Modelling And Analysis of Honeycumb Airless Tire

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Abstract- *The airless tire is a single unit replacing the pneumatic tire, wheel and tire assembly. It replaces all the components of a typical radial tire and is comprised of a rigid hub, connected to a shear band by means of flexible, deformable polyurethane spokes a nd a tread band, all functioning as a single unit. The Tweel, a kind of airless tire, though finds its generic application in military and earth moving applications due to its flat proof design can also render the pneumatic tire obsolete in domestic cars. Our proj ect involves design and analysis of an airless tire for domestic cars; this will be followed by a stress analysis study. The model will be do in Pro E and analysis will do in Ansys.*

I. INTRODUCTION

The Tweel (a portmanteau of *tire* and *wheel*) is an airless tire design concept developed by the French tire company Michelin. Its significant advantage over pneumatic tires is that the Tweel does not use a bladder full of compressed air, and therefore it cannot burst, leak pressure, or become flat. Instead, the Tweel assembly's inner hub connects to flexible polyurethane spokes which are used to support an outer rim and these engineered compliant components assume the shock-absorbing role provided by the compressed air in a traditional tire.

Sometimes, we get so used to a certain product that no true changes are ever really made for years, decades even. So begins an article discussing the development of airless tires, something that has become more prevalent in the past few years. A few tire companies have started experimenting with designs for non pneumatic tires including Michelin and Bridgestone, but neither design has made it to mass production. Creating a new non pneumatic design for tires has more positive implications than one might think. For one thing, there are huge safety benefits. Having an airless tire means there is no possibility of a blowout, which, in turn, means the number of highway accidents will but cut significantly. Even for situations such as Humvees in the military, utilizing non pneumatic tires has a great positive impact on safety. Tires are the weak point in military vehicles and are often targeted with explosives. If these vehicles used airless tires, this would no longer be a concern. There is also an environmental benefit to using this type of tire. Since they never go flat and can be retreaded, airless tires will not have to be thrown away and replaced nearly as often as pneumatic tires. This will cut down landfill mass significantly. Because of the benefits, I believe that it is extremely important that research and production of airless tires is continued and increased. This type of innovation works well in conjunction with several engineering codes of ethics, and thus should be embraced by engineers everywhere. Cars are things that people use every day, so any improvements over existing designs would affect the lives of the majority of people. Learning about such a topic, therefore, I believe holds extreme value especially for us freshmen engineering students. In doing research into these kinds of topics that hold significant meaning, we can see that what we will do can make a difference.

Tire Technology

Before the technology of airless tires is discussed, it is important for the reader to understand how standard pneumatic tires function, and what advantages and disadvantages there are to using them. A brief overview of the general concepts of airless tires will then follow.

Pneumatic Tires

The basic design of all pneumatic tires is very similar, even though there are many different types. They all include an inner core that holds pressurized air which is then covered with a layer of rubber that comes in contact with the road, called a tread. The tread helps keep traction with the road and prevents slipping and skidding. The tread has the tendency to wear down over time, so if the tire has not gone flat, a person will usually replace it at this point.

A main reason for using pneumatic tires is the deformation that occurs during rotation. As the tire rolls, the weight of the car pushing down on it causes the tire to flatten slightly. This, in turn, causes the tire to have a larger surface area to be in contact with the ground, which makes for better traction. It also gives a slight cushioning effect, making running over small rocks or debris unnoticeable. Or, as writer for How Stuff Works Ed Grabianowski puts it, If you've ever taken a ride in an old fashioned carriage with wooden wheels, you know what a difference a pneumatic tire makes.

Pneumatic tires have their advantages, but they also have their disadvantages as well. The possibility of a blowout or flat (when air is let out suddenly from the tire) is a major concern because they have the tendency to cause severe accidents. The task of regulating tire pressure is also a disadvantage because consumers are usually not very good at it. Although it may help with traction to have the tires a little flat, it comes at the price of handling. When there is not enough air pressure in the tire, the sidewalls flex causing the tire to not quite follow the desired line of steering.

It is because of these disadvantages that tire companies have taken an interest in designing airless tires

Airless Tires

Although each company has a different design approach to the airless tire, most share the same basic concepts. The main concept that must be considered when trying to design a non pneumatic tire is the issue of deformation. The tire must be strong enough to hold the car and withstand a large amount of abuse, as well as be able to deform slightly when it comes in contact with the road. Most companies that have designed airless tires have used a strong, metal core with supports radiating outward made of some type of composite material. The tire is then usually treaded with a rubber compound.

There are many different approaches to the design of the supports. This accounts for the main differences between the overall designs of each company's version of the airless tire.

Advantages of airless tyres

- Eliminates air leaks or tyre blow outs.
- With no air pressure you are left with consistent economy and handling.
- Its flexibility provides an increase in surface area of contact.
- No maintenance needed.
- To lengthen tread life.
- Facilitate recycling.
- Makes Vehicle more Efficient have high lateral strength for better handling without a loss
- in comfort.
- Vehicle remains under control even in emergency brake.
- Remains mobile even with some of the spokes damaged or missing.
- Durability & Long Life.
- Can take gunfire or explosion.
- Less environmental impact.

