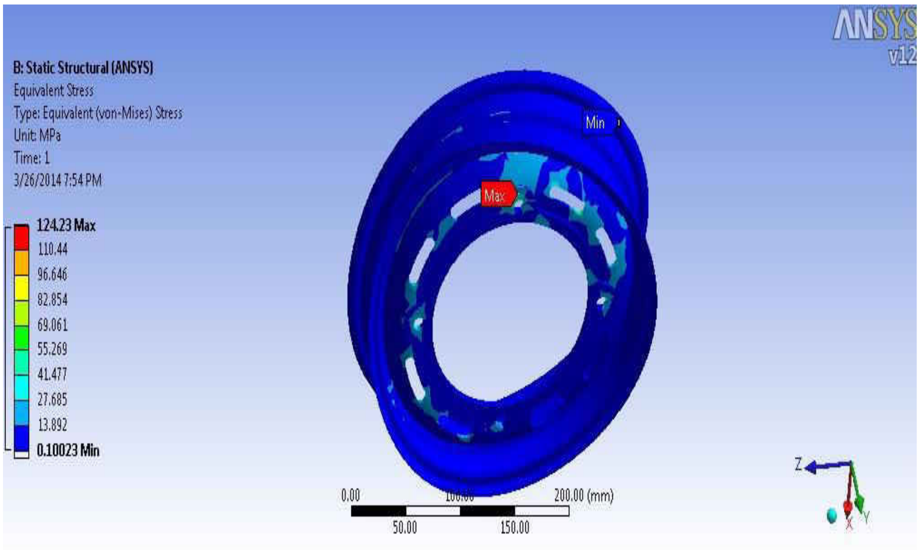

Fig.3.Von Mises Contour plot at 275.79 Kpa tyre inflation pressure and radial load of 175 kg.

C. Analysis with tyre inflation pressure 275.79 kpa and radial load of 200 kg.

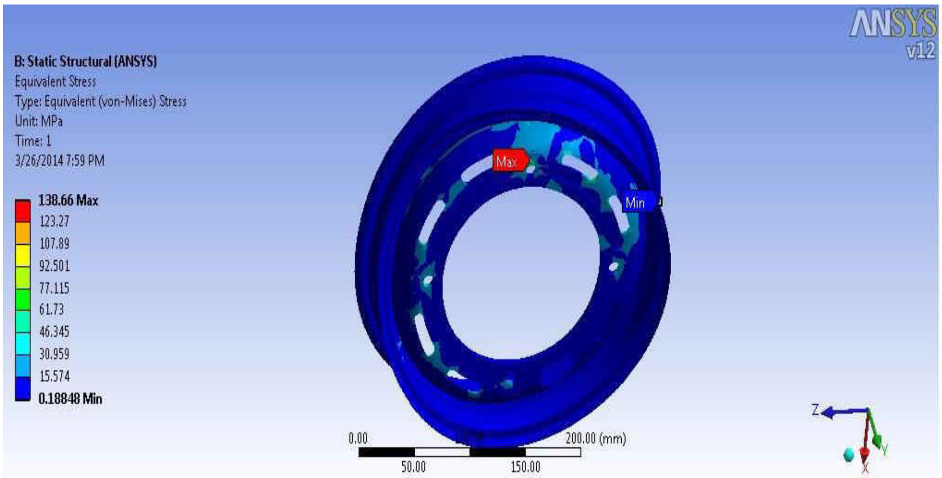

Fig.4. Von Mises Contour plot at 275.79 Kpa tyre inflation pressure and radial load of 200 kg.

Summary of Analysis:

With tyre inflation pressure of 279.75 kpa and different radial load. (Kg)	Max.	Min.	Max.
150	0.073734	0	109.81
175	0.084073	0	124.23
200	0.094412	0	138.66

Table 1. Analysis results at 279.5kpa Pressure and Various loads

Finite element analysis of rim using ANSYS Software provides displacement and von mises plot giving the values of strain and stress induced in rims under the influence of tyre inflation pressure and radial load employed. Analysis under two conditions is carried out ; in first case tyre inflation pressure is the only force acting on rim and in second case the tyre inflation pressure along with radial load is considered. The result of analysis is summarized in table1.By utilizing strain gauges the experimental analysis of rim us carried out to investigate the strain induced in rim under defined loading conditions. The experimental setup is as shown in fig.7.1. The comparison between experimental strain values with FEA strain values shows variation in results ranging from 0.679% to 11.23%.

