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BUMPING AND VIBRATIONAL ANALYSIS OF AIRLESS TYRE USING FINITE ELEMENT ANALYSIS

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Abstract

Before delving into the technological advancements in airless tyres, it's critical to understand what's missing in conventional tyres. The traditional pneumatic tyre is made up of an inner core that retains compressed air, which is then covered by the Tread, which is the rubber layer that comes into contact with the road. The tread will tear and perhaps wear during use, which is a problem. It is difficult for a vehicle to resist slipping and skidding without tread. When conventional tyres are torn out, the tyre's substance becomes waste, and over time, the automotive tyres may produce a significant amount of waste. According to a survey, tyres produce 2 million tonnes of solid trash. The pneumatic tyres that we use now are difficult to recycle. To address these issues, non-pneumatic (airless) tyres with a simple and long-lasting design have been designed. The exterior cylindrical piece is totally formed of Solid Rubber or Plastic, while the core has a rim. There is no air inside the tyres, which causes them to adhere to the surface for a short time and offers the car extra grip. The lateral rigidity of airless tyres should be 5 times that of ordinary pneumatic tyres. Vibration should be kept to a minimum because excessive vibration will degrade the vehicle's ride quality. The tyre's substance should be able to bear the pressure.

Keywords: Bumping analysis, Vibrational Analysis, Airless tyre, Finite Element Analysis

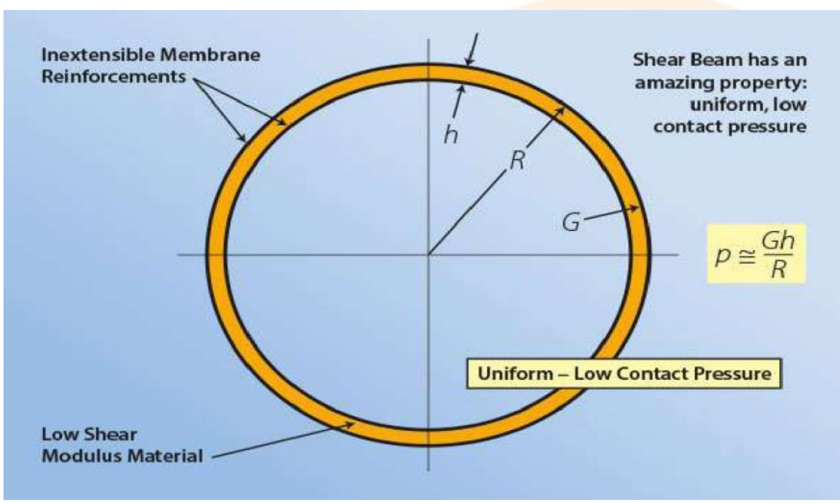
1. Introduction

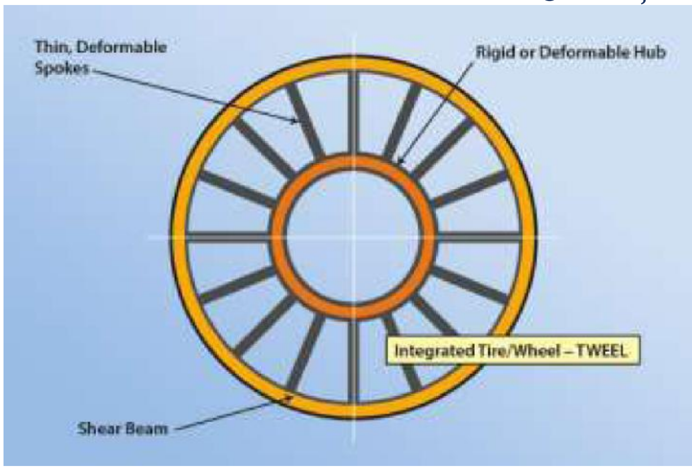
For more than 100 years, vehicles have been rolling along on cushions of air encased in rubber. We can become so accustomed to a product that no true adjustments are made for years, if not decades. So begins an essay about the development of airless tyres, which have become increasingly popular in recent years. A few tyre companies have started experimenting with designs for non-pneumatic tyres including Michelin and Bridges tone, but neither design has made it to mass production.

