# Experimental investigation & analysis of tyre deformation for enhancing its life

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**Abstract- Tyre is a part of vehicle which is in actual contact the road surface. Tyre is a band of layers of rubber, fabric & steel rods mounted one by one on the rim of a wheel & transmit the various loads & power to the road. This paper presents the work that deals with the strength of the tyre investigated on finite element analysis method (FEA) & validated with experimental setup. Two different tyres of material are used with variation in material properties of cord & changing the gauges of plies of tyre. Experimental analysis is carried to evaluate tyre strength of the reinforcing material in bias-ply tyre of truck. In this test, a plunger is forced perpendicular to the tread. The plunger penetration distance & the force test points are then used to calculate an average breaking energy that must exceed minimum breaking energy. This help to find out the flexibility of tyre. In order to improve design of solid tyres, it is necessary to be able to predict the mechanical behaviour of the tyre under applied load. Also stress-strain and strain energy density distribution developed should be analysed. This can lead to the identification of locations at risk to damages and also results in a guidance for components and compound formulations optimisation.**

**Keywords – Tyre deformation**

## I. INTRODUCTION

A tire or tyre is a ring shaped covering that fits around a wheel's rim to protect .It is made of an elastic material, natural or synthetic rubber, reinforced with textile cord ply fabric carcass, enclosing bead rings. In a bias ply tyre, the carcass ply cords extend to the bead diagonally to form a structure. Tread is area which is in actual contact with the road surface. It consist of following constructions as shown in figure 1.1

*1.1 Inner liner:* The inner liner is an extruded halobutyl or butyl based rubber sheet compounded with additives that result in low air permeability. The inner liner assures that the tyre will hold high-pressure air inside, without the air gradually diffusing through the rubber structure.

*1.2 Body ply:* The body ply is a calendered sheet consisting of one layer of rubber, one layer of reinforcing fabric, and a second layer of rubber. The earliest textile used was cotton; later materials include rayon, nylon, polyester, and Kevlar. Passenger tyres typically have one or two body plies. Body plies give the tyre structure strength. Truck tyres, off-road tyres, and aircraft tyres have progressively more plies. The fabric cords are highly flexible but relatively inelastic.

*1.3 Sidewall:* Sidewalls are non-reinforced extruded profiles with additives to give the sides of the tyre good abrasion resistance and environmental resistance. Additives used in sidewall compounds include antioxidants and antiozonants. Sidewall extrusions are nonsymmetrical and provide a thick rubber area to enable molding of raised letters. The sidewalls give the tyre resistance against the environment.

*1.4 Beads:* Beads are bands of high tensile-strength steel wire encased in a rubber compound. Bead wire is coated with special alloys of bronze or brass. Coatings protect the steel from corrosion. Copper in the alloy and sulfur in the rubber cross-link to produce copper sulfide, which improves bonding of the bead to the rubber. Beads are inflexible and inelastic, and provide the mechanical strength to fit the tyre to the wheel. Bead rubber includes additives to maximize strength and toughness.

*1.5 Bead Filler:* The filler is a triangular extruded profile that mates against the bead. The filler provides a cushion between the rigid bead and the flexible inner liner and body ply assembly. Alternatively called "apex" (as in the diagram above).

*1.6 Tread:* The tread is a thick extruded profile that surrounds the tyre carcass. Tread compounds include additives to impart wear resistance and traction in addition to environmental resistance. Tread compound development is an exercise in compromise, as hard compounds have long wear characteristics but poor traction whereas soft compounds have good traction but poor wear characteristics.

*1.7 Carcass:* The rubber-bonded cord structure of a tyre integral with the bead which provides the requisite strength to carry the load.

