Gyadari Ramesh et al. Int. Journal of Engineering Research and Applications www.ijera.com
ISSN: 2248-9622, Vol. 5, Issue 8, (Part - 5) August 2015, pp.01-08

RESEARCH ARTICLE OPEN ACCESS

Fe Analysis of Effect of Tyre Overload and Inflation Pressure on Rolling Loss in Cars

Gyadari Ramesh[1], Malloji Mallesham[2], Dr.VVRLS.Gangadhar[3]
[1] HEAD, Department of Mechanical Engineering, Princeton College of Engineering & Technology, Hyderabad
[2]Asst.prof, Department of Mechanical Engineering, Princeton College of Engineering & Technology, Hyderabad
[3]Principal, Department of Mechanical Engineering, Princeton College of Engineering & Technology, Hyderabad

Abstract
Rolling loss or rolling resistance is an ever important property for the tyre and automotive industries because of its practical implication. Fuel consumption and tyre rolling loss in all types of automobiles have become increasingly important because of adverse environmental effects (air pollution and global warming) and economic costs (high petroleum price).
In this thesis, the effect of rolling resistance and overload on fuel consumption of automobile car tyres is discussed. The investigations are made on two tyre models of automobile cars Skoda Rapid and Ford Classic. Theoretical calculations are also done to determine the rolling resistance due to inflation pressure. The default weight is considered for 5 persons and also the tyre overload is considered by taking 6 and 7 people's weight.
Index Terms— rolling resistance, Skoda Rapid and Ford Classic, inflation pressure, Pro/Engineer, ANSYS,

I. INTRODUCTION

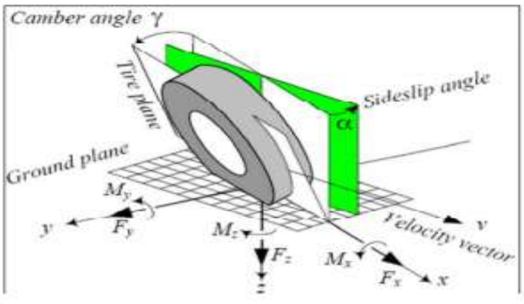
The pneumatic tyre plays an increasingly important role in the vehicle performance of road. However, this status is achieved because of more than one hundred years' tyre evolution since the initial invention of the pneumatic tyre by John Boyd Dunlop around 1888. Tyres are required to produce the forces necessary to control the vehicle. As we know that the tyre is the only means of contact between the road and the vehicle but they are at the heart of vehicle handling and performance (Nicholas, 2004). The inflated rubber structure provides comfortable ride for transportation. With the growing demand for the pneumatic tyre, many improvements have been made based on the initial conception, such as the reinforcement cords, the beads, the vulcanization, the materials and the introduction of the tubeless tyre. The relationship between human and tyre and environmental surrounding play an important role for developing of tyre technology. These concerns include traffic accidents caused by tyre failure, the waste of energy due to bad tyre conditions, the pollution through the emission of harmful compounds by tyres, and the degradation of road surfaces related to tyre performance, etc.

Tyre as one of the most important components of vehicles requires to fulfil a fundamental set of functions are to provide load-carrying capacity, to provide cushioning and dampening against the road surface, to transmit driving and braking torque, to provide cornering force, to provide dimensional stability, to resist abrasion (Mir Hamid, 2008). Tyres have ability to resist the longitudinal, lateral, and vertical reaction forces from the road surface without severe deformation or failure. Tyre performance is depends on the tyre rolling resistance, cornering properties, tyre traction, tyre wear, tyre temperature, tyre noise, tyre handling and characteristics, etc. There are various losses associated with the vehicle that affect its fuel economy as it is being operated. These losses include engine, driveline, aerodynamic and rolling losses, while the rolling loss is associated with the vehicle tyres.

II. TYRE AXIS TERMINOLOGY

It is need to understand some of the basic terminology for tyre, especially regarding the systems of coordinates, orientations, velocities, forces, moments. Nomenclature and definitions based on the SAE standard as shown in Figure 1 X-axis is the intersection of the wheel plane and the road plane with positive direction forward. The Z-axis perpendicular to the road plane with positive direction downward. The Y-axis in the road plane, its direction being chosen to make the axis system orthogonal and right hand. There are several forces, moments and angles that prove to be very important in tyre behavior. All these forces can be seen as the forces and moments acting on the tyre from the road. First, there are two main angles to consider, the camber angle and the slip angle. The camber angle is the inclination angle from its vertical position while the slip angle is the difference in wheel heading and direction.