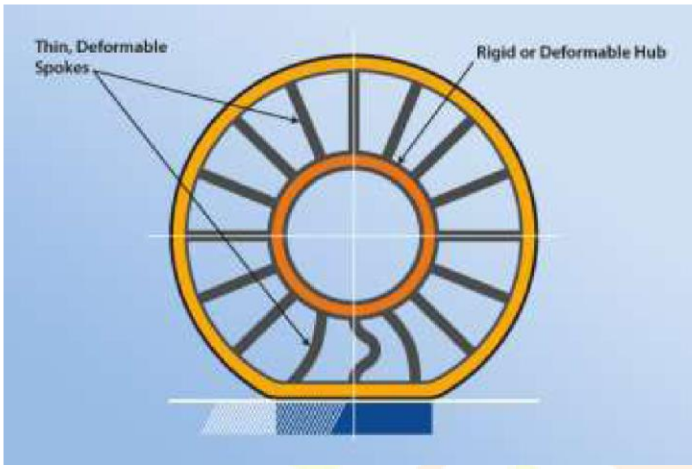
Increasing a new non-pneumatic tyre design has more advantages than one might assume. For starters, there are significant safety advantages. There is no risk of a blowout with an airless tyre, which means the frequency of highway accidents will be greatly reduced. Even in military applications such as Humvees, using non-pneumatic tyres improves safety significantly. Military vehicles' tyres are a weak vulnerability and are frequently targeted with explosives. This would not be an issue if these vehicles had airless tyres.

Using this sort of tyre also has an environmental benefit. Airless tyres will not need to be thrown away and replaced nearly as often as pneumatic tyres because they never run flat and may be retreaded. This will result in a large reduction in landfill mass. Because of the advantages, I feel it is critical that airless tyre research and production be continued and expanded. This form of invention is compatible with various technical codes of ethics, and engineers everywhere should embrace it. People use cars every day, thus any upgrades to present designs would have a significant impact on the majority of people's lives. As a result, I believe that learning about such a topic is really valuable, particularly for us freshmen engineering students. We can see that what we will accomplish can make a difference by conducting research into these types of problems that have substantial importance.

Fig:1 Pneumatic Tyre







Dr. R. Ramachandra (2017) : Design and Analysis of Air less Tires

This paper is about In becoming assembled, an airless tyre is a single unit that replaces the pneumatic tyre. It consists of an unbending centre point connected to a shear band via ways for adaptable, deformable polyurethane spokes and a tread band, all of which act as a single unit. Because of its level confirmation configuration, the Tweel, a type of airless tyre, finds generic application in military and earth moving applicant particles, rendering the pneumatic tyre obsolete in do mastic vehicles. Our study will outline an inquiry of an airless tyre for performing mastic cars, following by a contemplate anxiety assessment. The model will be created in Pro E, while the study will be carried out in Ansys.

2.Mihir Mangesh Pewekar, Sambhaji D. Gaikwad(2018):

Strength Validation of Hexagonal Cellular Spoked Non-Pneumatic Tires for Automobiles through Finite Element Analysis

Composite materials and structures, the subject of this paper, might be considered a major paradigm of the contemporary scientific revolution. Non-Pneumatic tyres, commonly known as "Airless Tires," were invented as a result of widespread adoption of such a paradigm. The purpose of this paper is to investigate the deformation mechanisms of the honeycomb cellular structure. Due to the decreased spoke stiffness of the NPTs when they are intended to have the same load carrying capacity as the pneumatic tyre, a lower contact pressure is obtained with the NPTs than with the pneumatic tyre. The deformation processes are verified using the ANSYS Mechanical APDL solver's Finite Element Prediction. This document focuses solely on NPT adaption for automobiles. This adaptation is investigated using four different loading scenarios: compressive, lateral shear, lateral torsion, and circumferential torsion. Without proof of strength in these types of loads, a tyre cannot be put into service. In the FEA environment, this document restricts the analysis to independent analysis of each loading. These loadings are discussed and quantified in order to validate the strength of these tyres. The localised stress concentration, maximum deflection, and deformation forms in the cellular spokes, as well as the contact stresses at the tyre road interface, are the focus of the study. The quantitative and qualitative results are presented in this document. These sets of results create the foundation on which the conclusions are built.

Materials and Methods

One or more design workstations, a digital computer, plotters and other output devices, and storage devices make up the hardware part of a CAD/CAM system. The link between the components is depicted. Furthermore, the CAD/CAM system would include a communication interface that would allow data to be transmitted to and from other computer systems, allowing for some of the benefits of computer integration. In a CAD system, the workstation is the interface between the computer and the user.The design of the CAD workstation and its available features have an important influence on the convenience, productivity, and quality of the user´s output. The workstation must include a digital computer with a high-speed control processing unit (CPU). It contains require a and logic/arithmetic section for the system. The most widely used secondary storage medium in CAD/CAM is the hard disk, floppy diskette, or a combination of both. The typical I/O devices used in a CAD system. Input devices are generally used to transfer information from a human or storage medium to a computer where ¨CAD functions¨ are carried out. There are two basic approaches to input an existing drawing: model the object on a drawing or digitize the drawing. The standard output device for CAD/CAM is a CRT display. There are two major of CRT displays: random-scan-line-drawing displays and raster-scan displays. In addition to CRT, there are also plasma panel displays and liquid-crystal displays.