Experimental setup:

In order to evaluate the performance of rim with constant inflation pressure and radial load experimental investigation was carried out. Fig.5.shows experimental set up

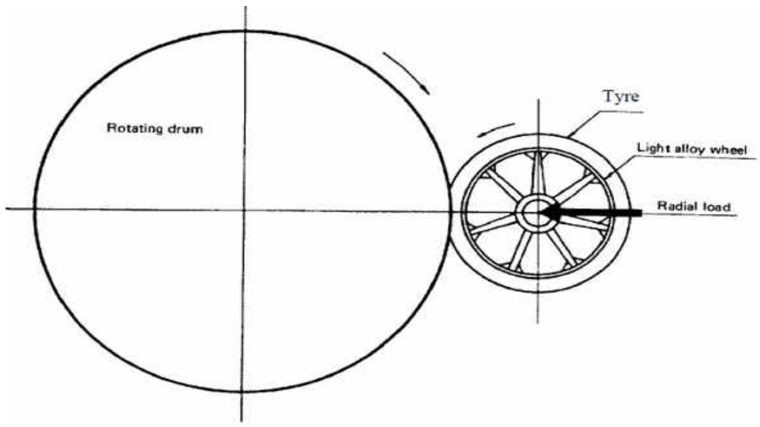

Fig.5. Experimental set up

A radial drum on left side is stationary while bracket along with rim is movable so that radial load can be applied. Movement to the rim bracket is given by hydraulic circuit. Five strain gauges placed in the rim at the locations shown in fig.6, measured the normal contact pressure and their build up with tyre inflation pressure. To avenge the effect of surface irregularities, pressure measurement were taken with different tyres.

Fig.6.Strain gauge location on the rim

Experimental Result

Wheel rim with inflation pressure of 275.79kpa mounted on movable bracket which moves back and forth against stationary drum, so as to vary the radial load applied on rim . As strain gauges are mounted on outboard side of rim flange so it gives strain values of outboard side of flange area. The test is carried out for changing positions of strain gauge in contact with stationary drum.

Result Discussion

Experimental stress analysis can be as much as an art as it is a science. Accuracy of strain readings strongly depends on mounting, instrumentation and human error. Overall, strain gauge readings verified the validity of the finite element model. Locations and placement of the gauges were limited the outside of the rim. The rim portion was targeted as the optimum location as it is critical in the geometry of the wheel. The disk192portion was ignored as the strains in these areas are not as critical and are of magnitude less than the rim area chosen. Machine accuracy, temperature and tire inflation pressure all affected the analog readings. Several readings were made repeatedly, and results differ each time by a small amount. At best the experiments can point out trends in the strain data, when compared to the analytical finite element data.

The load imparted from the tire due to the bead seat of the rim under loading of the automobile is not quite understood. Several attempted to determine the effect of inflation pressure superimposing pressure on the entire circumference of the bead seat were presented, but are highly dependant on tire construction.

True modelling of the rim under radial loading for actual loading of the car weight transferred to the rim is a highly nonlinear contact problem, that has to be thoroughly understood. Stresses were found to be moderately low for all inflation pressures, and the effect of the air pressure is evident in the graphs. Actual displacement in the tire wheel system would be absorbed by the tyre, so that radial load analysis on a wheel without the tire is a conservative design. Resulting stresses for an associated load due to radial load on a automobile, in conjunction with the inflation pressure are relatively low. Critical areas in rim design have been identified as the bead seats, the well, and the hump. All of these areas insure the rim remains in contact with the tire. Critical areas identified in the disk, include the disk hat and the bolt circle location. The Von Mises stresses calculated in the disk are much lower than the Von Mises stresses calculated in the rim. Of all the critical areas in the wheel, the inboard bead seat was identified as the highest stressed area in the wheel. The influence of inflation pressure does effect the state of stress and displacement in the rim. In most cases the higher the inflation pressure the higher there resulting state of stress. But in some instances in certain locations, a reduced inflation pressure will cause more displacement and ultimately stress.

Conclusion:

From the experimental and finite element results, it can be concluded that under radial load with appropriate acceleration factor, the aluminum rim stresses are concentrated in the bead seat areas, the well and the safety hump. These stresses, fortunately are below the endurance limit stresses for the aluminum alloy, and thus redesign of the wheel for the purpose of increased safety in case of sudden air loss is feasible.The purpose of the bead seats is to retain the tire under the reaction of the inflation pressure. The well is designed in the rim to aid in mounting of the tire to the rim.The American safety hump maintains tire contact with the rim during a cornering maneuver, where the bead would tend to drift to the interior potion of the rim.

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