Disadvantages of airless tyres

- Lack of adjustability One of the biggest disadvantages of the Tweel is that once it has been manufactured, it cannot be adjusted. In this case if the car needed a different kind of setting, a whole new set of Tweels will be required. On the plus side Tweels are made with five times the lateral stiffness compared to pneumatic tyres, enabling very responsive handling.
- Not as economic as pneumatic tyres Michelin are currently working on enabling the Tweels to be as fuel efficient as pneumatic tyres. Currently they are within 5% of the rolling resistance and mass levels.
- Vibration This could be one of the Tweels biggest downsides. Vibrations become considerate once a vehicle is driving above 50 mph, while causing a lot of noise. Also disturbing is the amount of heat the Tweels generate. Long distance journey with tweels would be very unpleasant unless these areas are improved upon.
- Different Manufacturing process Another problem is that creating airless tyres requires a totally different manufacturing process. At this point of time, the tyre industry revolves around the manufacture of traditional pneumatic tyres. To modify factories and service equipment would be a major change, and the facilities just don’t exist yet.

Applications of airless tyres

- They are used on some small vehicles such as riding lawn mowers and motorized golf carts.
- They are also used on heavy equipment such as backhoes, which are required to operate on sites such as building demolition.

Types of tires

Design

The Tweel consists of a band of conventional tire rubber with molded tread, a shear beam just below the tread that creates a compliant contact patch, a series of energy absorbing polyurethane spokes, and an integral inner rim structure. Both the shear beam and the polyurethane spokes can be designed to provide a calibrated directional stiffness in order that design engineers are able to control both how the Tweel handles and how it handles loads. The inner hub structure may be either rigid or compliant, depending on the application requirements, and as such may contain a matrix of deformable plastic structures that flex under load and subsequently return to their original shape. By varying the thickness and size of the spokes, Michelin can manipulate the design elements to engineer a wide array of ride and handling qualities. The tread can be as specialized as any of today's tires and is replaceable when worn.

Benefits and Drawbacks

Potential benefits of the Tweel include not only the obvious safety and convenience of never having flat tires, but also, in automotive applications, the Tweel airless tire has the potential to be able to brake - a significant performance compromise that is inherent to pneumatic tires. Unlike a pneumatic tire, a Tweel can be designed to have high lateral stiffness while simultaneously having low vertical stiffness. This can be achieved because, in the design elements of a Tweel, the vertical and lateral stiffness are not inseparably linked and can thus be optimized independently. Because there is no air bladder under the tread, tread patterns can, if desired, even incorporate water evacuation through holes in the design thus eliminating or significantly reducing hydroplaning. Michelin expects the tread to last two to three times as long as a conventional tire. Because the tread rubber around the outer circumference is replaceable when worn (as opposed to disposing of a whole worn tire), the potential environmental impact of a Tweel airless tire can be less than that of a conventional pneumatic tire.

II. MATERIALS

Introduction

A composite material is usually made up of at least two materials out of which one is the binding material, also called matrix and the other is the reinforcement material. By definition, composite materials consist of two or more constituents with physically separable phases. Composites are materials that comprise strong load carrying material (known as reinforcement) imbedded in weaker material (known as matrix). Reinforcement provides strength and rigidity, helping to support structural load. The matrix or binder maintains the position and orientation of the reinforcement. Significantly, constituents of the composites retain their individual, physical and chemical properties yet together they produce a combination of qualities which individual constituents would be incapable of producing alone. The reinforcement may be platelets, particles or fibers and are usually added to improve mechanical properties such as stiffness, strength and toughness of the matrix material.

Advantages of Composites

Light Weight - Composites are light in weight, compared to most woods and metals. Their lightness is important in automobiles and aircraft, for example, where less weight means better fuel efficiency (more miles to the gallon). People who design airplanes are greatly concerned with weight, since reducing a craft’s weight reduces the amount of fuel it needs and increases the speeds it can reach. Some modern airplanes are built with more composites than metal including the new Boeing 787, Dream liner.

- High Strength - Composites can be designed to be far stronger than aluminium or steel. Metals are equally strong in all directions. But composites can be engineered and designed to be strong in a specific direction.

- Corrosion Resistance - Composites resist damage from the weather and from harsh chemicals that can eat away at other materials. Composites are good choices where chemicals are handled or stored. Outdoors, they stand up to severe weather and wide changes in temperature.

- High-Impact Strength - Composites can be made to absorb the sudden force of a bullet, for instance, or the blast from an explosion. Because of this property, composites are used in bulletproof vests and panels, and to shield airplanes, buildings, and military vehicles from explosions.

Nylon 4-6 (polyamide)

The name "nylons" refers to the group of plastics known as polyamides. Nylons are typified by amide groups (CONH) and encompass a range of material types (e.g. Nylon 6,6; Nylon 6,12; Nylon 4,6; Nylon 6; Nylon 12 etc.), providing an extremely broad range of available properties. Nylon is used in the production of film and fiber, but is also available as a moldings compound.

Nylon is formed by two methods. Dual numbers arise from the first, a condensation reaction between demines and dibasic acids produces a nylon salt. The first number of the nylon type refers to the number of carbon atoms in the demine, the second number is the quantity in the acid (e.g. nylon 6,12)

The second process involves opening up a monomer containing both amine and acid groups known as a lactam ring. The nylon identity is based on the number of atoms in the lactam monomer (e.g. nylon 4-6 or nylon 12 etc).

Polyethylene

This Polyolefin is readily formed by polymerizing propylene with suitable catalysts, generally aluminum alkyl and titanium tetrachloride. Polypropylene properties vary according to molecular weight, method of production, and the copolymers involved. Generally polypropylene has demonstrated certain advantages in improved strength, stiffness and higher temperature capability over polyethylene. Polypropylene has been very successfully applied to the forming of fibers due to its good specific strength which is why it is the single largest use of polyethylene. Polyethylene also happens to be one of lightest plastics available with a density of 0.905 g/cm2.