APPLICATIONS OF CAD/CAM

The emergence of CAD/CAM has had a major impact on manufacturing, by standardizing product development and by reducing design effort, tryout, and prototype work; it has made possible significantly reduced costs and improved productivity. Some typical applications of CAN/CAM are as follows:

- Programming for NC, CNC, and industrial robots
- Design of dies and molds for casting, in which, for example, shrinkage allowances are pre-programmed
- Design of tools and fixtures and EDM electrodes Quality control and inspection for instance, coordinate-measuring machines programmed on a CAD/CAM workstation; Process planning and scheduling. AutoCAD is a computer-aided drafting and design system implemenented on a personal computer. It supports a large number of devices. Device drivers come with the system and include most of the digitizers, printer/plotters, video display boards, and plotters available on the market.

AutoCAD supports 2-D drafting and 3-D wire-frame models. The system is designed as a single-user CAD package. The drawing elements are lines, poly lines of any width, arcs, circles, faces, and solids. There are many ways to define a drawing element. For example, a circle can be defined by center and its radius, three points, and two end points of its diameter. The system always prompts the user for all options. Of course, the prompt can be turned off by advanced users. Annotation and dimensioning are also supported. Text and dimension symbols can be placed on anywhere on the drawing, at any angle, and at any size. A variety of fonts and styles are also available.

2. Results and discussion

FINITE ELEMENT ANALYSIS

Finite Element Method is a numerical procedure for solving continuum mechanics of problem with accuracy acceptable to engineers. Finite Element Method is a mathematical modeling tool involving discretization of a continuous domain using building-block entities called finite elements connected to each other by nodes for once and moment transfer. This process includes Finite Element Modeling and Finite Element Analysis. In displacement based FEM, stiffness of the entire structure (part or assembly) is assembled from stiffness of individual elements. Loads and boundary conditions are applied at the nodes and the resulting sets of the simultaneous equations are solved using matrix methods and numerical techniques. In short, FEM is a numerical method to solve ordinary differential equations of equilibrium.

Starting with simple linear static stress and heat transfer analysis, complex simulations involving highly non-linear, fluid flow and dynamic events can be successfully analyzed on a personal computer using a host of popular software including Cosmos, NASTRAN, ANSYS and NISA among others.

Three steps in the finite element calculation.

- Modeling
- Meshing the model
- Analysis

MESH GENERATION

The geometry is discretized to form a mesh of elements and nodes. This means that the structure is broken down into small sub regions on which the numerical analogue of the governing equations can be developed. The meshed layout depends on following.

- The geometry of the structure
- The type of analysis, i.e. static, dynamic, thermal or non linear
- The boundary conditions
- The loading
- The required result

TYPE OF MESH GENERATIONS

- Automatic mesh generations
- Parametric (manual) mesh generation

Automatic mesh generation

Transition in areas of stress gradient is not possible using auto mesh. The auto mesh tetrahedron element is a constant strain element. It's straightforward to label the nodes to reduce bandwidth in simple systems (or regions). Large systems, on the other hand, make the operations almost impossible. Controlling the mesh yields outcomes with a 70 percent error rate, while the quality of auto-meshed sections with geometric transitions is uncontrollable.

Parametric (manual) mesh generation

For components with significant cycle fatigue, a structured (parametric) finite element should be utilised. With greater convergence in findings, control of mesh transition in areas of stress gradient is achievable employing structural elements such as brick with 8(or) 20 nodes. The use of brick components in a finite element model results in monatomic convergence. Manual meshing of structured meshed components with geometric transition control is feasible with brick elements.

MESH THE MODEL

Meshing involves three main steps:

- Set the element attributes and material properties
- Set mesh controls

Types of element:

To get typical responses of a structure system, many types of elements can be used in Engine casing models. Elements are classified according to their primary structural functions. a form that is triangular Internal forces in shell elements are expressed in force per unit length at the mid-surface and in force per unit area at the top and bottom of the element.It is primarily used to determine local stress levels in cellular superstructure or in cellular pier and caissons. It is generally recommended to use the full behavior unless the entire structure is planar and is adequately restrained.

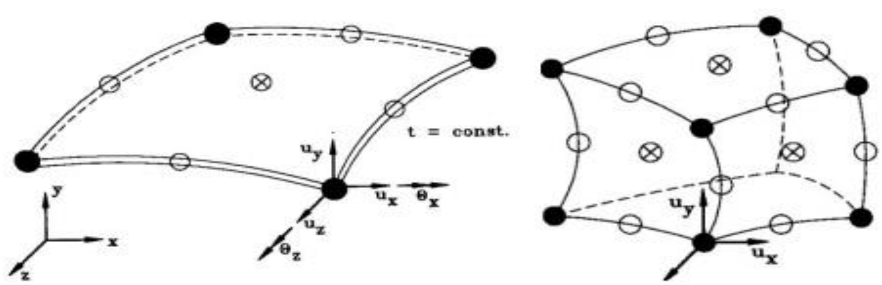


Fig5.12. 1Shell element

a) Plate Element

b) A plate element is a two-dimensional solid element that mimics the behaviour of a flat plate. As Degrees of Freedom, there are two out-of-plane rotations and the normal displacement (DOF). In two dimensions, these pieces model plate bending behaviour. In the element's plane, the element can simulate the two normal moments and the cross moment. The plate element is a type of shell element that doesn't have any membrane loadings.

c) Tetrahedron elements:

The form function interpolates the solution between discrete values collected at mesh nodes. As a result, proper functions must be utilised, and as previously stated, low order polynomials are commonly used as shape functions. Linear shape functions are employed in this project.

