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Design and Analysis of Airless Tire

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ABSTRACT:The airless tire is a single unit replacing the pneumatic tire, wheel and valve 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 and a tread band, all functioning as a single unit.Our project involves design and analysis of airless tyre for trucks. The design is carried out on PRO-E software and analysis (vibration, structural,thermal) will be done on ANSYS software.

KEYWORDS: Nonpneumatic tyre, Flexibility,Safety, Environmental concerns, Future,Spokes,Modalanalysis, Structural analysis, Thermal analysis, Modelling, NPT.

I. INTRODUCTION

For more than 100 years, vehicles have been rolling along on cushions of airencased in rubber. Sometimes, we get so used to a certain product that no true changes areever really made for years, decades even. So begins an article discussing the developmentofairlesstires,somethingthathasbecome moreprevalentinthepastfewyears.A fewtire companies have started experimenting with designs for non-pneumatic tires includingMichelinandBridgestone,butneitherdesign hasmade itto massproduction.

Creating a new non-pneumatic design for tires has more positive implications thanone might think. For one thing, there are huge safety benefits. Having an airless tire meansthere is no possibility of a blowout, which, in turn, means the number of highway accidentswill but cut significantly. Even for situations such as Humvees in the military, utilizingnon-pneumatic tires has a great positive impact on safety. Tires are the weak point inmilitary vehicles and are often targeted with explosives. If these vehicles used airless tires,thiswould no longerbeaconcern.

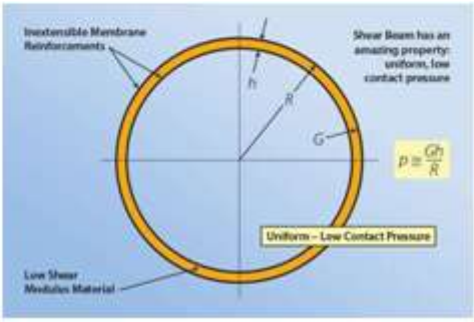
There is also an environmental benefit to using this type of tire. Since they never goflat and can be retreaded, airless tires will not have to be thrown away and replaced nearlyasoftenas pneumatictires.This willcut downlandfillmass significantly.

Because of the benefits, I believe that it is extremely important that research andproduction of airless tires is continued and increased. This type of innovation works well inconjunction with several engineering codes of ethics, and thus should be embraced byengineerseverywhere.Carsarethingsthatpeopleuse everyday,soanyimprovementsoverexistingdesignswouldaffectthelivesofthemajorityofpeople.Learningaboutsucha topic, therefore, I believe holds extreme value- especially for us freshmen engineeringstudents. In doing research into these kinds of topics that hold significant meaning, we canseethat whatwewill do can makeadifference

The basic design of all pneumatic tires is very similar, even though there are many differenttypes. They all include an inner core that holds pressurized air which is then covered with alayer of rubber that comes in contact with the road, called a tread. The tread helps keeptraction with the road andprevents slipping and skidding.The treadhas the tendency towear down over time, so if the tyre has not gone flat, a person will usually replace it at thispoint A main reason for using pneumatic tires is the deformation that occurs duringrotation. As the tire rolls, the weight of the car pushing down on it causes the tyre to flattenslightly.

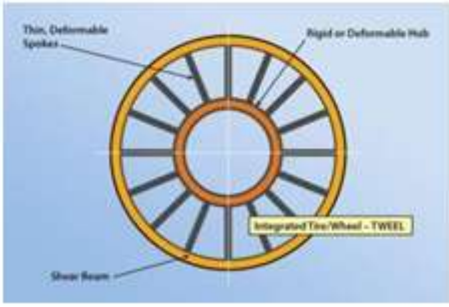
WHAT IS AIRLESS TYRE (TWEEL)

Airless tires or Non-pneumatic tyres (NPT), are the tires that are not supported byair pressure. These tyres are also called as Tweel which is a merger of the words tyre andwheel. This is because the Tweel does not use a traditional wheel hub assembly. The Tweelconcept was first announced by Michelin back in 2005. It's structure is a solid inner hubmounted onto the vehicles axle, that is surrounded by polyurethane spokes.This forms apattern of wedges, which help to absorb the impacts of the road. These spokes look similartotheonesfoundonbicyclesandplaystheshock-absorbingroleofthecompressedairasinatraditionaltyre.Asheerbandisthenstretchedacrossthespokes,which formstheouter edge of the tyre. It is the tension of the band and the strength of the spokes thatreplaces the air pressure used on traditional tyres. When a vehicle drives over an obstacle, asleeping policeman for example, the tread and shear bands give way as the spokes bend,before they quickly bouncebackintoshape.