Material Properties:

Properties	Nylon4-6	Polyethylene
Young's Modulus (GPa)	4.8	2.7
Poisson's Ratio	0.4	0.4
Density (kg/m^3)	1150	1400

Properties of Materials

III. INTRODUCTION TO DESIGN SOFTWARES

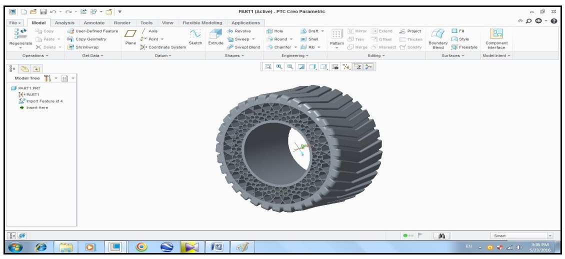
Computer Aided Design (CAD)

CAD is used to design and develop products, which can be goods used by end consumers or intermediate goods used in other products. Cadis also extensively used in the design of tools and machinery used in the manufacturer of components. Cadis also used in the drafting and design of all types of buildings, from small residential types (house) to the largest commercial and industrial types. CAD is used thought the engineering process from the conceptual design and layout, through detailed engineering and analysis of components to definition of manufacturing methods.

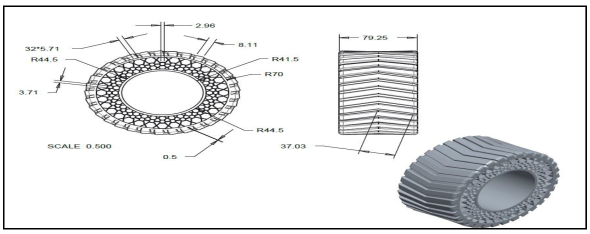
Introduction to PRO/E

PRO/E is the industry's de facto standard 3D mechanical design suit. It is the world's leading **CAD/CAM /CAE** software, gives a broad range of integrated solutions to cover all aspects of product design and manufacturing. Much of its success can be attributed to its technology which spurs its customer's to more quickly and consistently innovate a new robust, parametric, feature based model. Because that ***PRO/E*** is unmatched in this field, in all processes, in all countries, in all kind of companies along the supply chains.***PRO/E*** is also the perfect solution for the manufacturing enterprise, with associative applications, robust responsiveness and web connectivity that make it the ideal flexible engineering solution to accelerate innovations. ***PRO/E*** provides easy to use solution tailored to the needs of small medium sized enterprises as well as large industrial corporations in all industries, consumer goods, fabrications and assembly. Electrical and electronics goods, automotive, aerospace, shipbuilding and plant design. It is user friendly solid and surface modeling can be done easily.

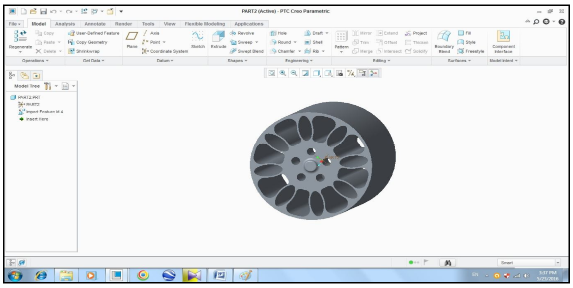
MODALING



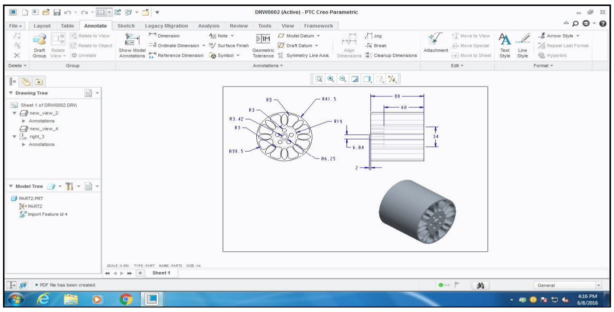
Outer rubber portion (tire)



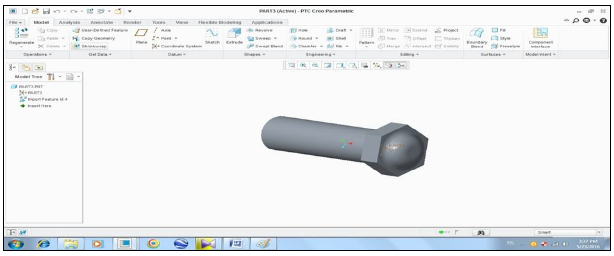
Detail view of outer rubber portion (tire)



Metal Rim



Detail view of Metal Rim



Bolt

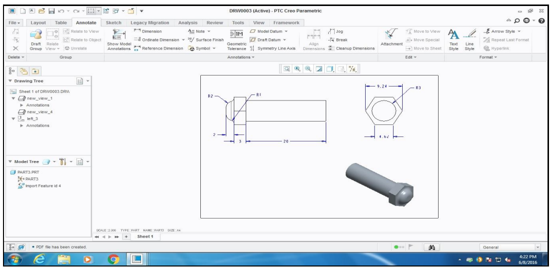
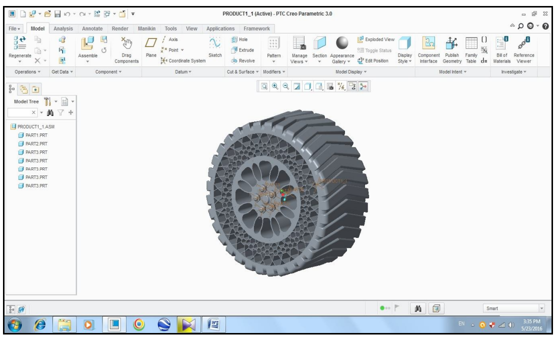


Fig- 4.6 : Detailed view of Bolt



Total Assembly view of Air less tire.