For three-dimensional finite element simulations it is convenient to discretize the simulation domain using tetrahedrons, as depicted. Thus, linear shape functions must be defined for each tetrahedron of the mesh, in order to apply the Galerkin method.

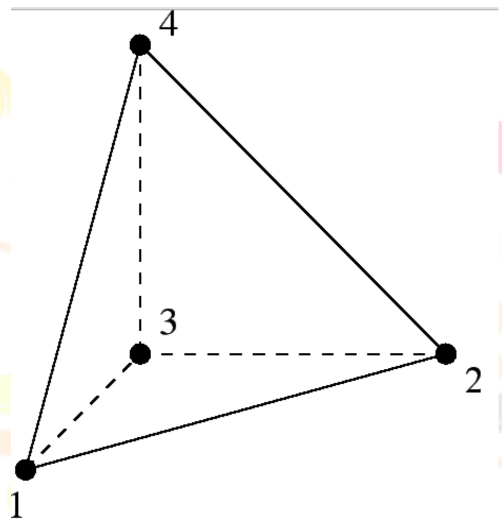


Fig5.12. 2 Tetrahedron element

MESHING

As is customary when dealing with FEM, in this thesis project it was required to establish the mesh size that would achieve the greatest balance of processing time and accuracy in order to ensure that the program's outputs were comparable to reality. A higher mesh quality results in a more precise solution. For example, one can polish the mesh in sections of the geometry with strong gradients to improve the fidelity of the solutions in that area. This also means that if a mesh is not sufficiently polished, the solution's precision is limited. As a result, mesh quality is determined by the desired precision.

Number of Elements=567384

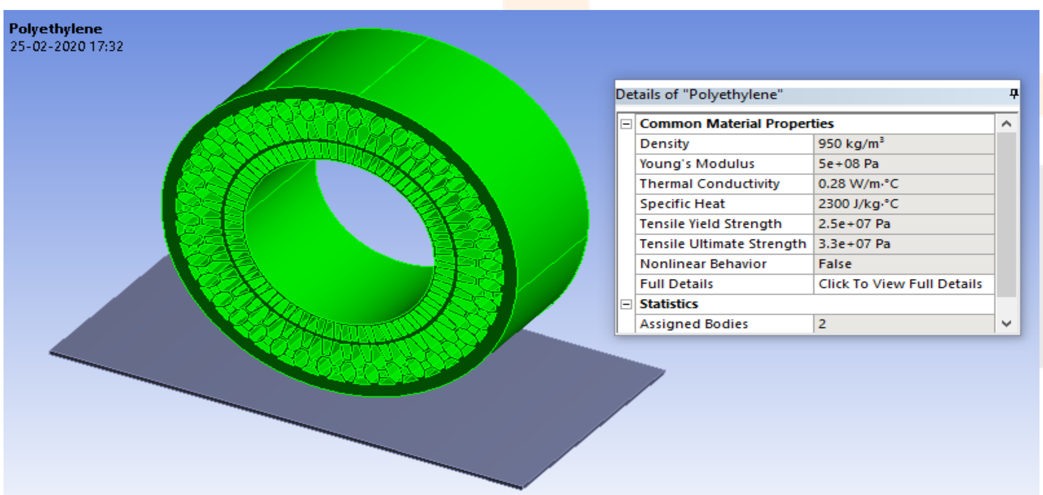
Number of Nodes =102630

Shape checking was done in ANSYS in order to ensure that the model has minimum error percentage than the threshold limit of 5% **(NAFEMS).**our model has the error percentage of 0.75% only which is in the limit.

MATERIAL PROPERTIES

- The material of Non Pneumatic Tyre plays a major role Which also acts as a stiffeners because of the absence of the air.
- Material should be flexible and should posses the properties of the rubber like materials .
- Flexible but it should have to withstand wear and tear and friction without any failure.
- Usually the Non pneumatic Tyres are made of solid plastics or rubbers. Here in this project the Polyethylene is used as a material for the non pneumatic tyre.