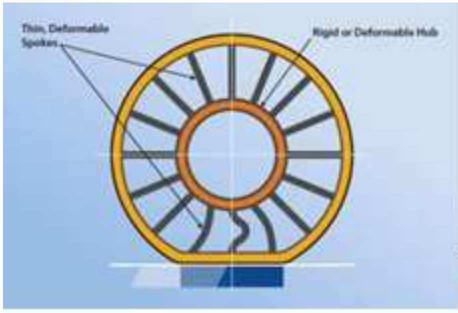


HOW IT WORKS

TheAirlesstyre(Tweel)doesn'tuseatraditionalwheelhubassembly.Asolidinner hub mounts to the axle and is surrounded by polyurethane spokes arrayed in a patternof wedges. A shear band is stretched across the spokes, forming the outer edge of the tyre.On it sits the tread, the part that comes in contact with the surface of the road. The cushionformed by the air trapped inside a conventional tyre is replaced by the strength of thespokes, which receive the tension of the shear band. Placed on the shear band is the tread,the part that makes contact with the surface of the road. When the Tweel is running on theroad,thespokesabsorbroaddefectsthesamewayairpressuredoesinthecaseofpneumatic tyres. The flexible tread and shear bands deform temporarily as the spokes bend,then quickly go back to the initial shape. Different spoke tensions can be used, as requiredby the handling characteristics and lateral stiffness can also vary. However, once producedtheTweel's spoke tensions andlateral stiffness cannotbeadjusted



(without surface contact)



(with surface contact)

DIFFERENT DESIGN APPROACHES

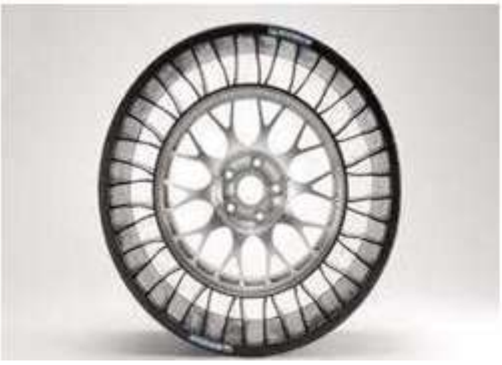
There are many different approaches to the design of the supports. This accountsfor themain differences between the overall designs of each company's version ofthe airless tyre.

1.NASA and the Apollo Lunar Rover

The first major attempt at creating an airless tyre was in 1970 for NASA's ApolloLunar Roving Vehicle. The tyres were made of steel strands woven together to form theshape, and then were coated with zinc. In order to gain traction, titanium chevrons wereaddedtotheoutersurface

2.Michelin

The next main attempt at creating an airless tyre was called the Tweel (combinationof tyre and wheel) by the tyre company, Michelin. Their design consisted of a thin rubbertreadwithV-shapedspokes madeofpolyurethane.

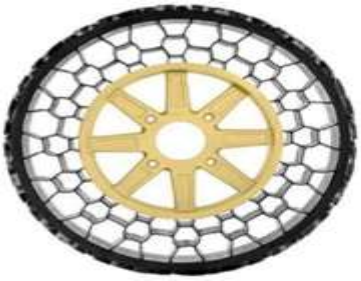


3.Bridgestone

Thecoreismadeofrigidalluminiumandhasthermoplasticspokesradiatingoutward at an angle in opposite directions on each side. This creates more stability and lesslateral movement in the tyre. Bridgestone also fixed the vibration and noise problem in thisway as well. The main issue with their design was that debris had the tendency to getcaughtinthegapsbetweenspokes.Inaddition,thematerialsusedinthetyresarerecyclable, contributing to the efficient use of resources. Further, by pursuing extremelylow rolling resistance and contributing to reductions in CO2 emissions through use ofproprietary technologies, Bridgestone believesit is possible to achieve even higher levelsofenvironmentalfriendlinessandsafety.Bridgestoneispursuingthistechnologicaldevelopmentwiththeaimofachievinga"cradletocradle"processthatproactivelymaximizes the cyclical use of resources from worn tyres into new tyres and the use ofrecyclableresources.