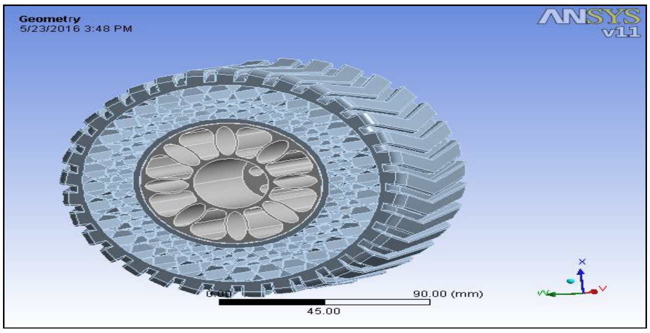
Introduction to FEM

The finite element method is numerical analysis technique for obtaining approximate solutions to a wide variety of engineering problems. Because of its diversity and flexibility as an analysis tool, it is receiving much attention in almost every industry. In more and more engineering situations today, we find that it is necessary to obtain approximate solutions to problem rather than exact closed form solution. It is not possible to obtain analytical mathematical solutions for many engineering problems. The finite element method has become a powerful tool for the numerical solutions of a wide range of engineering problems. It has been developed simultaneously with the increasing use of the high- speed electronic digital computers and with the growing emphasis on numerical methods for engineering analysis. This method started as a generalization of the structural idea to some problems of elastic continuum problem, started in terms of different equations.

PROCEDURE

Importing the Model

In this step the PRO/E model is to be imported into ANSYS workbench as follows, In utility menu file option and selecting import external geometry and open file and click on generate. To enter into simulation module click on project tab and click on new simulation



Imported from Pro/E

Defining Material Properties

To define material properties for the analysis, following steps are used. The main menu is chosen select model and click on corresponding bodies in tree and then create new material enter the values again select simulation tab and select material.

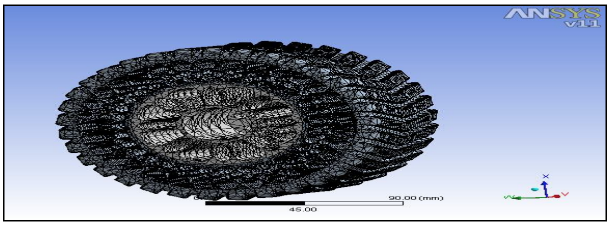
Defining Element Type

To define type of element for the analysis, these steps are to be followed, Chose the main menu select type of contacts and then click on mesh-right click-insert method

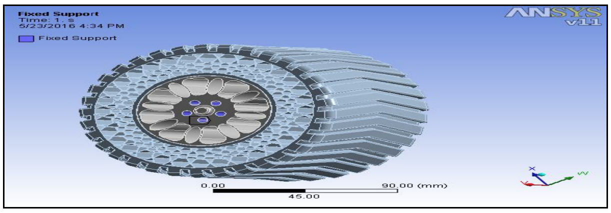
Method - Tetrahedrons
Algorithm - Patch Conforming
Element Mid side Nodes – Kept

Meshing the model

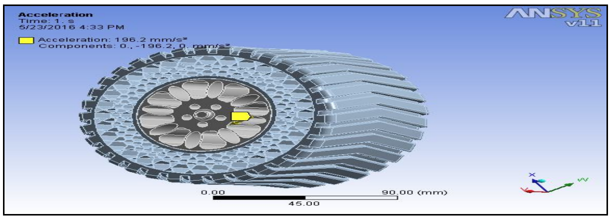
To perform the meshing of the model these steps are to be followed, Chose the main menu click on mesh- right click- insert sizing and then select geometry enter element size and click on edge behavior curvy proximity refinement