Figure 1: Tire Axis Terminology



III. PERFORMANCE PARAMETERS

Tyre performance is affected by the rolling resistance, tyre wear, tyre noise, tyre temperature, cornering properties.

3.1 Rolling Resistance

The rolling resistance of a wheel (FR) is made up of four components. The sum of these components is equal to the total rolling resistance Components such as Tyre rolling resistance (FR, T), Road rolling
FR = FR, T + FR, Tr + FR, α + FR, fr
Resistance (FR, Tr) Resistance due to tyre slip angle (FR, α) Resistance due to bearing friction and residual braking (FR, fr). Tyre rolling resistance is depends up on the following parameters.

3.2 Tyre Temperature

The temperature of the tyre has significant effect on rolling resistance of tyre. Increasing of rolling resistance of tyre is due to the deflection and energy loss in the material.

3.3 Tyre Inflation Pressure and Load

Tyre inflation pressure determines the tyre elasticity and combination with load, determines the deflection in the sidewalls and contact region. The overall effect of rolling resistance is depends on the elasticity of the ground. On the soft surfaces like sand, high inflation pressure results in increased ground penetration work and therefore higher coefficients while the lower inflation pressure decreasing ground penetration. Thus the optimum pressure depends on the surface deformation characteristics.

3.4 Speed of Vehicle

The rolling resistance is directly proportional to speed because of increasing of flexing work and vibration in the tyre body. Influence of speed becomes more important when combines with lower inflation pressure.

3.5 Tyre Material Design

The material and thickness of both the tyre sidewalls and the tread determines the stiffness and energy losses in the rolling tyre. The cord material in the sidewall has only a small effect, but the cord angle and tyre belt properties have significant influence on rolling resistance of tyre.

3.6 Tyre Slip Angle

Wheels Tractive and braking forces shows higher effects on rolling resistance due to the wheel slip angle. At a few degree of slip the rolling resistance coefficient may nearly double in the magnitude (Thomas, 1992).

3.7 Tyre Wear

The wear performance of a tyre is its ability to reach high mileages. One way of evaluating this wear performance is consider the duration of tyre service life, which is the mileage after which a point on the tread has reached the legal limit of the wear indicator. The duration of a tyre's Service life depends on the mass loss from the tread, which is usually expressed in g/100 km, and by the transverse worn profile which enables the wear shape of the tread to be qualified. The duration of a tyre's service life depends on the condition in which the tyre is used, that is the type of driver and the geographical area. Wear is depend upon many parameters, which gives designer to modification tyre force applied on tyre or changes in rubber or ground surface (Olivier et al., 1998).

IV. LITERATURE SURVEY

PARAMETRIC STUDY AND EXPERIMENTAL EVALUATION OF VEHICLE TYRE PERFORMANCE by Virkar D S1 and Thombare D G

The purpose of this review paper is to study of effect of the different tyre operating parameters on tyre performance and review of testing setup to test these tyre performance parameters. The testing of tyre performance parameters by experimentally is help to designer to correlate the relationships of parameters and to design the tyre, hence it is need to testing of tyre. Knowledgeabout dynamic properties of tyres are an essential for any kind of research and development activities on vehicle dynamics. The main purpose of laboratory testing is to separate the properties of the tyre from the vehicle, achieve high rate of reproducibility and to optimize the cost. This review paper gives the information regarding of different researcher's works on inter laboratory tyre testing setup for measuring tyre performance parameters and also this review paper helps to understand the factors on which tyre performance parameters is depends.

TYRE INFLATION PRESSURE INFLUENCE ON A VEHICLE STOPPING DISTANCES by VladimírRievaj, JánVrábel, Anton Hudák

Health and ensure the safety of the road is now a priority in Europe. The authors deal with the adhesion problems of tyres – ground contact under process of vehicle braking. The proper tyre pressure is just part of many factors inflicting stopping distances of vehicle. The article describes the stopping distance dependence on tyre pressure. It has been tested three probable options (e.g. overcrowding, under-inflation and adherence to the values specified by the manufacturer).

DESIGN OF AUTOMATIC TYRE INFLATION SYSTEM by Hemant Soni, Pratik Golar, AshwinKherde

Driven by studies that show that a drop in tyre pressure by just a few PSI can result in the reduction of gas mileage, tyre life, safety, and vehicle performance, we have developed an automatic, self-inflating tyre system that ensures that tyres are properly inflated at all times. Our design proposes and successfully implements the use of a centralized compressor that will supply air to all four tyres via hoses and a rotary joint fixed between the wheel spindle and wheel hub at each wheel. The rotary joints effectively allow air to be channeled to the tyres without the tangling of hoses. With the recent oil price hikes and growing concern of environmental issues, this system addresses a potential improvement in gas mileage; tyre wear reduction; and an increase in handling and tyre performance in diverse conditions. In this paper we have taken into consideration design aspects of the ATIS.