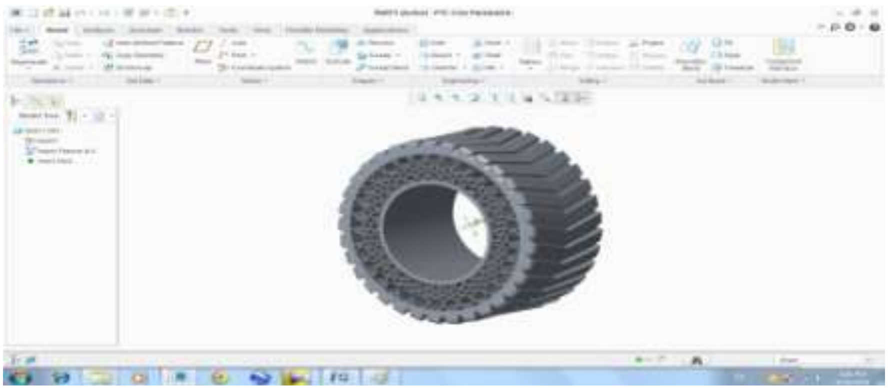
4.ResilientTechnologies,LLC

As stated before, the productionof airless tyreswould be extremely beneficial tothemilitary.ThegroupResilient Technologies,LLCisworkingwiththemilitarytodevelop such a tyre for Humvees. To meet the requirements of heavy loads and roughterrain, these tyres are quite industrial-looking.



MODELLING

The model is developed using Part modelling software by using Pro-E (CREO-parametric).



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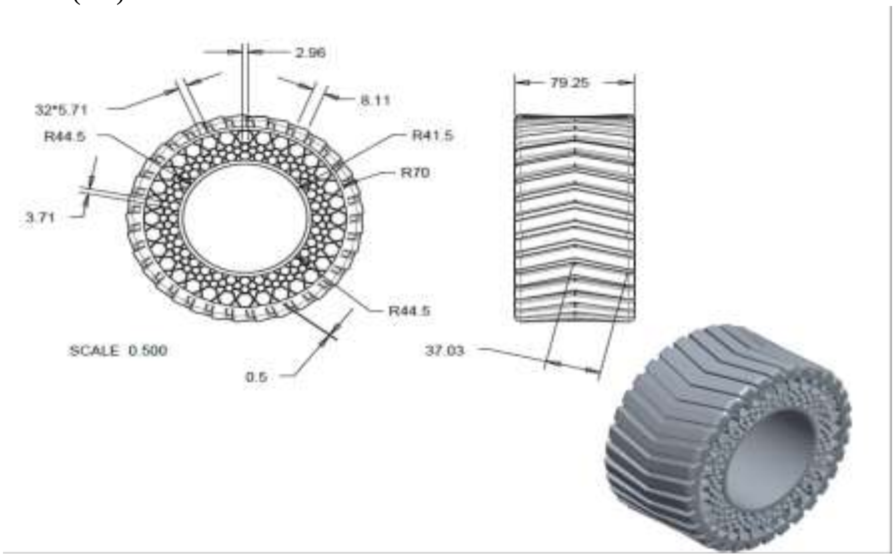
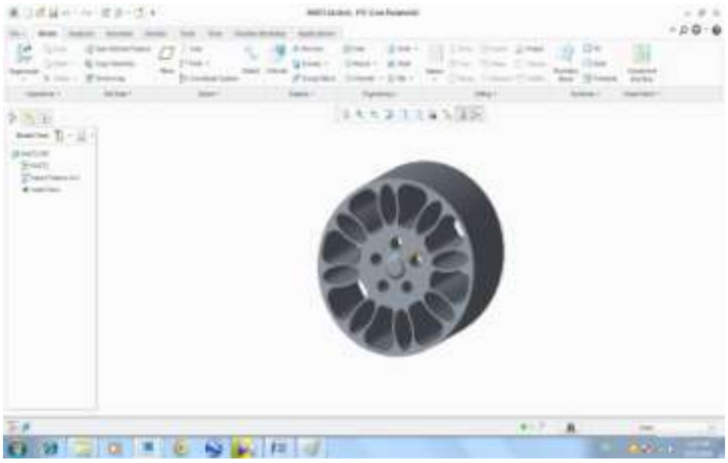
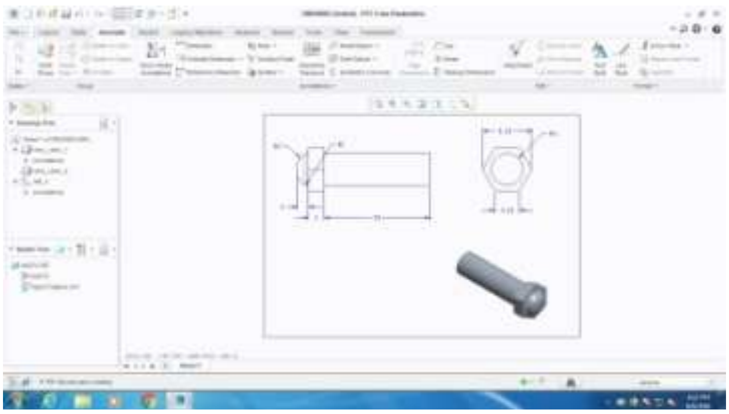
Outer rubber portion (tire)



Detail view of outer rubber portion (tire)



