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ANALYSIS OF SIDE-WALLED REINFORCED RUN FLAT TYRE

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Abstract – *The first rubber tires appeared in the mid-1800s. They were solid or cushion tires in which the rubber itself carried the load, absorbed shocks, and resisted cutting and abrasions. The pneumatic or air-filled tire, which carried the load and absorbed shocks by the compressed air in the tire casing, was patented as early as 1845. Solid rubber tires were preferred over pneumatic tires because of their durability, so pneumatic tires fell into disuse.*

The first use of pneumatic tires for automobiles was pioneered by the Michelin brothers, André and Édouard. They equipped a car with pneumatic tires and drove it in the 1895 Paris-Bordeaux road race. Though André and Édouard didn't win the race, they generated popular interest in pneumatic tires, and Michelin & Cie became a leading producer of tires in Europe. At the same time, solid rubber tires disappeared from the highways, mostly because of legislation that discouraged their use because they were hard on the roads.
In 1898 Goodyear Tire and Rubber Company—named after George Goodyear, the discoverer of vulcanized rubber—was formed in America by Frank Seiberling. For the next fifty years automobile tires were made up of an inner tube that contained compressed air and an outer casing that protected the inner tube and provided traction.

Michelin first introduced steel-belted radial tires in Europe in 1948. Radial tires are so named because the ply cords radiate at a 90 degree angle from the wheel rim, and the casing is strengthened by a belt of steel fabric that runs around the circumference of the tire. In radial tires, the ply cords are made of nylon, rayon, or polyester. The advantages of radial tires include longer tread life, better steering characteristics, and less rolling resistance, which increases gas mileage.

Thus, the pneumatic radial tires found maximum usage in most cars manufactured since the late 1990s.

However, since a few years, a new technology has emerged which combines the benefits of a pneumatic tyre and a solid tyre, which makes it even safer, and this technology is Run-flat tires. These tyres have the similar construction to that of pneumatic radial tyres but with an added reinforcement to the tyre sidewall in an event of a puncture. Punctures at high speeds can result into immediate loss of traction, which plagues road travel safety but run-flat tyres are capable of the loads even after loss of pressure in the tyre.

This project aims at analysing the run-flat tyre and comparing it with pneumatic radial tyre for similar loading conditions. The main aim of this project is the demonstration of the usefulness of a run-flat tyre over normal pneumatic radial tyre. However, the methods to manufacture will not be discussed as it is a vast area of research in polymer engineering. Thus mechanical properties of standard materials will be used,

Autodesk Inventor 2015 was used to design the three dimensional models.

Key Words: Pneumatic tires, Radial tyres, Pneumatic tires, run-flat tyres, Reinforcement, Ansys, Inventor Professional.

1. INTRODUCTION

Two different tires (Design closest to the current available products.) have been analysed using FEM:

1) Run-Flat tyre (Design closest to the current available products.)

2) Radial Tyre

When a traditional tyre experiences a sudden loss of tyre pressure, the rim of the wheel brings the full weight of the vehicle to bear on the collapsed sidewalls. Once the sidewalls collapse, the vehicle can barely be manoeuvred and the tyres are destroyed after a short distance. Run-flat technology in turn promotes maximum safety in the event of a pressure loss. The secret of the Run-flat tyre lies in the reinforced sidewalls of the tyre. The reinforced sidewalls supports the rim, should the tyre suffer a loss of tyre pressure, and prevents the tyre walls from becoming squashed between the wheel rim and the road. The geometrical models of these structures have been prepared in Autodesk Inventor Professional Student 2015 CAD software.

The following images show the dimensions of parts and 3D isometric views of the final models. The Finite Element Method (FEM) has been employed for the purpose of analysis. ANSYS 15.0, a widely used software for structural analysis using FEM, has been used for all the computer based analysis operations of this project.