V. AIM OF THE PROJECT

In this thesis, the effect of tyre over load and inflation pressure on the rolling loss and fuel consumption is analyzed. The investigations are made on two models of tyre Skoda Rapid and Ford Classic. The analysis is done by applying the loads of car weight and person's weight. When the car is overloaded, also analysis is done. Analysis is done by applying inflation pressure.
Modeling is done in Pro/Engineer and analysis is done in Ansys

VI. CALCULATION OF INFLATION PRESSURE IN TYRES

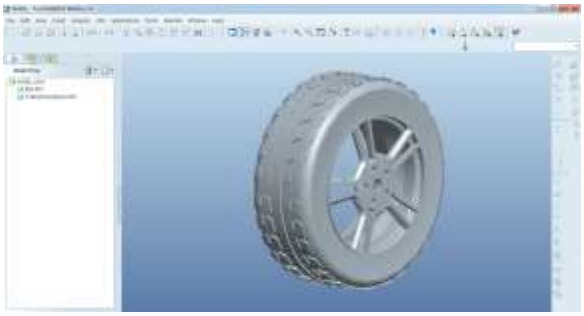
Aspect ratio = (section height)/(section width)×100
Section height = (od-id)/2
= (63.6620-50)/2
=13.6620/2
= 6.831mm
Width = OD-ID
= 63.6620-50
=13.6620mm

Inflation pressure:
$P=3p/(2\pi a^2)\ \sqrt{(1-(r/a))2}$
$= (3\times250)/(2\times3.14)\ \sqrt{(1-(31.83/50))2}$
$=0.04777070064\times0.7711941649$
$=0.0368404N/mm2$

VII. 3D MODELS OF TYRE AND RIM ASSEMBLY

Skoda

FORD



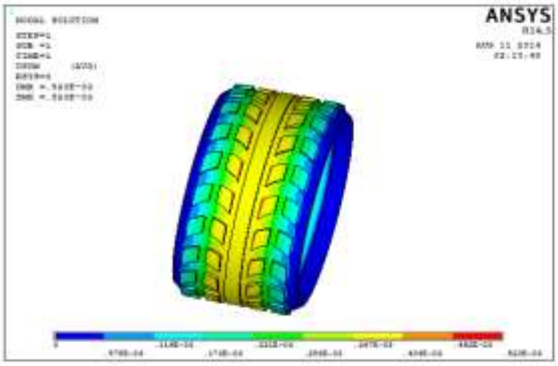
7.1 STRUCTURAL ANALYSIS OF SKODA TYRE
7.1.1 CAR WEIGHT + 5 PERSONS WEIGHT
Imported model

Material properties: Rubber
Density $=0.00000233 Kg/mm^3$
Young's modulus $=50000 N/mm^2$
Poisson's ratio=0.49
Solid Element – 3D Solid 186