Metal rim



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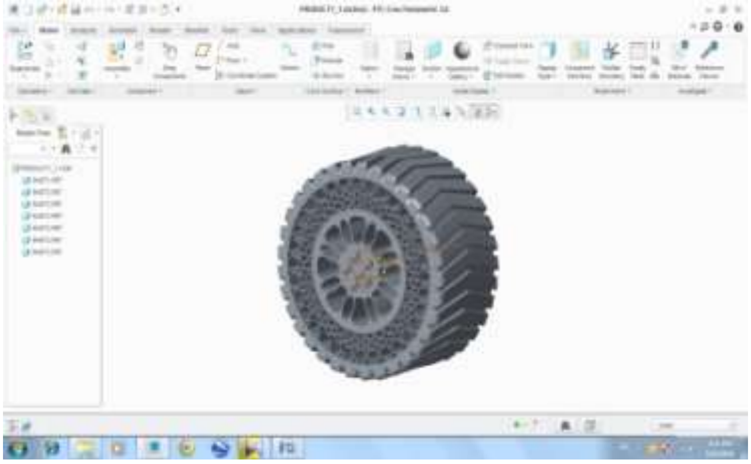
Detailed view of Bolt



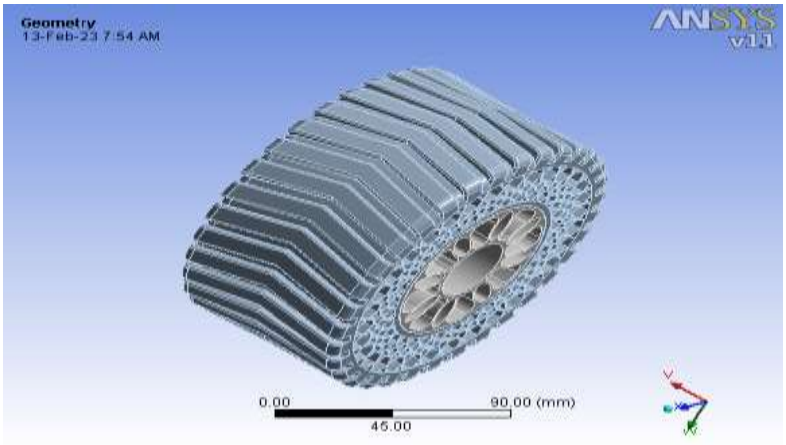
Total Assembly view of Air less tire

ANALYSIS
The analysis of airless tyre will be done on ANSYS software.

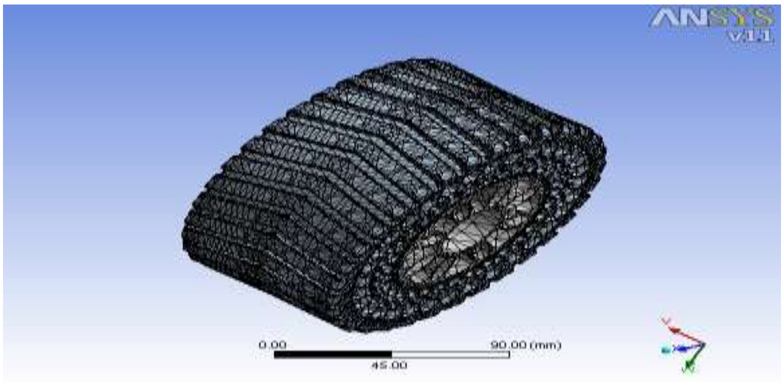
MATERIALS USED

Properties	Nylon 4-6	Nitrile Rubber
Young's modulus (GPa)	4.8	2
Poisson's ratio	0.4	0.499
Density(kg/m3)	1150	960

Importing the model
In this step the CREO file is to be converted into IGES file and imported into ANSYS workbench