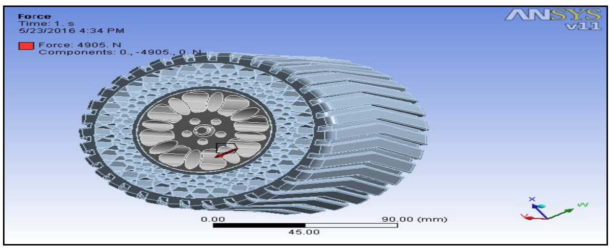
Meshing



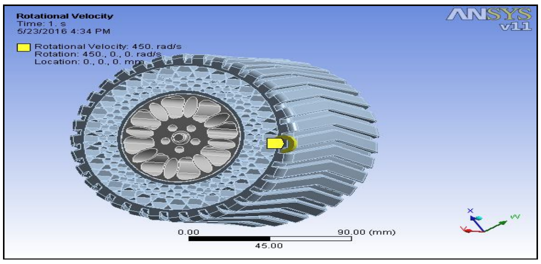
Fixed supports



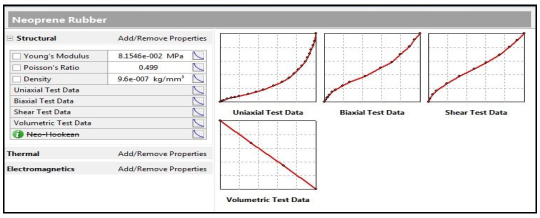
Acceleration application



Force application

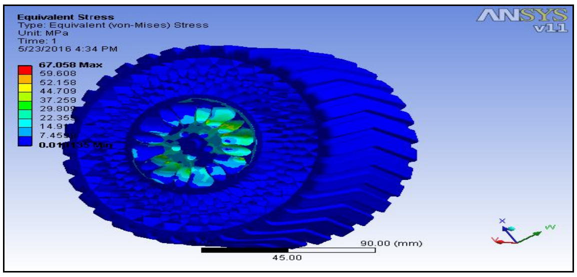


Rotational velocity

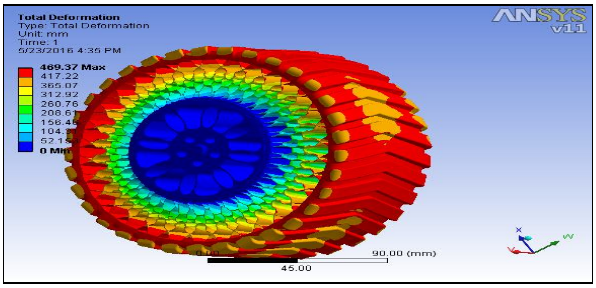


Material Properties

Static Stractrual Analysis:

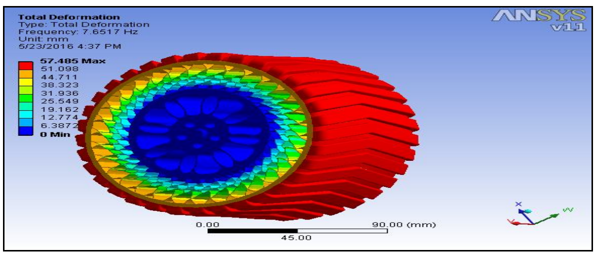


Equivalent stress

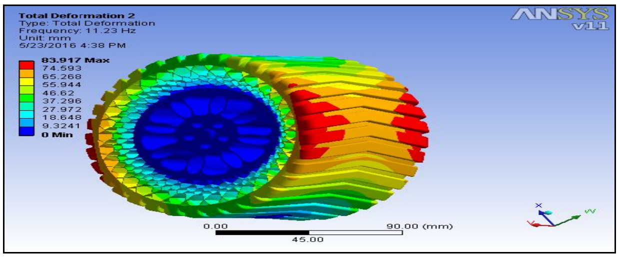


Total Deformation

Mode Analysis:



At Mode 1



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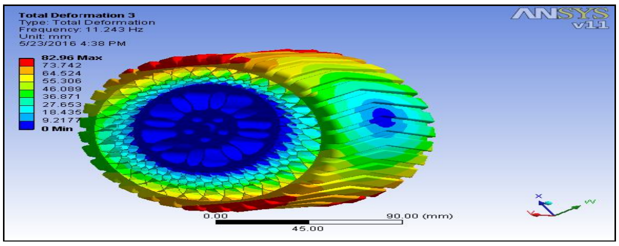

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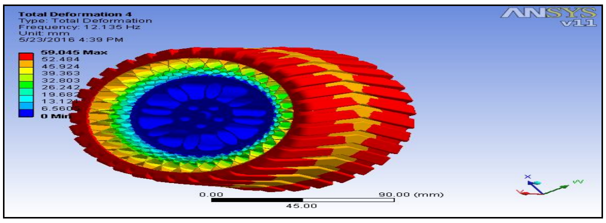

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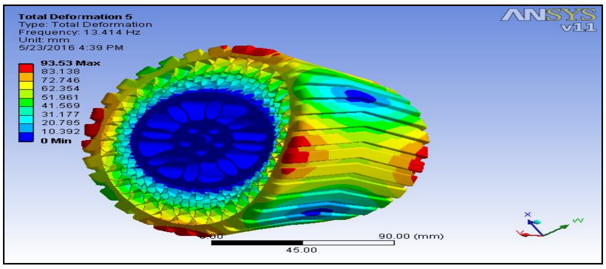

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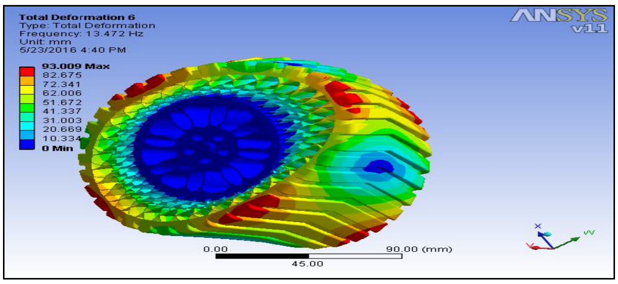

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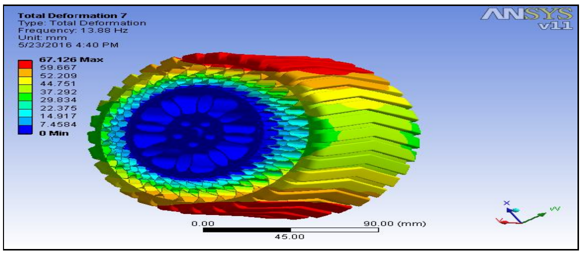