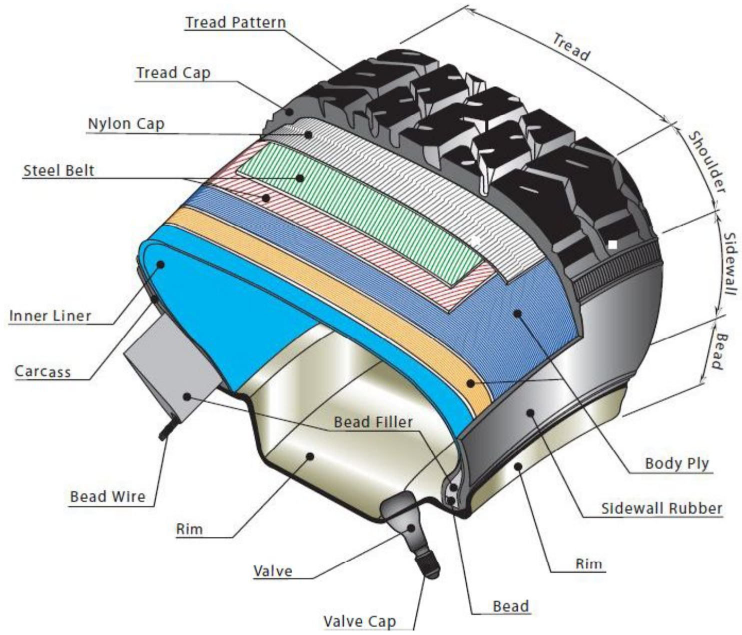



Fig1.1: Cross section view of tyre[14]

## II. PROBLEM DESCRIPTION

Tyre is a part of vehicle which is in actual contact with road surfaces. Solid tyres usually face the major problems of failure due to heat buildup and riding comfort. In order to improve design of solid tyres, it is necessary to be able to predict the mechanical behavior of the tyre under applied load. Solid tyres mostly consist of layers of the various rubber compounds of varying thickness to form a composite structure. The solid tyre being modeled constitutes of three rubber layers with different properties and steel wires. The arrangement of rubber layers in solid tyre can affect the distribution of strain energy density and deflection under loading affects tyre performance.

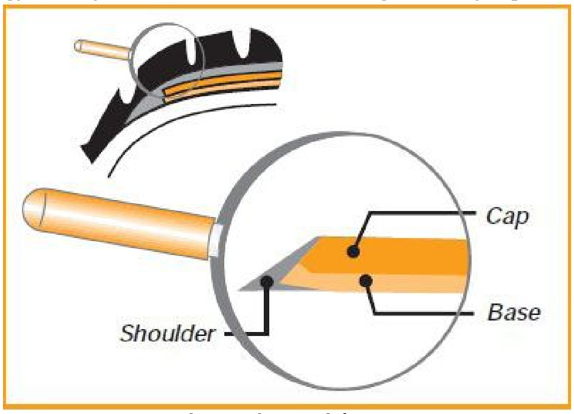



Fig 1.2: The area showing deformation more

There were few problems faced by X tyre that as shown in figure 1.2 .It has tread area at the top below that it has breakers and the carcass. According to the observation & testing it was found that Centre portion was wearing out more so the tyre was deflecting more. So it was task to vary the thickness of plies without changing outer diameter. Base area consists of carcass & cap area consists of tread below that breakers. Base area was suffering oxidation when comes in contact with atmosphere which is to be avoided. If cap area becomes less & base area increases it will directly touch the tread causing wear out. In X tyre , 1st band consist of 3 plies, 2nd band has 3 plies,3rd band has 2 plies ,while two breakers.

## III. EXPERIMENTAL ANALYSIS ON PLUNGER TESTING MACHINE SETUP

*Introduction*

The test was designed to evaluate the strength of the reinforcing materials in bias-ply tyres and their resistance to road hazards. The tyre strength test in plunger testing machine consists of forcing a 38mm(1.5 inch) for light truck diameter cylindrical steel plunger with a hemispherical end perpendicularly into to the centermost tread rib of a mounted and inflated tyre at the rate of 50-mm (2-inches) per minute. This is repeated at five equally spaced points around the circumference of the tyre as per the standards, the force and penetration (travel) of each plunger application is recorded. If the tyre fails to break before the plunger is stopped by reaching the rim (plunger "bottom-out"), the force and penetration is recorded as the rim is reached. The test points are then used to calculate an average breaking energy W = [(FxP)/2], where W = Energy, inch-pounds; F =Force, pounds; and P = Penetration, inches. To pass, the average energy must exceed the appropriate "minimum breaking energy" specified for that tyre.