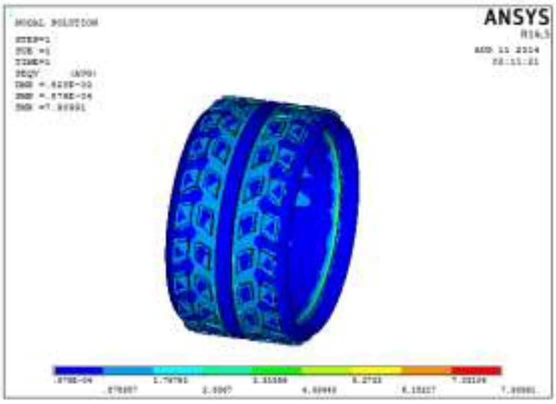
Meshed model

At pressure 1.65N/mm^2

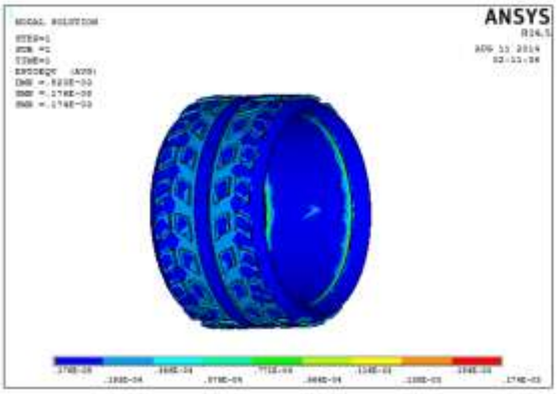
Displacement



Stress



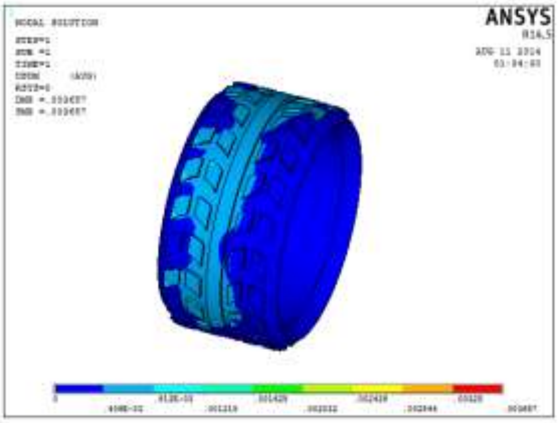
Strain



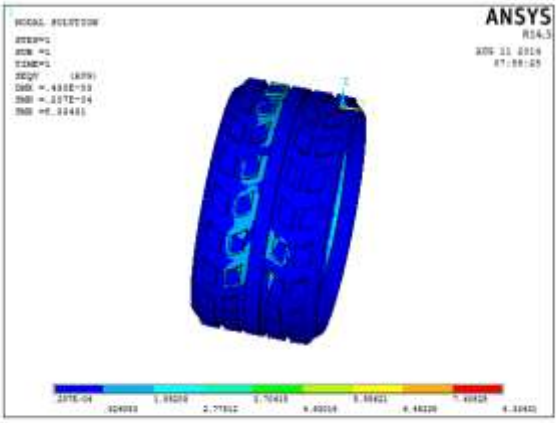
7.1.2 CAR WEIGHT + 6 PERSONS WEIGHT

Pressure - 1.717N/mm^2

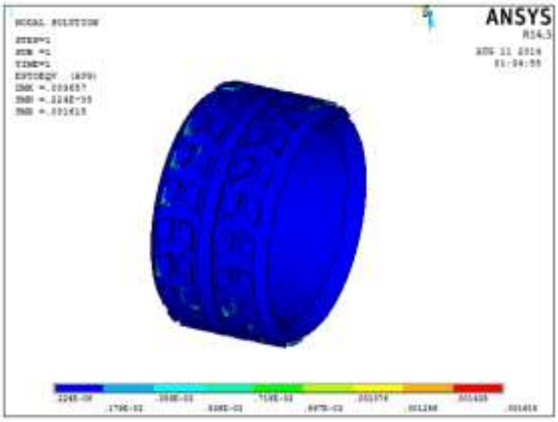
Displacement



Stress