Material	**Youngs modulus (Gpa)**	**Poission ratio**	**Density (kg/m3)**
Polyethylene	0.8	0.42	950



BOUNDARY CONDITIONS

Boundary condition

Each tyre model is tested with three different load cases Out of which the optimistic design has to be identified. The load cases are

- **Dead Load :**

The car is immobilized in this state. All of the vehicles own weight as well as the weight of four average-sized passengers will be spread between the vehicle's four wheels.

Tyres must sustain the loading condition with little deflection owing to the vehicle's dead load without failure.

Bump Load :

When the vehicle is moving, additional dynamic forces are applied to the wheels. When a vehicle approaches a sudden bump in the road, the majority of the vehicle's weight is transferred to the wheel that hits the bump, causing the wheel to experience a sudden shock load. The tyres must be able to withstand and absorb abrupt shock loads.

Modal (Natural Frequency) :

To provide rider comfort, the tyres must have the ability to absorb shocks and vibrations from the contact surface, such as a road or a bump.

The purpose of the modal analysis is to determine how the tyres vibrate under fixed conditions.

DEAD LOAD ANALYSIS

A surface is considered to simulate the exact of the road like conditions.

The spoke and the axial will transfer the dead weight of the vehicle to the tyre .Here a vehicle of 1300 Kg with average of 4 persons with 80kg weight is taken into account for the force.