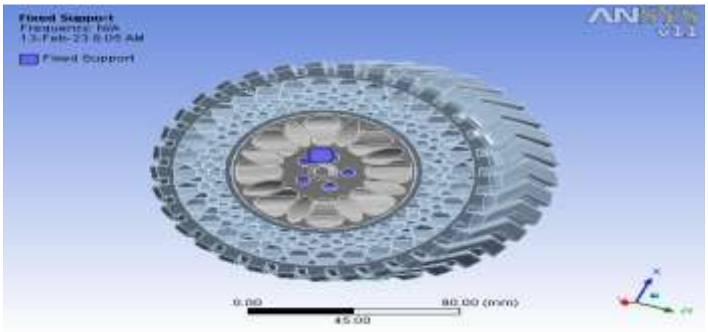


MESHING
Meshing is the process of Dividing geometric shape into Elements



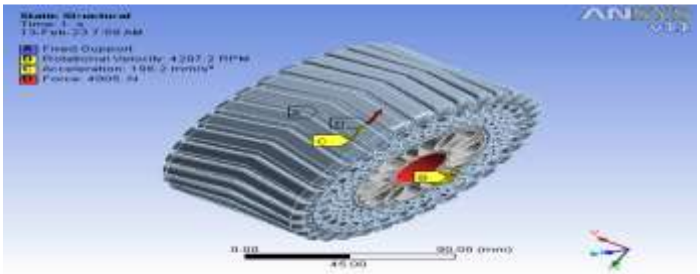
FIXED SUPPORTS

In this model the fixed supports are Bolts

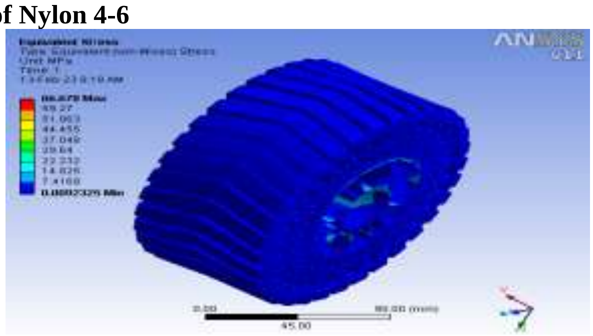


Applying below parameters to model

Acceleration (mm/s2)	Force (N)	Rotation velocity (RPM)
196	4905	4300



Static Structural Analysis of Nylon 4-6



Equivalent stress

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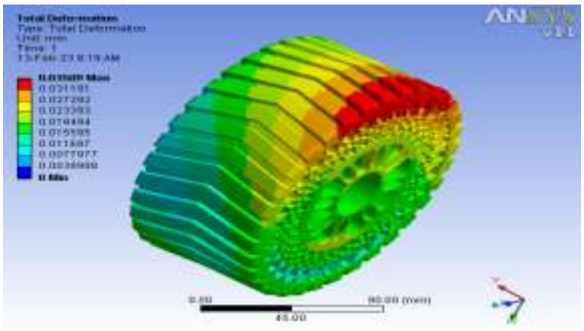
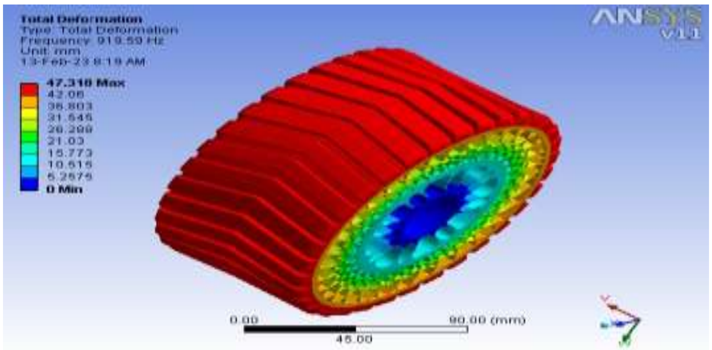
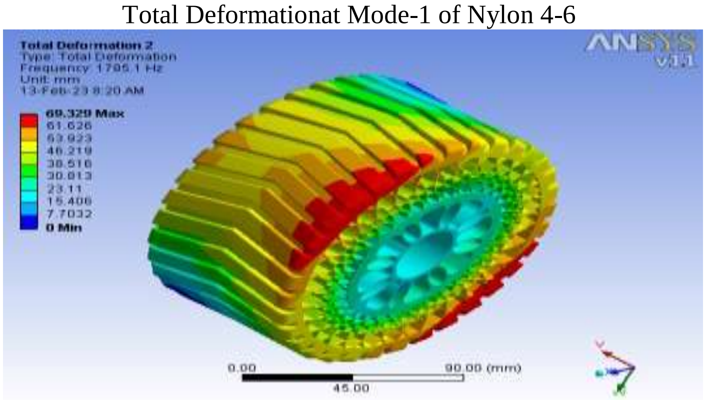