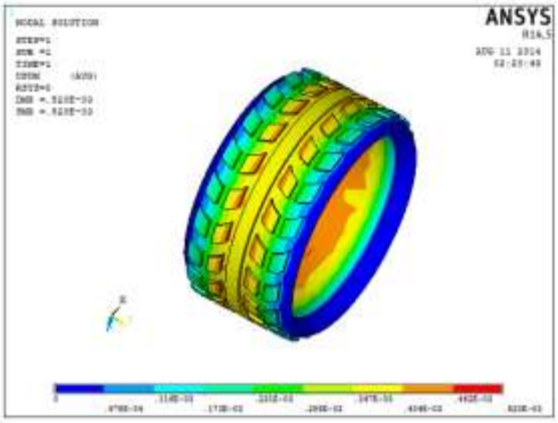


Strain

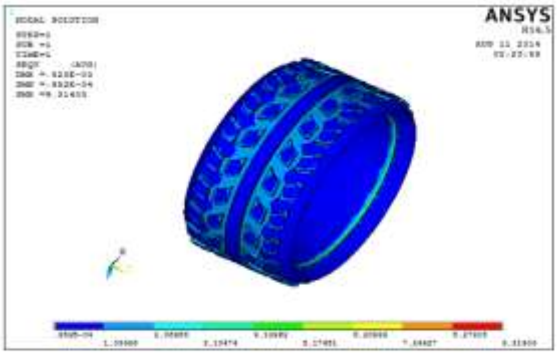


7.1.3 CAR WEIGHT + 7 PERSONS WEIGHT At 1.639N/mm^2

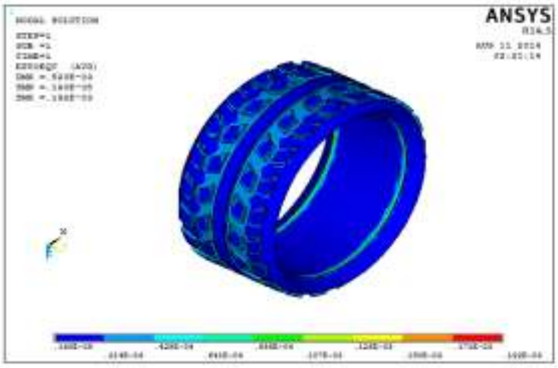
Displacement



Stress



Strain

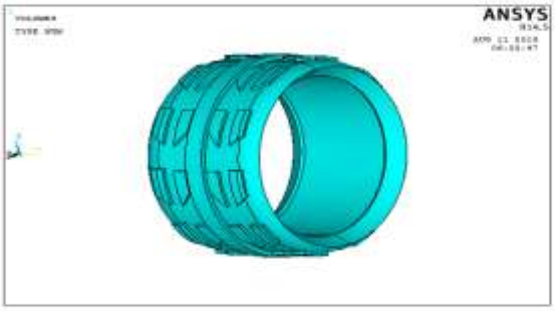


7.1.4 STRUCTURAL ANALYSIS OF FORD TYRE CAR WEIGHT + 5 PERSONS WEIGHT

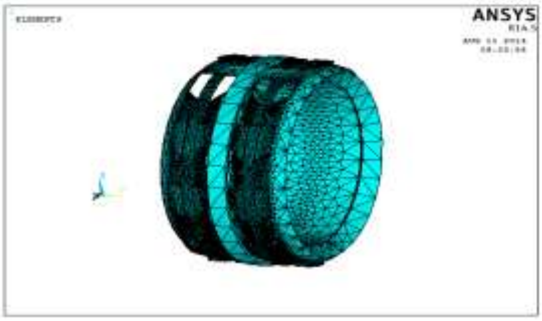
Material properties:

Rubber
Density =0.00000233
Young's modulus =50000
Poisson's ratio=0.49

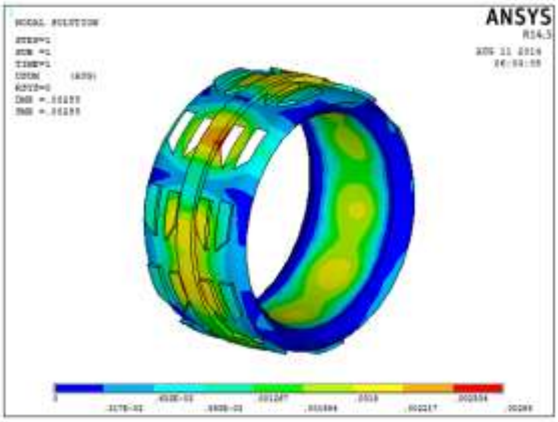
Imported Model



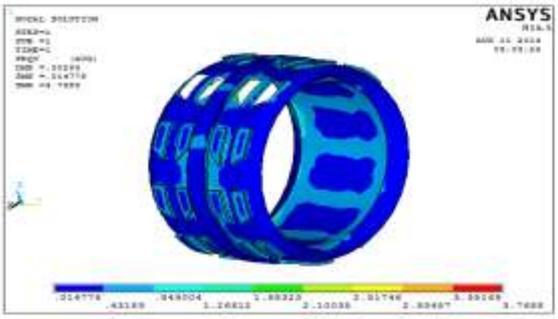
Meshed model



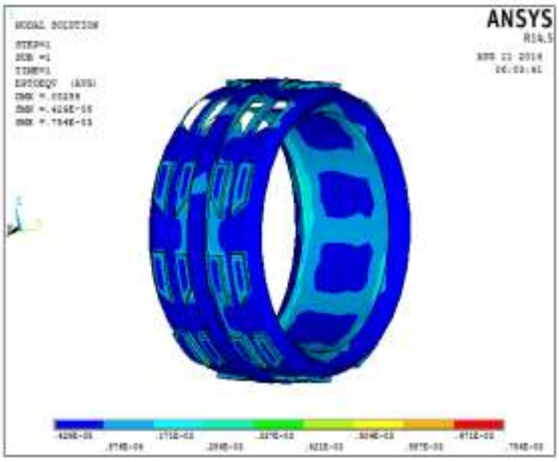
Pressure At 2.415N/mm^2
Displacement



Stress

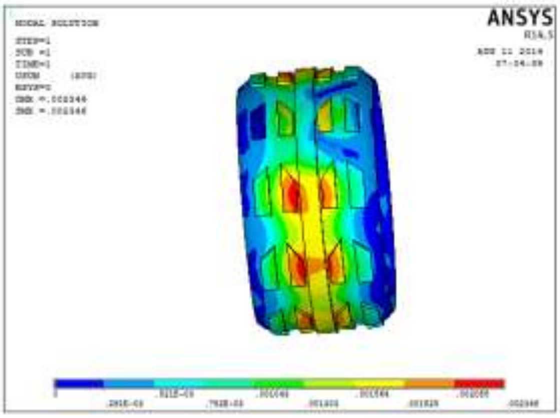


Strain

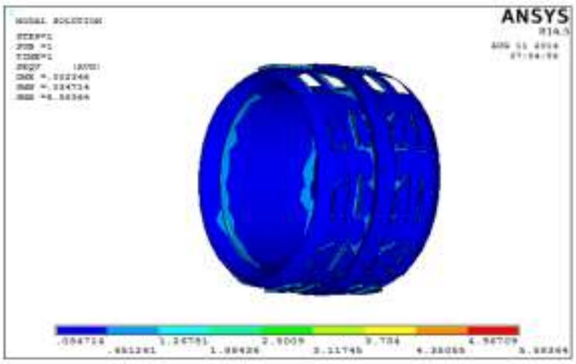


7.1.5 CAR WEIGHT + 6 PERSONS WEIGHT
At pressure 2.415 N/mm^2

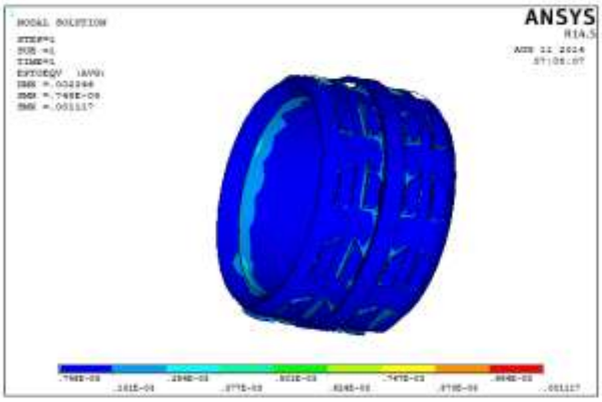
Displacement



Stress

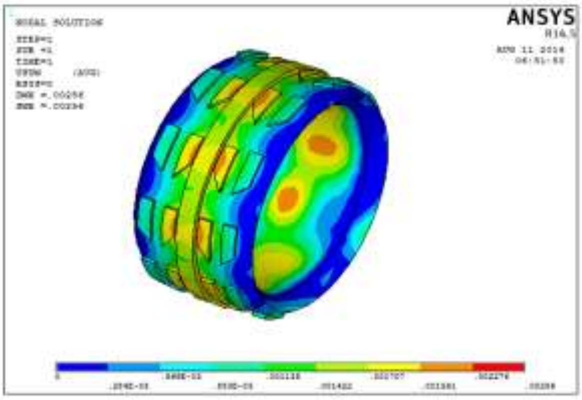


Strain

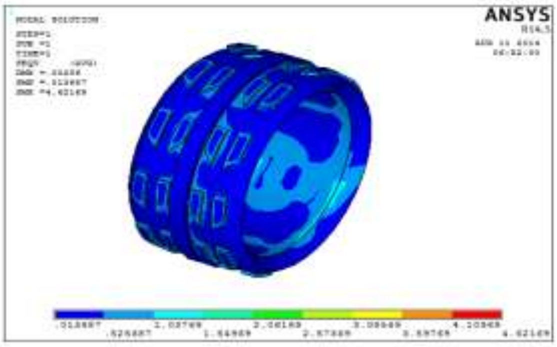


7.1.6 CAR WEIGHT + 7 PERSONS WEIGHT
At pressure 2.415 N/mm^2

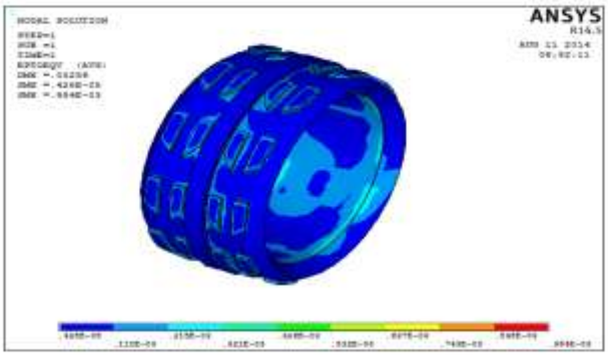
Displacement



Stress

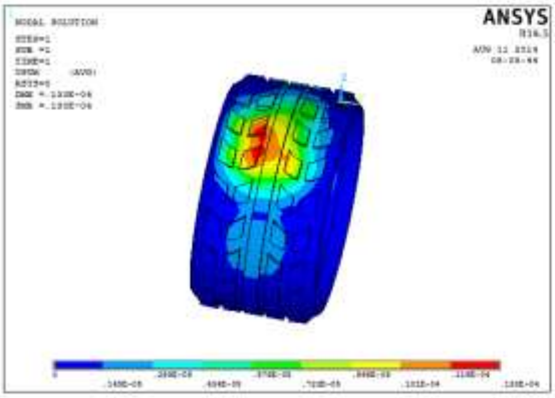


Strain

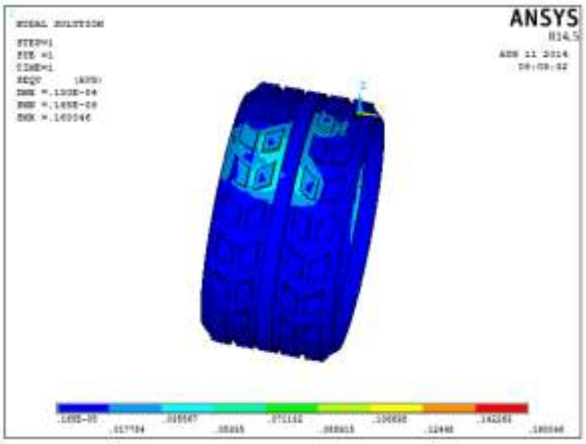


7.1.7 STRUCTURAL ANALYSIS OF SKODA TYRE AT INFLATION PRESSURE INFLATION PRESSURE - 0.036N/mm^2

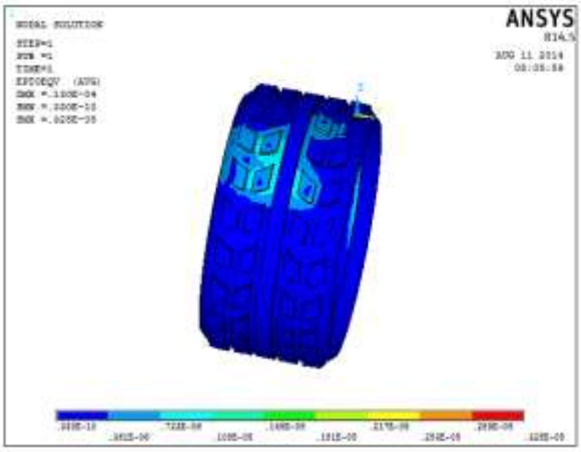
Displacement



Stress

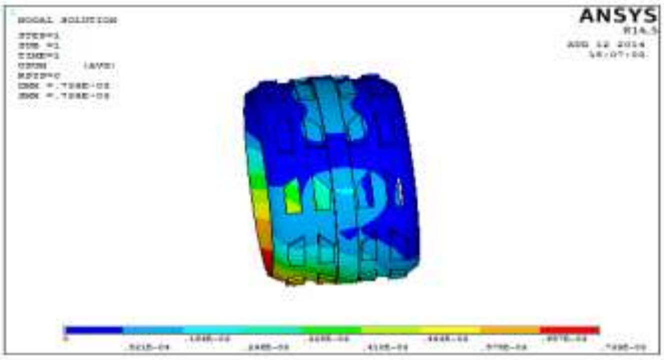


Strain

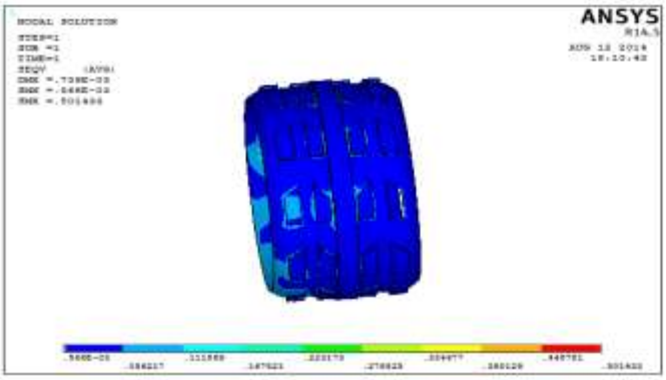


7.1.7 STRUCTURAL ANALYSIS OF FORD TYRE INFLATION PRESSURE - 0.036N/mm^2

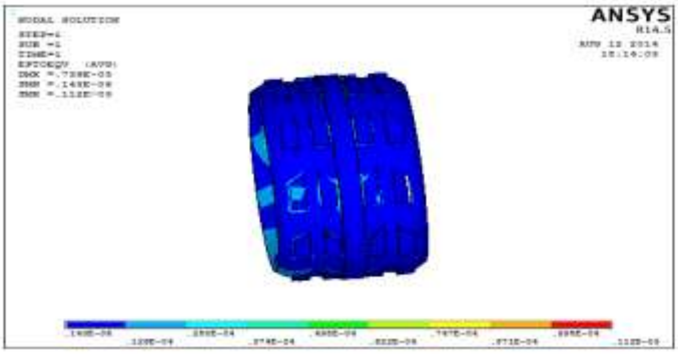
Displacement



Stress



Strain



VIII. RESULTS TABLE

8.1 SKODA TYRE

Pressure (N/mm^2)	Displacement (mm)	Stress (N/mm^2)	Strain
At 1.65	0.520e-03	7.90991	174e-02
At 1.717	0.003657	8.33431	0.001615
At 1.639	0.520e-03	9.31402	0.192e-03