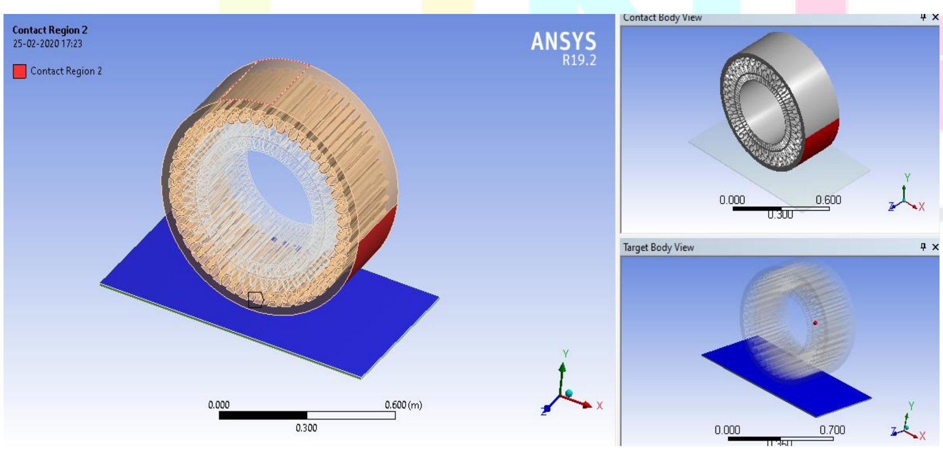


Fig: Contact between road and tyre

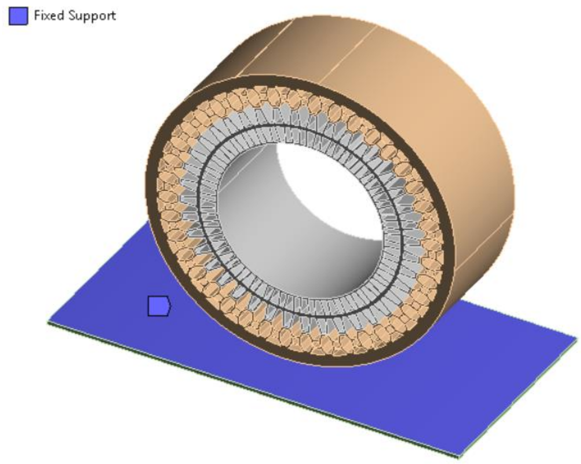


Fig: Fixed support

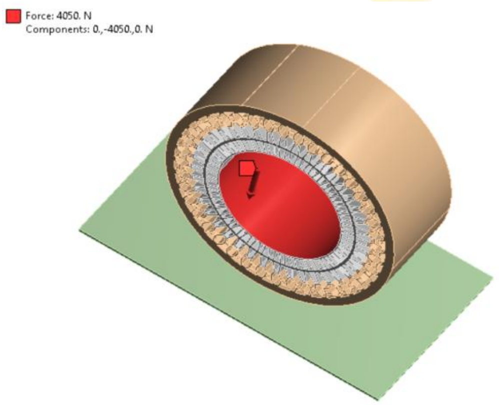


Fig:Vertical (Dead) Force

DEAD LOAD ANALYSIS -TYRE MODEL 1

Total Deformation (mm

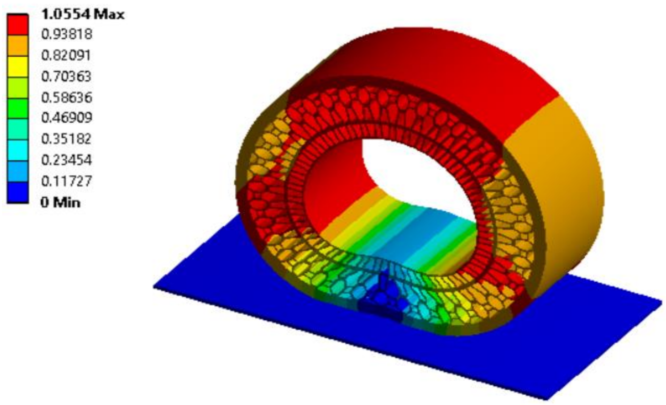


Fig: Deformation

Equivalent stress (Mpa

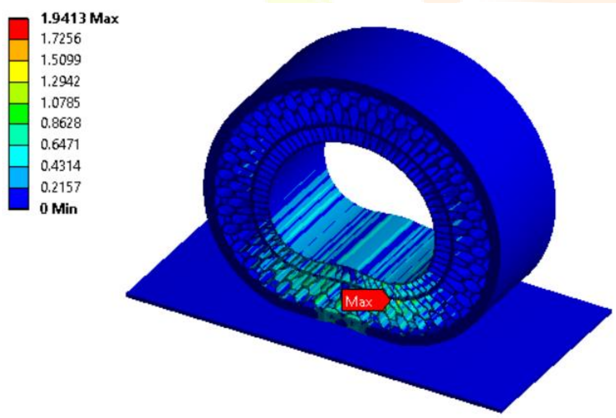


Fig: Vonmises Stress

DEAD LOAD ANALYSIS -TYRE MODEL 2

Total Deformation (mm

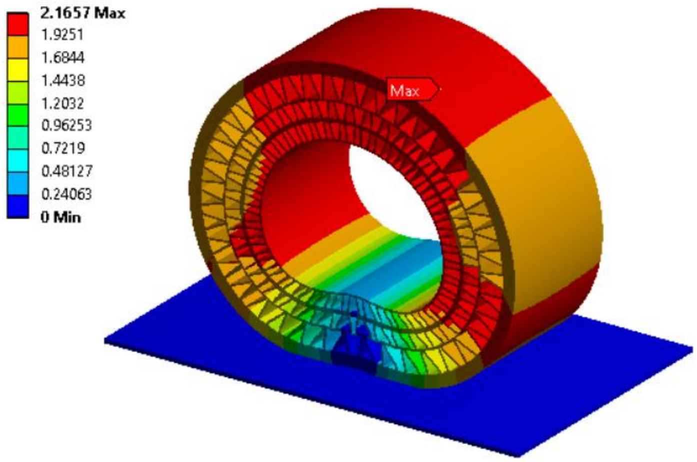


Fig: Vonmises Stress

Equivalent stress (Mpa

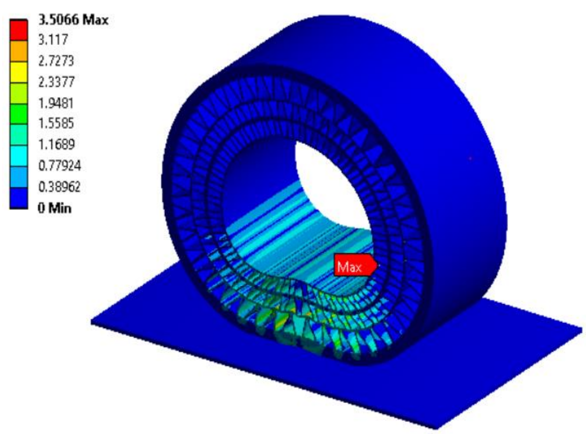


Fig: Vonmises Stress

DEAD LOAD ANALYSIS -TYRE MODEL 3

Total Deformation (mm

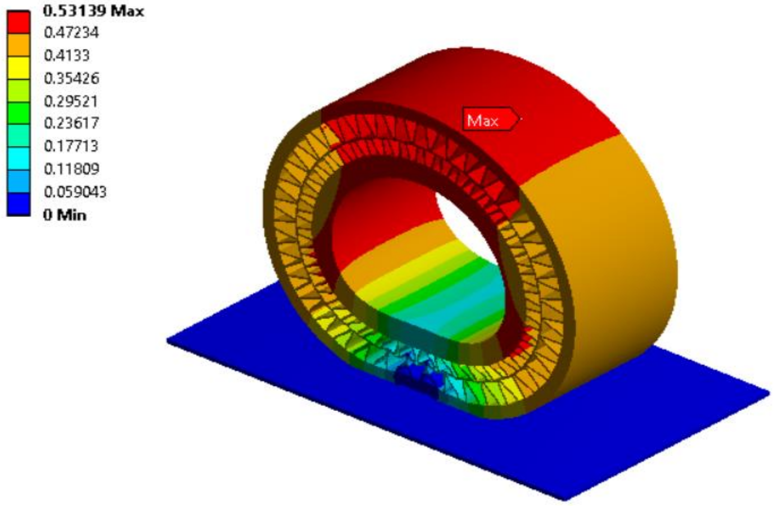


Fig: Deformation

Equivalent stress (Mpa)