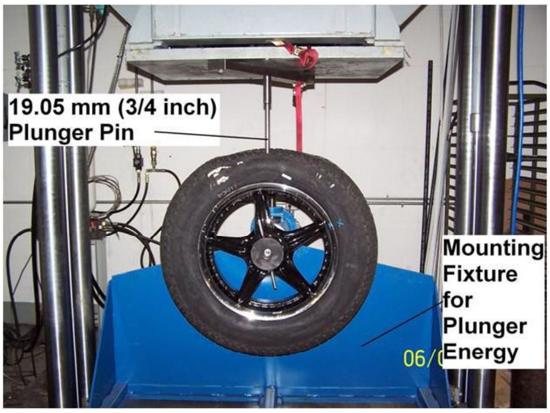



Fig 3.1: Plunger testing machine

*Test procedure*

The test is conducted by installing the tyre/wheel assembly in the test machine and forcing a 38-mm diameter cylindrical steel plunger with a hemispherical end perpendicularly into the tread rib as near the centerline as possible, avoiding penetration into the tread groove, at a rate of 50-mm per minute. The force and penetration is recorded for the five test points equally spaced around the circumference of the tyre. If the tyre fails to break before the plunger is stopped by reaching the rim, the force and penetration as the rim is reached is recorded and used to calculate the energy for each test point by means of one of the following formulas:

$$W = \frac{F \times P}{2000}$$

Where W = Energy, joules;
F = Force, Newtons;
P = Penetration, mm; or

$$W = \frac{F \times P}{2}$$

Where W = Energy, inch-pounds;

F = Force, pounds;
P = Penetration, inches.

To determine the breaking energy value for the tyre, the average of the five values is obtained. The maximum energy is calculated at the point the tyre ruptures in terms of tread separation, ply separation, cord separation by a close visual examination of the tyre[1].

## IV. PLUNGER TESTING MACHINE ON “X” TYRE

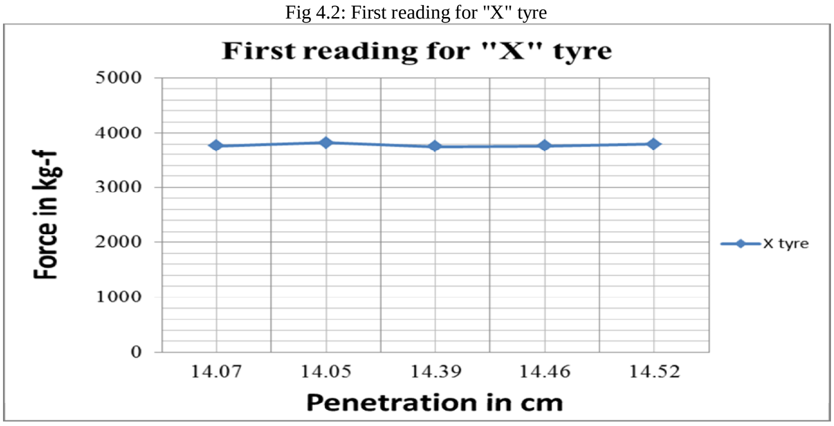
In X tyre there are total 6 inner ply, 2 outerply, 2 Breakers & Innerliners. The topmost layer is tread then 2 breakers , carcass consisting on total 8 plies. They have varying thickness /gauges.

Table 4.1 First Reading for“ X” tyre

| Sr.No | F Force (kg-f) | P Penetration (cm) | Breaking energy $W = \frac{F \times P}{2}$ Kg-f-cm | Tube failure |
|---|---|---|---|---|
| 1 | 3766.5 | 14.07 | 26497.3 | NO |
| 2 | 3823.6 | 14.05 | 26860.8 | NO |
| 3 | 3753.0 | 14.39 | 27002.8 | NO |
| 4 | 3762.6 | 14.46 | 27203.6 | NO |
| 5 | 3800 | 14.52 | 27588.0 | YES |

Average breaking energy: 27030.5kg-f-cm
Minimum plunger energy specified: 21310 kg-f-cm
Range of breaking energy: 26497.3 to 3800 kg-f-cm
i.e. 126.68%