Inflation pressure(0.036)	0.130e-04	0.160046	0.325e-05

8.2 FORD TYRE

Pressure (N/mm^2)	**Displacement (mm)**	**Stress (N/mm^2)**	**Strain**
At 2.415	0.00285	3.7688	0.754e-03
At 2.415	0.002346	5.58364	0.001117
At 2.415	0.00256	4.62169	0.954e-03
Inflation pressure(0.036)	0.739e-03	0.510433	0.112e-03

Calculation for Fuel Consumption With Respect To Inflation Pressure

8.3 ROLLING RESISTANCE FOR CONSIDERED LOADS

Skoda Rapid (kerb wt – 1500Kg)	Ford classic (kerb wt - 1150Kg)
1850kg	1500kg
1920kg	1570kg
1990kg	1640kg

IX. CONCLUSION

In this thesis, the effect of tyre over load and inflation pressure on the rolling loss and fuel consumption is analyzed. The investigations are made on two models of tyre Skoda Rapid and Ford Classic. The analysis is done by applying the loads of car weight and person's weight. When the car is overloaded, also analysis is done. Analysis is done by applying inflation pressure. The material used for tyre is rubber.

Modeling is done in Pro/Engineer and analysis is done in Ansys. The analysis is done by applying the car weight + 5 persons weight, overloading the tyre, that is, car weight + 6 persons weight and car weight + 7 persons weight. The analysis is also done by applying the inflation pressure By observing the analysis results, the stresses produced are less than the yield strength value of rubber even the tyre is overloaded. The rolling loss will be more for overloading than the specified load and the fuel consumption