Total Deformation

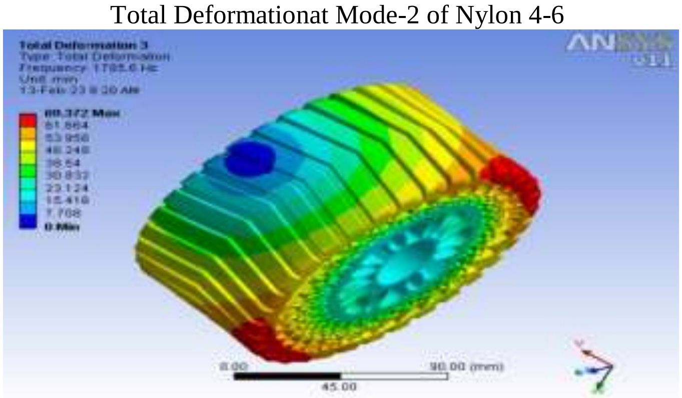
Modal Analysis of Nylon 4-6



Total Deformationat Mode-1 of Nylon 4-6



Total Deformationat Mode-2 of Nylon 4-6



Total Deformationat Mode-3of Nylon 4-6

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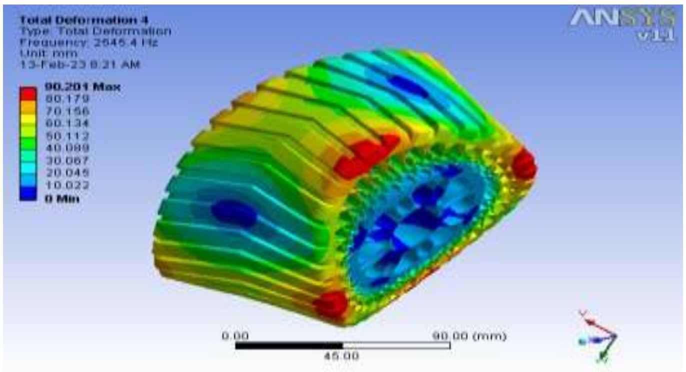
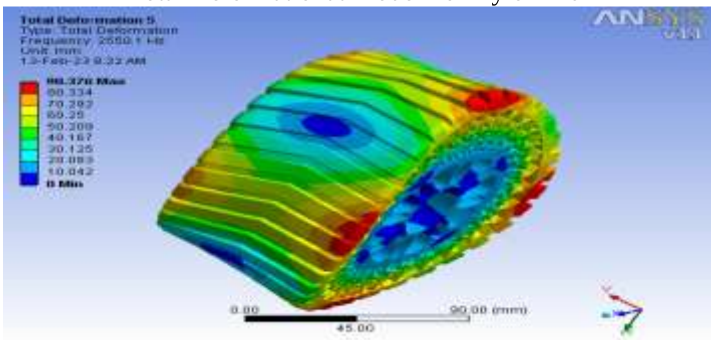
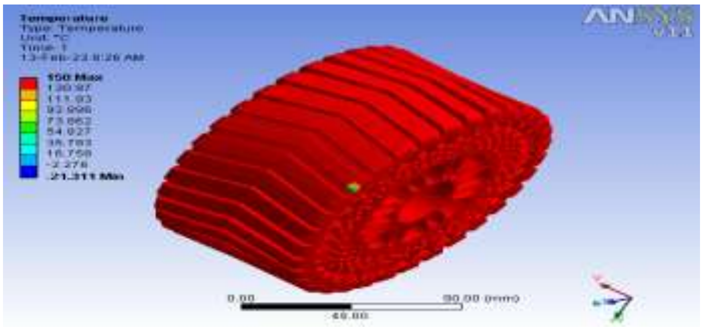