Fig 4.2: First reading for "X" tyre




## V. PLUNGER TESTING MACHINE ON “Y” TYRE

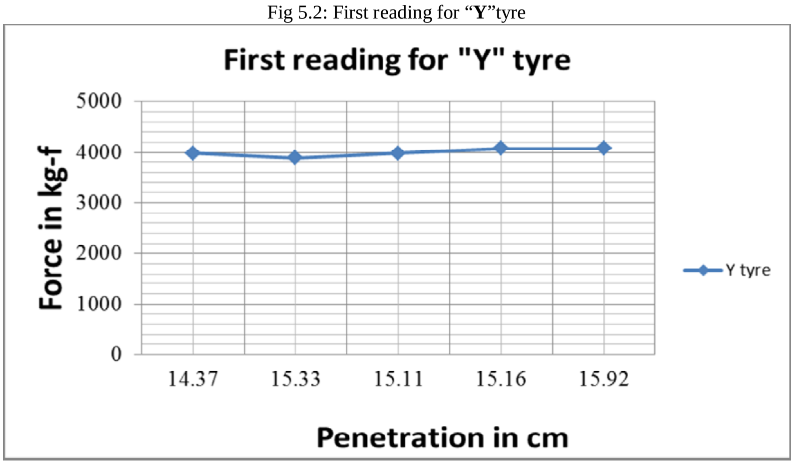
In Y tyre there are total 8 inner ply, 2 outer ply , 2 Breakers &Innerliners. The topmost layer is tread then 2 breakers, carcass consisting on total 10 plies. They have varying thickness /gauges.In this tyre we have added 2 innerply more which increses total strength of tyre.

Table 5.1 First Reading for " Y " tyre

| Sr. No | F Force (kg-f) | P Penetration(cm) | Breaking energy $W = \frac{F}{}$ Kg-f-cm | Tube failure |
|---|---|---|---|---|
| 1 | 3982.7 | 14.37 | 28615.7 | NO |
| 2 | 3889.9 | 15.33 | 29816.1 | NO |
| 3 | 3979.69 | 15.11 | 30066.6 | NO |
| 4 | 4071.50 | 15.16 | 30862 | NO |
| 5 | 4071.10 | 15.92 | 32406 | yes |

Average breaking energy: 3035.28 kg-f-cm
Minimum plunger energy specified: 21310 kg-f-cm
Range of breaking energy: 28615.7 to 32406 kg-f-cm
i.e. 142.43 %

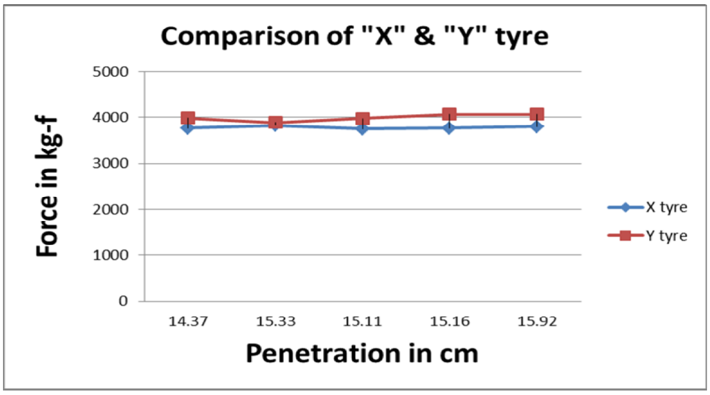
Fig 5.2: First reading for "**Y**"tyre




VI. RESULTS

When we compare that "X" & "Y" tyre we have found that , Y tyre has more strength about 20% of increase in breaking energy of tyre. WE can also see the difference between two by plotting the graph. Also found that the X tyre undergoes more deformation in less force as compared to Y tyre

Fig 6.1 Comparison of “X”&“Y” tyre




## VII. CONCLUSIONS

It has been found that in X tyre there are only 6 innerplies and was having less minimum breaking energy while in Y tyre due to increase in 2 plies that has become total 8 plies there has been total 20% of increse in minimum breaking energy.This conludes that without changing the outer diameter of tyre and by changing , the strength of tyre can be increased.

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