2. MANUFACTURING OF TIRES

Pneumatic tires are manufactured according to relatively standardized processes and machinery, in around 455 tire factories in the world. With over 1 billion tires manufactured worldwide annually, the tire industry is the major consumer of natural rubber. Tire factories start with bulk raw materials such a synthetic rubber (60% -70% of total rubber in the tire industry Carbon rubbers, chemicals and produce numerous specialized components that are assembled and cured. This article describes the components assembled to make a tire, the various materials used, the manufacturing processes and machinery, and the overall business model.

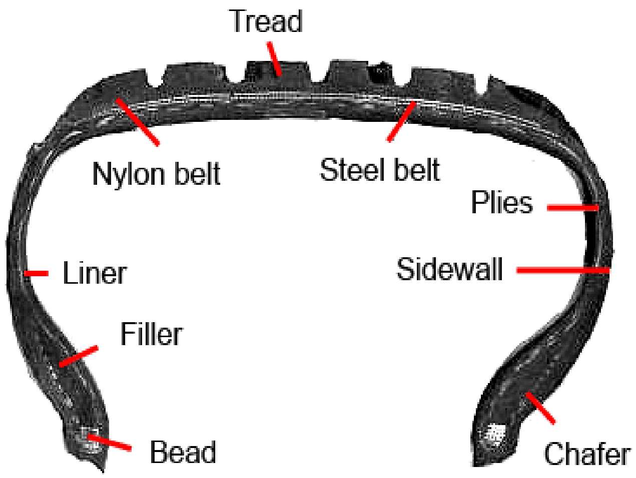

Fig:-1 Tyre Section

The tire is an assembly of numerous components that are built up on a drum and then cured in a press under heat and pressure. Heat facilitates a polymerization reaction that crosslinks rubber monomers to create long elastic.

A. Inner Liner

The inner liner is an extruded halobutyl rubber sheet compounded with additives that result in low air permeability. The inner liner assures that the tire will hold high-pressure air inside, without the air gradually diffusing through the rubber structure.

B. 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 tires typically have one or two body plies. Body plies give the tire structure strength. Truck tires, off-road tires, and aircraft tires have progressively more plies. The fabric cords are highly flexible but relatively inelastic.

C. Side

Sidewalls are non-reinforced extruded profiles with additives to give the sides of the tire 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 tire resistance against the environment. Sidewall plays an important role in strengthening of tire.

D. 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 tire to the wheel. Bead rubber includes additives to maximize strength and toughness of tyres.

E. Apex

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

F. Belt package

Belts are calendered sheets consisting of a layer of rubber, a layer of closely spaced steel cords, and a second layer of rubber. Belts give the tire strength and dent resistance while allowing it to remain flexible. Passenger tires are usually made with two or three belts.

G. Tread

The tread is a thick extruded profile that surrounds the tire 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.

H. Cushion gum

Many higher-performing tires include an extruded component between the belt package and the tread to isolate the tread from mechanical wear from the steel belts.

3. RADIAL TIRES

A radial tire (more properly, a radial-ply tire) is a particular design of vehicular tire. In this design, the cord plies are arranged at 90 degrees to the direction of travel, or radially (from the center of the tire). Radial tire construction climbed to 100% market share in North America following Consumer Reports finding the superiority of the radial design in 1968.

4. RUN FLAT TIRES

A run-flat tire is a pneumatic vehicle tire that is designed to resist the effects of deflation when punctured, and to enable the vehicle to continue to be driven at reduced speeds (under 56 mph (90 km/h)), and for limited distances (generally between 10 mi (16 km) to 50 mi (80 km), depending on the type of tire).

5. REINFORCEMENT OF SIDEWALL IN RUN-FLAT TIRES

A. Polyimide + Glass Fibre

Polyimide polymer has very high compressive yield strength and glass fibers have a very high tensile strength which makes this material most suitable for use in sidewalls.