Total Deformationat Mode-4 of Nylon 4-6

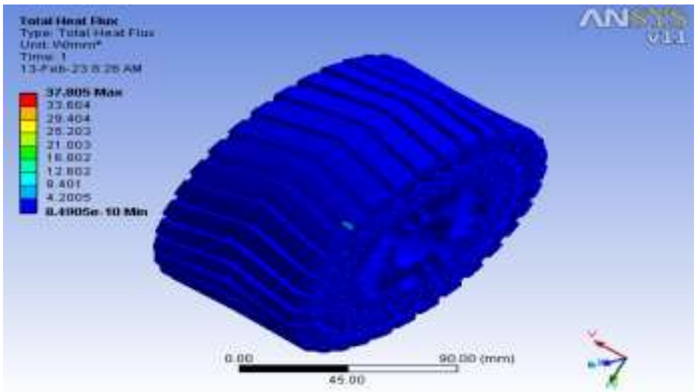


Total Deformationat Mode-5 of Nylon 4-6

Thermal Analysis of Nylon 4-6



OutPut Tempereture of Nylon 4-6



Total heat flux of Nylon 4-6

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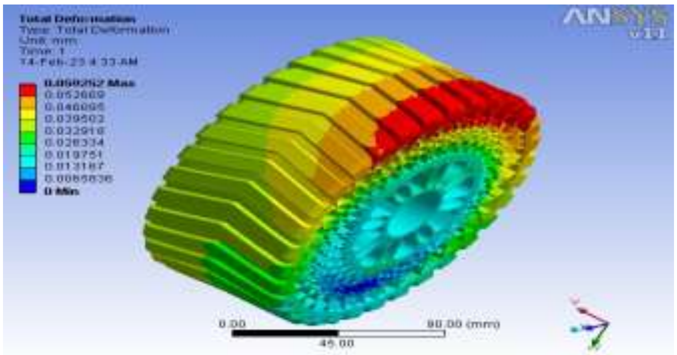
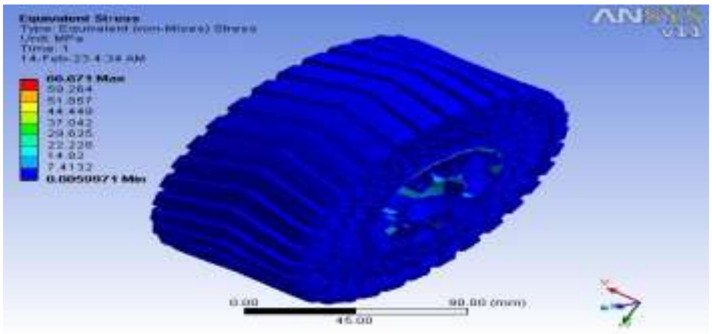
Static Stractrual Analysis of Nitrile Rubber

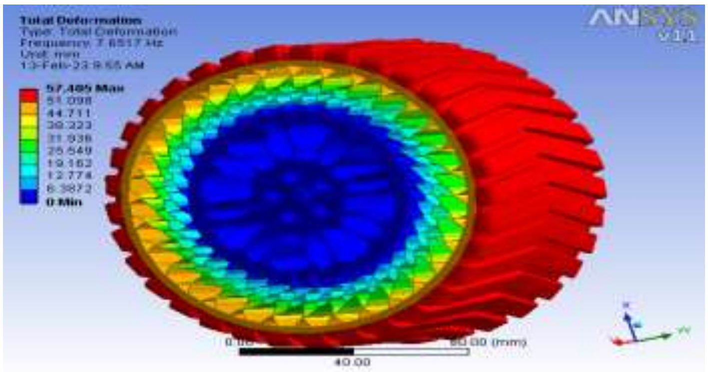


Total Deformation of Nitrile Rubber

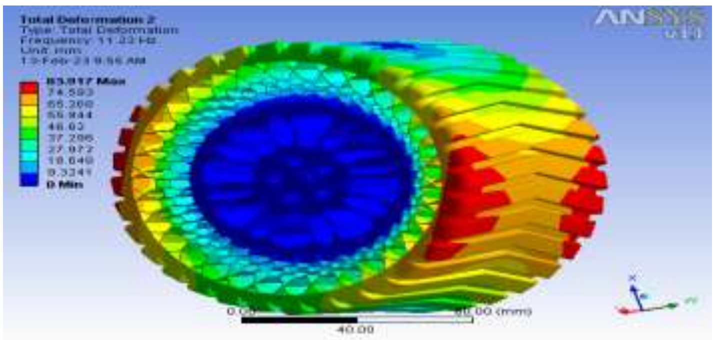


Equivalent stress of Nitrile Rubber

Modal Analysis of Nitrile Rubber



Total Deformationat Mode-1 of Nitrile Rubber



Total Deformationat Mode-2 of Nitrile Rubber

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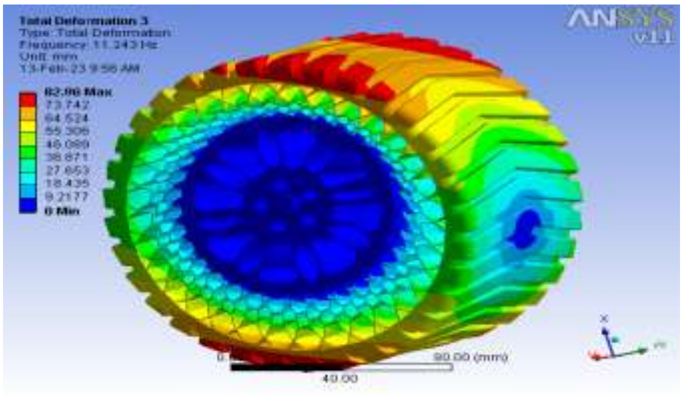
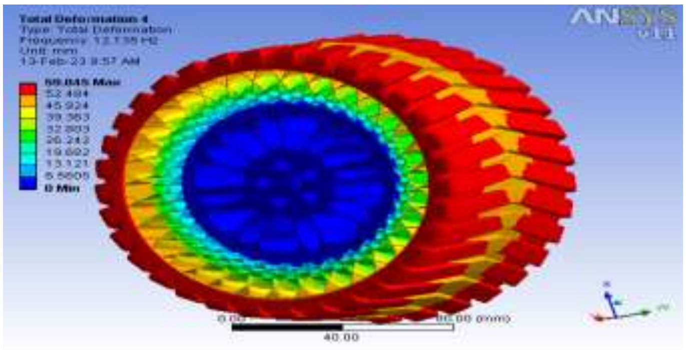
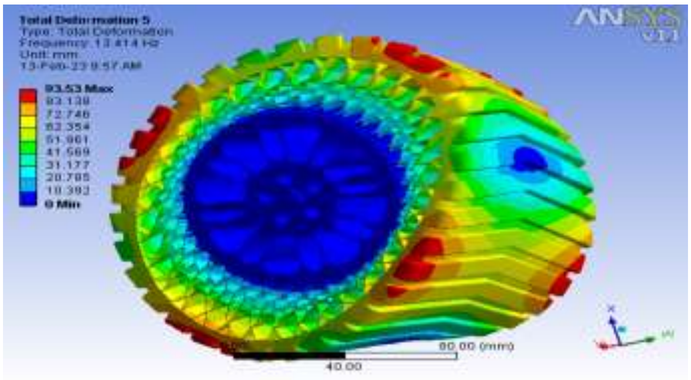