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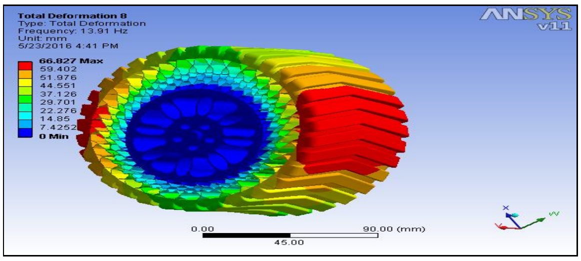

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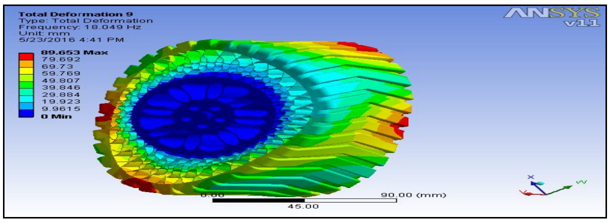

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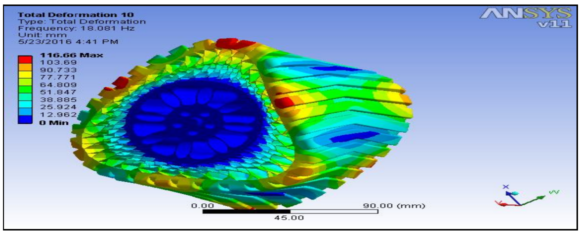
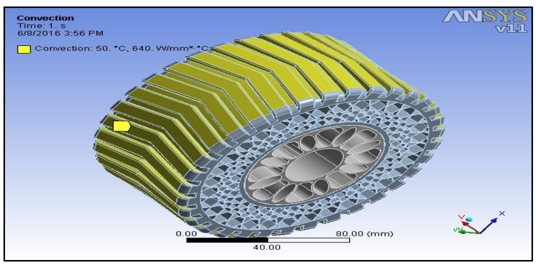
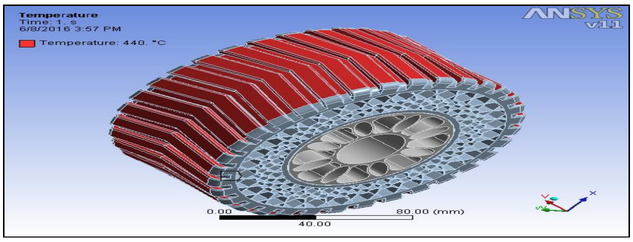


At Mode 10

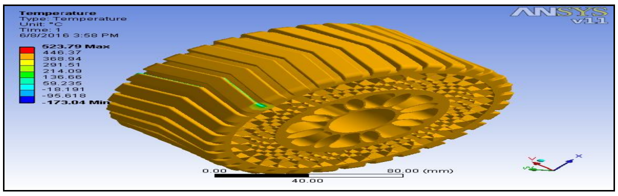
Thermal Analysis



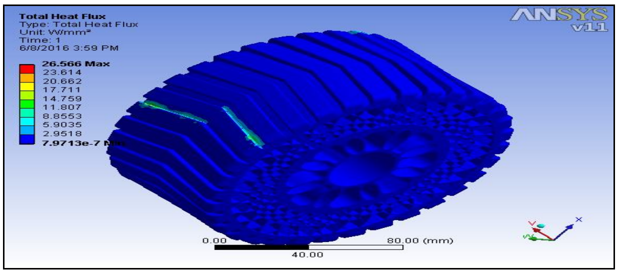
Heat convection



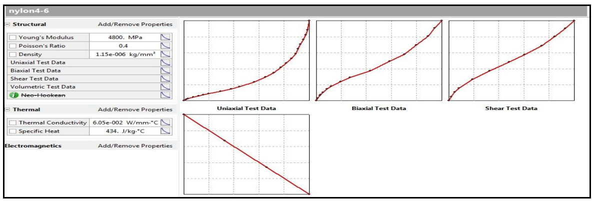
Temperature



Out Put Tempretature

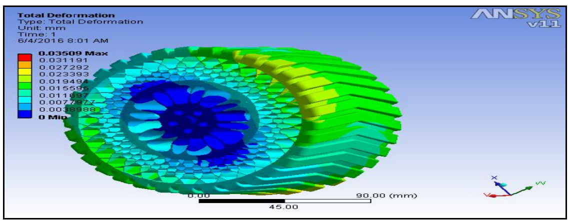


Total Heat Flux

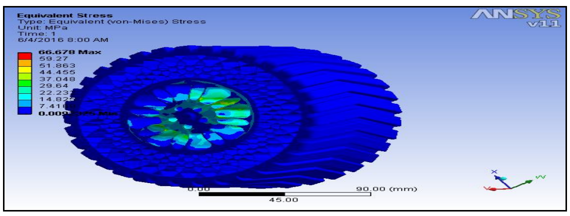


Material Properties of nyone4-6

Static Stractrual Analysis

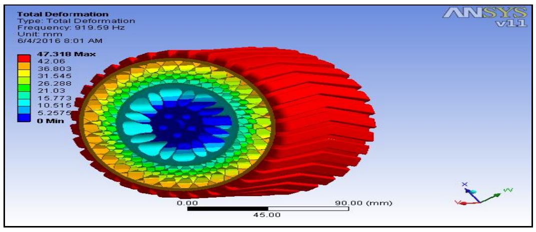


Total Deformation



Stress

Mode Analysis



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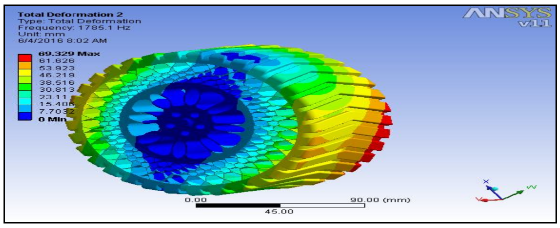