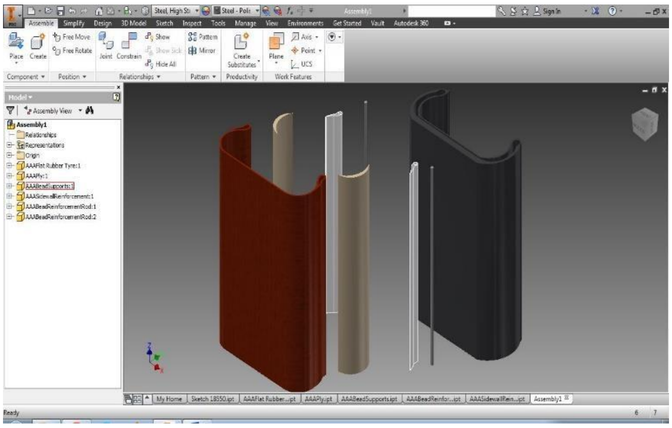

Fig:-2 All components of Run Flat tyre

The material properties for the reinforced material used is as follows:

Properties of Outline Row 3: Polyimide & Glass Fiber

	A	B	C	D	E
1	Property	Value	Unit		
2	Density	1560	kg m^-3		
3	Isotropic Secant Coefficient of Thermal Expansion				
6	Isotropic Elasticity				
12	Tensile Yield Strength	1.5E+08	Pa		
13	Compressive Yield Strength	2.22E+08	Pa		
14	Tensile Ultimate Strength	1.5E+08	Pa		
15	Compressive Ultimate Strength	2.5E+08	Pa		

Fig:-3 Material Properties of Polyamide & Glass fiber

6. ANALYSIS OF RADIAL TIRES

Analysis of Radial tires is done on Ansys Workbench by importing the assembly file from Inventor Professional 2015. A fixed base support is provided at the bottom of the tyre and pressure is applied from above. A pressure around 175000 Pa is applied on the tire and solved for deformation and other stresses accordingly.

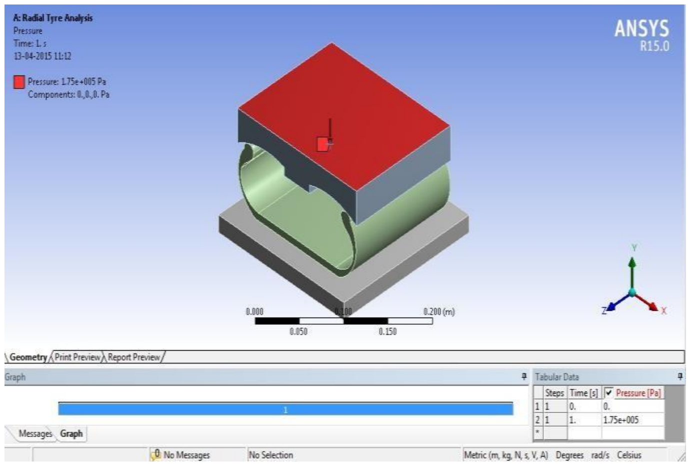

Fig:-4 Applying constrains for radial tires

The total deformation observed after analysis of radial tire is 1.3626 meters.