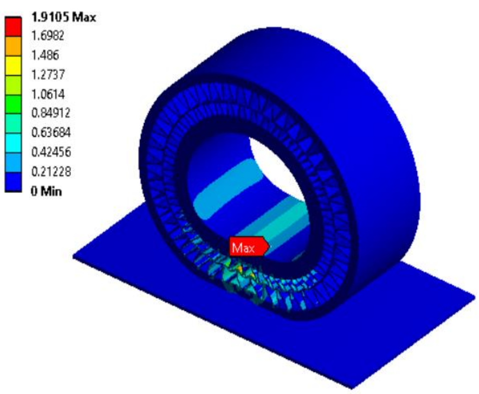


Fig: Vonmises Stress

BOUNDARY CONDITIONS

BUMP LOAD ANALYSIS

A surface is considered to simulate the exact of the road like conditions.

The spoke and the axial will transfer the dead weight of the vehicle to the tyre .Here a vehicle of 1300 Kg with average of 4 persons with 80kg weight is taken into account for the force.

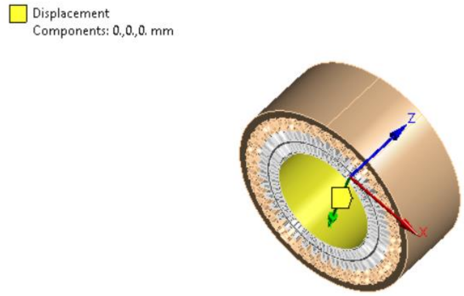
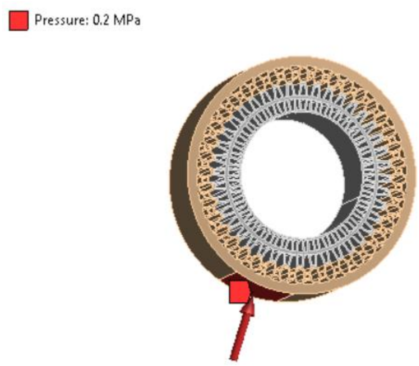


Fig: Fixed Boundary condition



<u>**BUMP LOAD ANALYSIS -TYRE MODEL 1**</u>

<u>**Total Deformation (mm)**</u>

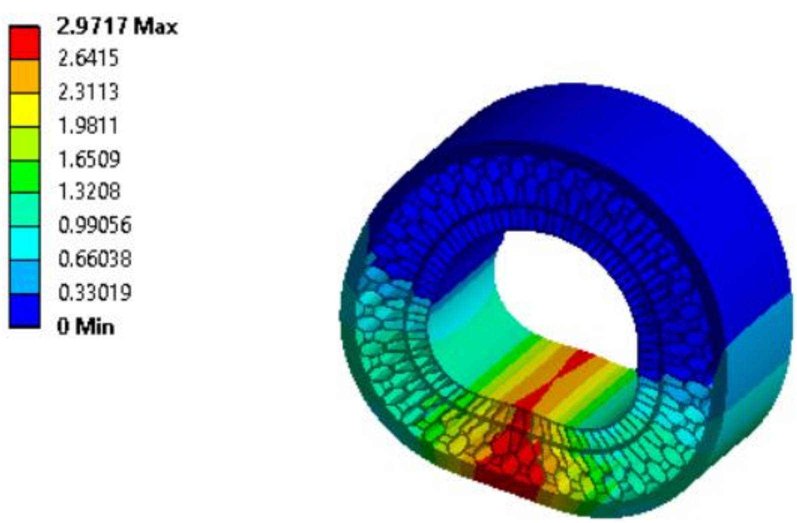


Fig: Deformation

Equivalent stress (Mpa)