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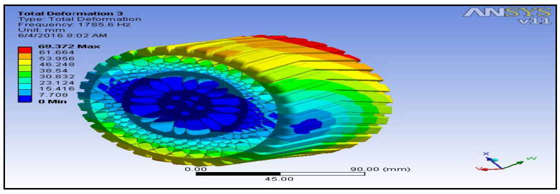

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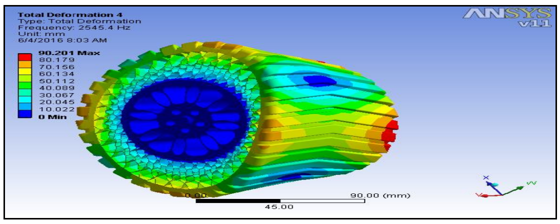

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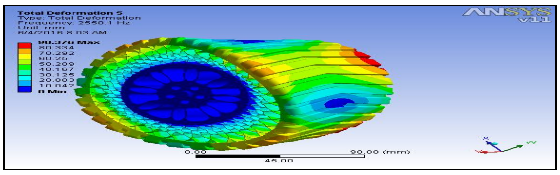
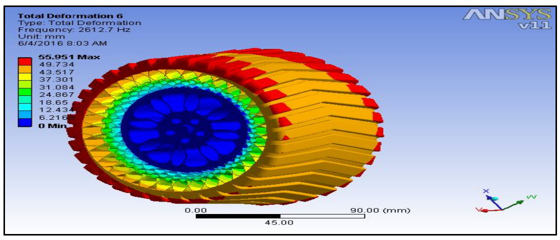


Mode 5



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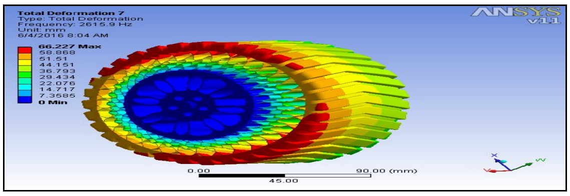
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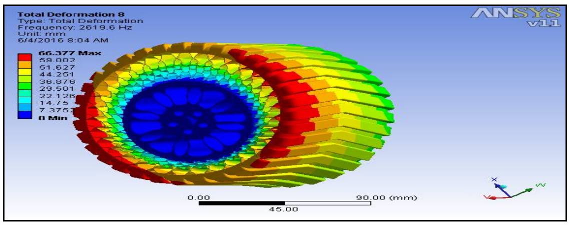
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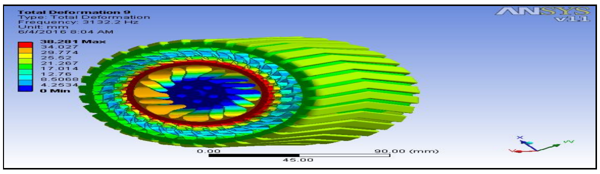
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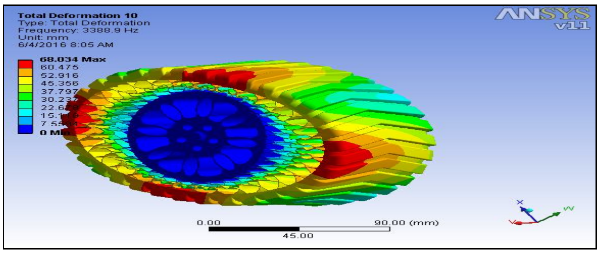
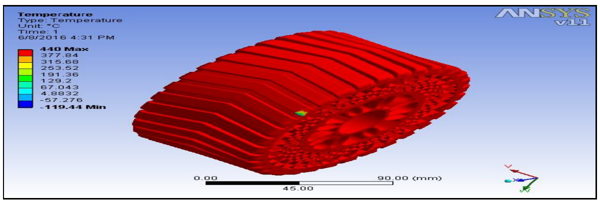
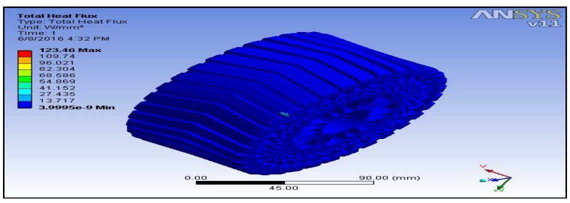

Mode 10

Thermal Analysis


Out Put Tempereture


Total heat flux

IV. TABLES & GRAPHS

Total deformation mode table

Modes \ Material	Neoprene Rubber (mm)	Nylon 4-6 (mm)
Mode 1	57.485	47.318
Mode 2	83.917	69.329
Mode 3	82.96	69.372
Mode 4	59.045	90.201
Mode 5	95.53	90.376
Mode 6	93.009	55.951
Mode 7	67.126	66.227
Mode 8	66.827	66.377
Mode 9	89.653	38.281
Mode 10	116.66	68.034