will also be more. A possible method of optimizing fuel consumption by adjusting tyre operating load/pressure conditions is suggested. Increasing tyre pressure is a convenient and inexpensive method of partially or fully compensating for rolling resistance increase. Some fuel saving might be accomplished by this method.

REFERENCES

[1.] Parametric study and experimental evaluation of vehicle tyre performance by Virkar D S1 and Thombare D G
[2.] Tyre inflation pressure influence on a vehicle stopping distances by VladimírRievaj, Ján Vrábel, Anton Hudák
[3.] Design of automatic tyre inflation system by Hemant Soni, Pratik Golar, AshwinKherde
[4.] Walter J D & Conant F S, TyreSciTechnol, 2 (1974) 238.
[5.] Lou A Y C, TyreSciTechnol, 6 (1978) 176.
[6.] Keefe R L &Koralek A S, in Tyre rolling resistance, edited by Schuring D J Rubber (Division AC S, Akron, Ohio), 1983, 78.
[7.] Bezbatchenko W, Title: The Effect of Tyre Construction on Fuel Economy" SAE paper #740067 Society of Automotive Engineers (1974) New York.
[8.] Schuring D J, TyreSciTechnol (1976) 3.
[9.] Williams A R, The Influence of Tyre and Road Surface Design on Tyre Rolling Resistance, Inst Petroleum Report, IPSI-003 (1981), London, UK.
[10.] Luchini J R, Peters I M & Arthur R H, TyreSciTechnol, (1994) 206.
[11.] Warholic, Tyre Rolling Loss Prediction from Finite Element Analysis of a Statically Loaded Tyre, M. S. E. Thesis, University of Akron, Akron, Ohio, 1987.