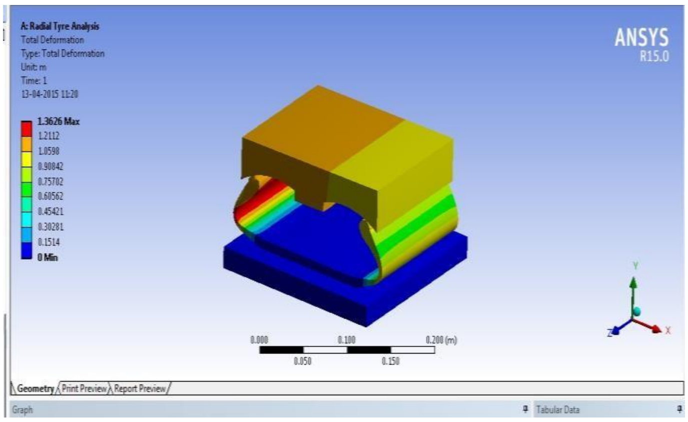

Fig:-5 Deformation for radial tires

The Equivalent Von- Mises stress observed is 2.4318E7 Pa

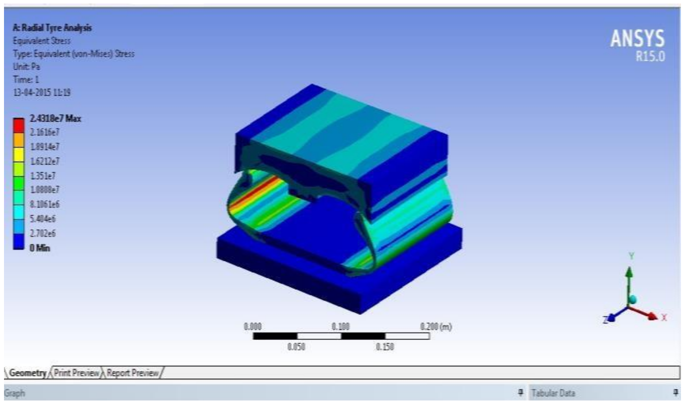

Fig:-6 Von-Mises stress for radial tires

The Equivalent Elastic Strain observed is 15.407 (Extremely high value due to failure)

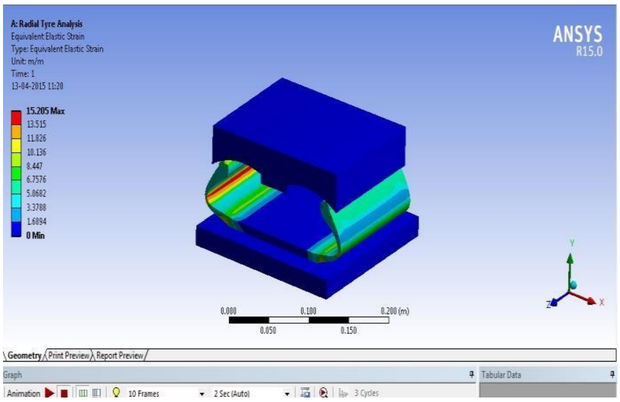

Fig:-7 Equivalent Elastic Strain for radial tires

7. ANALYSIS OF RUN FLAT TIRES

Analysis of Run flat tires is done similarly as radial tires. The assembly of run flat tyrs is different. The sidewall is reinforced with polyamide and glass fiber, whereas in radial tyre it is uniform. Fixed support is provided at the base and pressure of 175000 Pa is applied from above and solved for deformation and other stresses