Total deformation mode

Material	Total deformation (mm)		Stress (Mpa)	
	Minimum	Maximum	Minimum	Maximum
Neoprene Rubber	0	469.37	0.01635	67.058
Nylon 4-6	0	0.03509	0.009	66.678

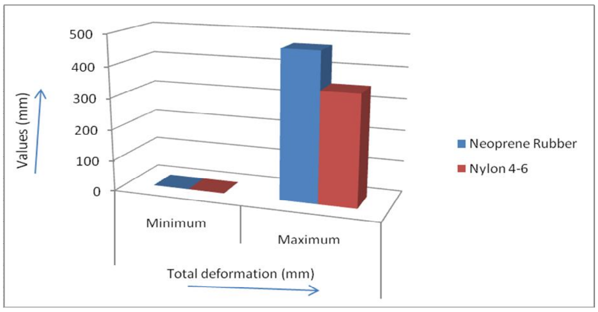
Total deformation & stress

Total deformation model graph

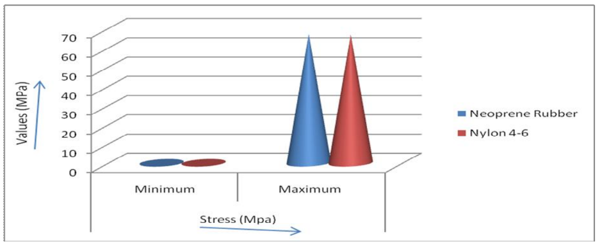
Total deformation model

Total deformation & stress table

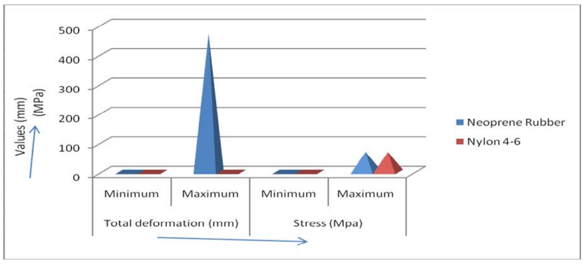
Total deformation & stress graph



Total deformation



Stress



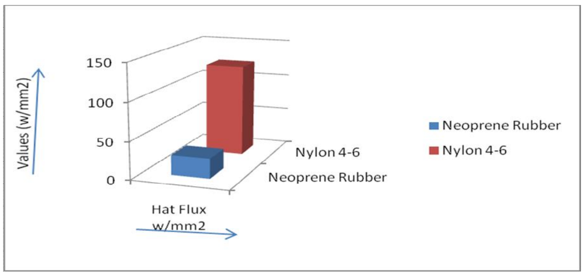
Total deformation & stress

Heat Flux & Temprature table

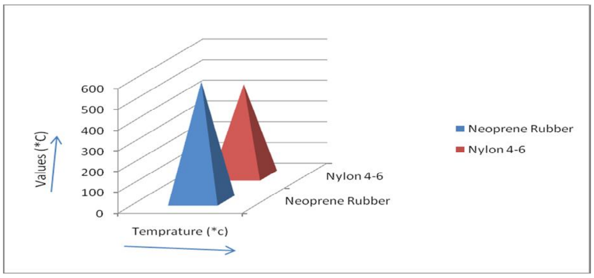
Material	Heat Flux (w/mm2)	Temprature (*c)
Neoprene Rubber	26.566	573.79
Nylon 4-6	123.46	440

Heat Flux vs Temprature

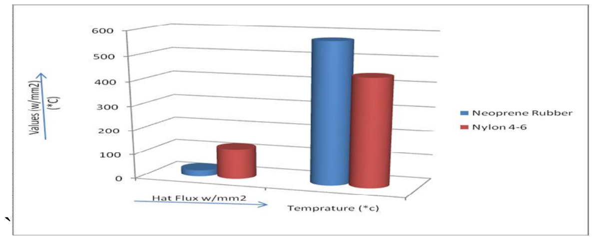
Heat Flux & Temprature graph



Heat Flux



Temprature



: Heat Flux & Temprature

V. RESULTS

The results from analysis can be replaced the air tire by Air-less tire. Air eliminated in the tire that provides good traction, cushion effect. The air less tire is analyzed by the FEA with two materials like **Neoprene Rubber** and **Nylon 4-6**. Analysis parameters of Air-less-tire are

From the above table we are concluded that, the material Nylon 4-6 is preferable one, by comparing to Neoprene Rubber.

From modal and thermal analysis also we are concluded that , the material Nylon 4-6 is preferable one, cause the material Nylon 4-6 is got less deformation at high frequency and heat flux also high.

Material	Total deformation (mm)		Stress (Mpa)		Heat Flux (w/mm2)	Temprature (*c)
	Minimum	Maximum	Minimum	Maximum		
Neoprene Rubber	0	469.37	0.01635	67.058	26.566	573.79
Nylon 4-6	0	0.03509	0.009	66.678	123.46	440

VI. CONCLUSION

From the design analysis it was concluded that the Diamond tyre structure was found out to be solid, and also bears more load comparative to the other structures. The material changes brought about in the carcass and also in the tread has also contributed to the reduction the total deformation. Thus the proposed work can bear a greater amount force and at the same time exhibits a comparatively small total deformation. These types of tyres can be mainly employed for the heavy load vehicles where the load factor is a main concern.

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