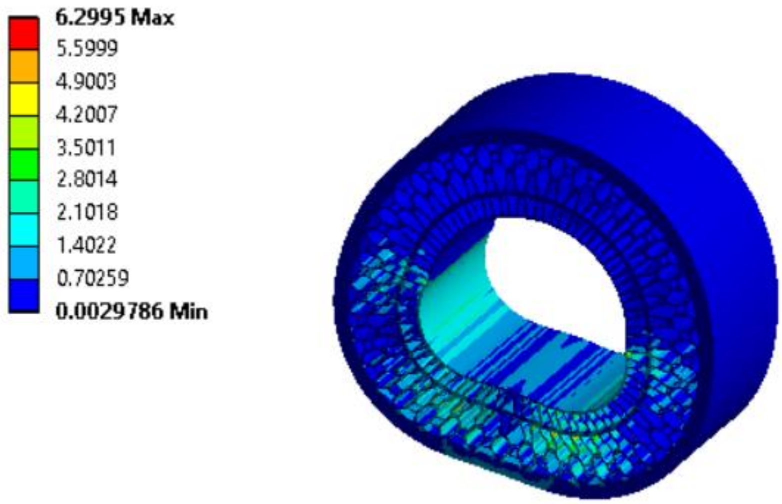


Fig: Vonmises Stress

BUMP LOAD ANALYSIS -TYRE MODEL 2

Total Deformation (mm

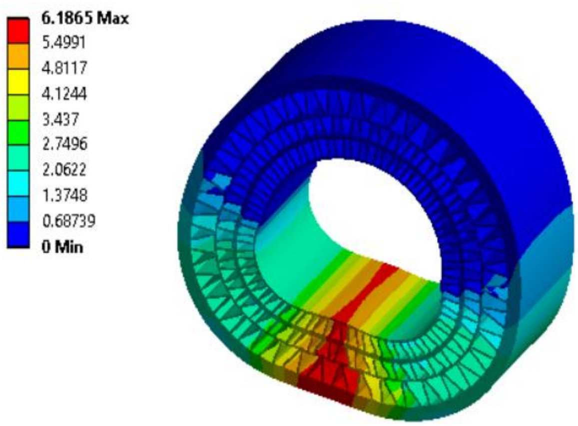


Fig: Deformation

Equivalent stress (Mpa)

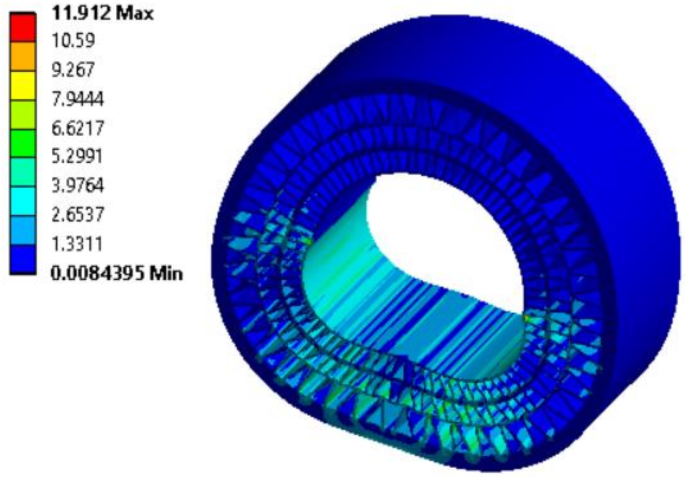


Fig: Vonmises Stress

BUMP LOAD ANALYSIS -TYRE MODEL 3

Total Deformation (mm)

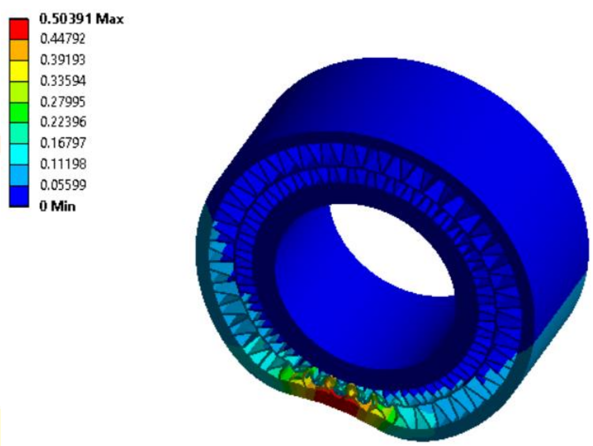


Fig: Deformation

Equivalent stress (Mpa)

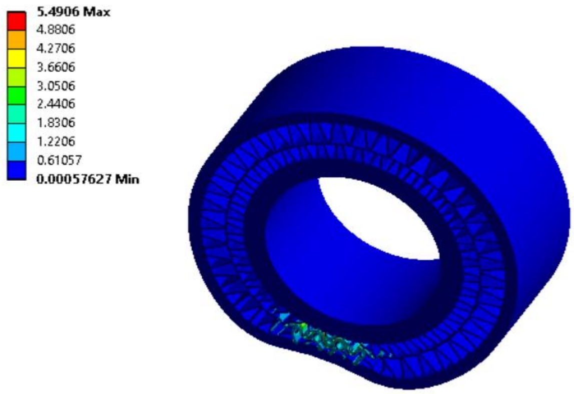


Fig: Vonmises Stress

3. Conclusion

The tyre design which has minimum deflection, posses the maximum stiffness.

Based on the results, The model 2 has more deflection probably it posses minimum stiffness.

Model 3 has less deflection and has the highest rigidity when compared to models 1 and 3.

The rigidity of non pneumatic tyres can be improved by replacing the honeycomb design with a suitable alternate and adding material to the inner band.