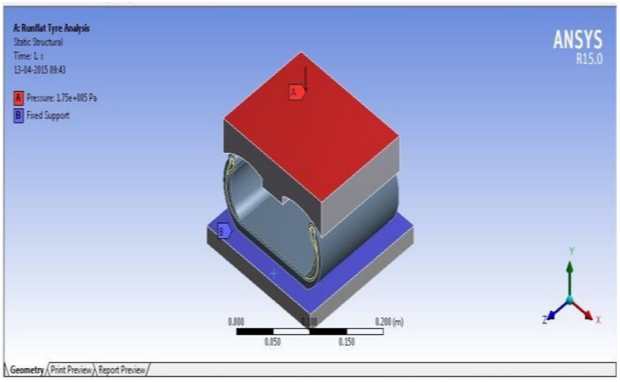

Fig:-8 Applying constrains for run flat tires

The Deformation observed after analysis of run flat tires is 7.4926E-6m

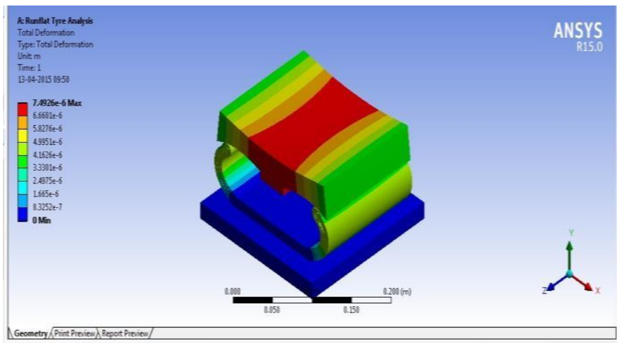

Fig:-9 Deformation for run flat tires

The Equivalent Von- Mises stress observed is 1.0658E7 Pa.

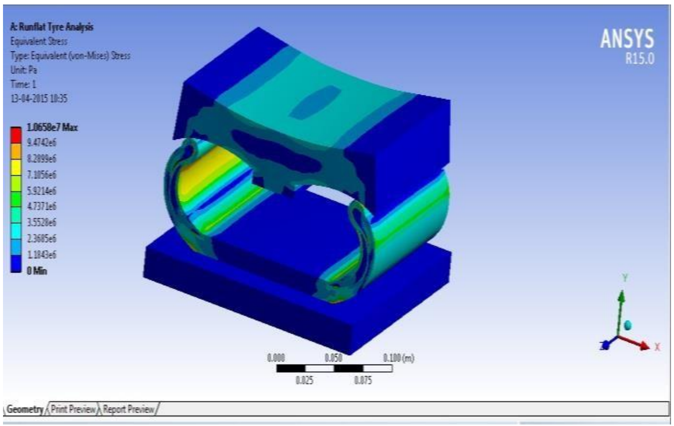

Fig:-10 Von-Mises stress for run flat tires

The Equivalent Elastic Strain observed is 7.5934e-4

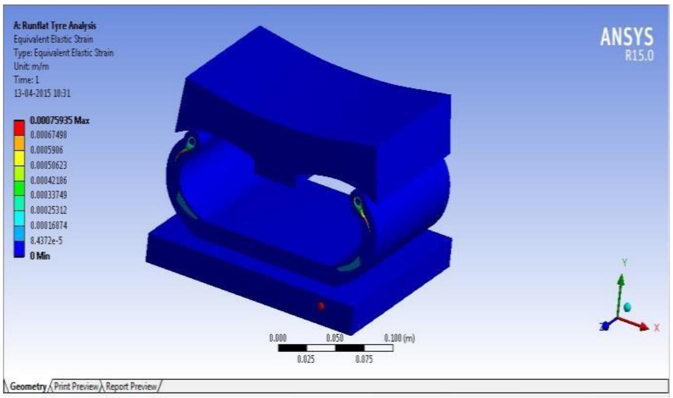

Fig:-11 Equivalent Elastic Strain for run flat tires

8. RESULTS

Table 1: Comparison of obtained results between the two tyres:

Physical Quantity	Radial Tyre	Run flat Tyre
Total Deformation	1.3626 m	**7.4926E-6 m**
Equivalent Stress (Von Mises)	2.4318E7 Pa	**1.0658E7 Pa**
Maximum Shear Stress	1.402E7 Pa	**5.4746E6 Pa**
Equivalent Elastic Strain	15.407(Extremely high value due to failure)	**7.5934e-4**

The values displayed in the above table are the maximum values of the respective physical quantities obtained in the analysis of the structures.

9. CONCLUSION

As seen from the results table above which is derived from the analysis of radial and run flat tyres we can draw the following conclusions.

The deformation seen in a punctured run flat tyres is much less as compared to a punctured pneumatic radial tyre thus making the use of run flat tyre safe.

The values of stresses and strains are also less for run flat tyres.

Thus by using the optimum reinforcing material whose design was derived from run-flat tyre products in the market and from various researches ,the analysis using ANSYS software was successfully performed.

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