Total Deformationat Mode-3 of Nitrile Rubber

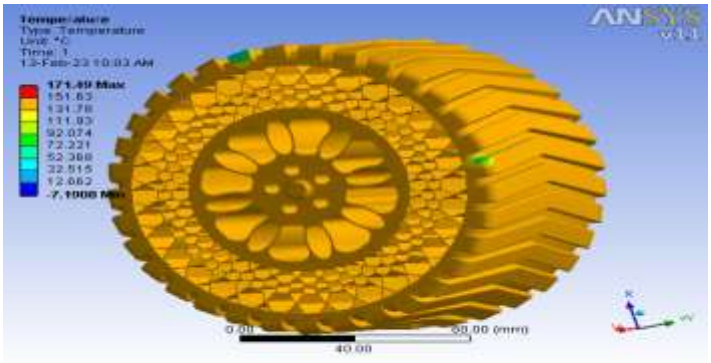


Total Deformationat Mode-4 of Nitrile Rubber

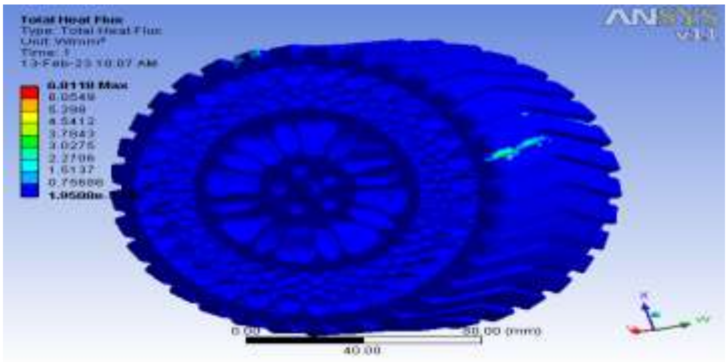


Total Deformationat Mode-5 of Nitrile Rubber

Thermal Analysis



Out Put Tempretature of Nitrile Rubber



Total Heat Flux of Nitrile Rubber

Total deformation modal table

Modes \ Material	Nitrile Rubber	Nylon 4-6
Mode 1	56.236	47.318
Mode 2	86.054	69.329
Mode 3	85.544	69.372
Mode 4	60.393	90.201
Mode 5	98.054	90.376

Total deformation & Stress table

Material	Total deformation (mm)		Equivqlent Stress (MPa)	
	Minimum	Maximum	Minimum	Maximum
Nitrile Rubber	0	0.059252	0.0059971	66.671
Nylon 4-6	0	0.03509	0.009	66.678

Heat Flux & Temprature table

Material	Heat Flux (W/mm^2)	Temprature (^{0}C)
Nitrile Rubber	175.54	350
Nylon 4-6	123.46	440

II. RESULTS & DISCUSSION

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 analysed by the FEA with two materials like **Nitrile Rubber** and **Nylon 4-6**. Analysis parameters of Air-less-tire are

Material	Total deformation (mm)		Stress (Mpa)		Heat Flux (W/mm^2)	Temprature (^{0}C)
	Minimum	Maximum	Minimum	Maximum		
Nitrile Rubber	0	0.059252	0.0059971	66.671	175.54	350

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Nylon 4-6	0	0.03509	0.009	66.678	123.46	440

From the above table I concluded that, the material Nylon 4-6 is preferable one, by comparing to Nitrile Rubber

III. CONCLUSION

Design and development of air-less tire eliminates air in the tire. Air-less tire can provide uniform traction and uniform wear while absence of air. The 4 side honey comb design satisfies the main functions of the tire. Air-less tire has two components that are outer band and flexible inner band. In the air-less tire design manufacturing point of view, material saving is obtained by replacing outer band only after tread wear. The flexible inner band repeated use obtained green engineering and also reduce the environmental pollution. In this thesis Nitrile rubber and Nylon 4-6 materials are used, among these two materials **Nylon 4-6** is preferable.

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