DESIGN AND STRUCTURAL ANALYSIS OF NON-PNEUMATIC TYRE

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ABSTRACT:

The NPT's inner hub is connected to flexible polyurethane spokes that support an outer rim and take on the pneumatic shock-absorbing functions of a standard tyre. In the future, NPT will take the place of conventional tyres so that drivers won't have to worry about balancing traction and comfort levels, checking tyre pressure, or highway blowouts. NPT's characteristics, such as contact pressure, rolling resistance, and weight carrying capacity, can be changed by changing the dimensions or materials used to make it. In this thesis the design takes care of the strains brought on by the force placed on the tyre and the tyre's rolling (RPM). ANSYS was utilised as a tool to analyse it. The static and modal analysis was performed on the designed tyre. modifying non pneumatic tyre modelling done in SOLIDWORKS software structural analysis done in Ansys software structural analysis is determine the total deformation von- misses strain von -misses stress for different materials at applying force 750N. Aluminum alloy, structural steel, titanium alloy materials used for non - pneumatic tyre. The design takes care of the strains brought on by the force placed on the tyre and the tyre's rolling (RPM). ANSYS was utilised as a tool to analyse it. The static and dynamic structural analysis was performed on the designed tyre.

Keywords: *Non-pneumatic tyre SOLID WORKS software, ANSYS Software, structural analysis.*

1. INTRODUCTION

The non-pneumatic tyre (NPT) with a hexagonal honeycomb structural design, which was initially created by the French tyre company Michelin, will be static and dynamically analysed in this research. The goal of the current review is to learn more about how airless tyres are made. In contrast to pneumatic tyres, airless tyres, often known as flat-proof tyres or tweels, are made with poly composite compound tread wrapped around a hub of flexible spokes. The fundamental benefit of this design is its durability because, unlike traditional tyres, airless tyres cannot blow out or deflate at highway speeds; therefore the driver does not need to worry about carrying a spare tyre. This tire's primary goal is to get rid of the tube. The tube inside a pneumatic tyre contains the air that causes the tyre to inflate and burst.

Tires that are not supported by air pressure are referred to as non-pneumatic tyres (NPT). They offer a safer place in the driving medium, are more practical, and are lasting. In terms of automobiles, the performance of the tyres determines the quality of the engine, transmission, and all other powertrain components. The predominant option for usage in automobiles subjected to various operating circumstances since Dunlop's discovery of the pneumatic tyre in 1888 has been this tire's many advantages, particularly:

1. Minimum rolling energy loss

2. Reduced vertical stiffness, which has a cushioning effect

3. Low mass,

4. Low contact pressure.

Although it has a number of benefits, its biggest disadvantage to date is the possibility that it could become flat while in use. Michelin and Bridgestone are two tyre firms that have begun experimenting with non-pneumatic tyre designs, but neither has seen large production. The benefits of developing a new, non-pneumatic tyre design are more than one may imagine. There are numerous safety advantages, to name one. The likelihood of a blowout is eliminated with an airless tyre, which considerably reduces the number of highway accidents. Using non pneumatic tyres has a significant positive impact on safety, even in situations like military Humvees. Since tyres are a military vehicle's weak spot, they are frequently the target of explosives. This wouldn't be a problem if these cars had airless tyres. Regarding airless tyres, there have been new innovations.

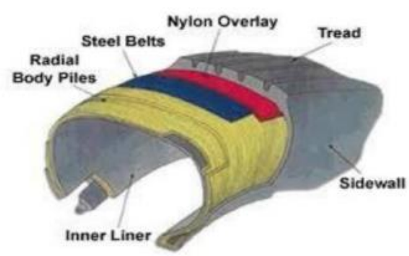
PNEUMATIC TYRE

Despite the wide variety of varieties, pneumatic tyres all share a very similar basic construction. They all have an inner core that is pressured and is coated with a tread—a layer of rubber that makes contact with the road—before being placed on top. The tread aids in maintaining road traction and guards against sliding and skidding. Since the tread has a propensity to wear out over time, a person will typically change the tyre at this stage even if it hasn't gone flat.

NON-PNEUMATIC TYRES (NPT)

Non-pneumatic tyres (NPT), often known as airless tyres, are tyres that are not supported by air pressure. The name "Tweel," a combination of the terms "tyre" and "wheel," is another name for these tyres. The Tweel does not employ a conventional wheel hub assembly, which explains this. Michelin originally introduced the Tweel concept in 2005. A solid inner hub attached onto the vehicle's axle and polyurethane spokes make up its structure. This creates a wedge-shaped pattern that helps to cushion the effects of the road.

These spokes have a bicycle-like appearance and function similarly to a typical tyre's air-filled shock absorber. After that, a sheer band is spread around the spokes to create the tyre's outside edge. The air pressure used on conventional tyres is replaced by the band's tension and the spokes' strength. When a vehicle over an obstruction, such a bump, the tread and shear bands give way and the spokes bend before immediately snapping back into place.



MAIN PARTS OF NON-PNEUMATIC TYRES

The 4 main parts of the non-pneumatic tyres includes:

- hub

- polyurethane spokes
- shear band
- thread band

POLYURETHANE SPOKES

In 1937, Otto Bayer and his colleagues at the I.G. Farben laboratory in Leverkusen, Germany, made the discovery of polyurethane (PU). The first research centred on polyurea (PU) products made from aliphatic diisocyanate and diamine before the intriguing features of PU made from aliphatic diisocyanate and glycol were discovered. As more blowing agents, polyether polyols, and polymeric isocyanates like poly methylene diphenyl diisocyanate (PMDI) became accessible throughout the years, PU transitioned from flexible PU foams to rigid PU foams (polyisocyanurate foams). The heat resistance and flame retardance of these PU foams with PMDI bases were good. In non-pneumatic tyres, this polyurethane is employed as the spokes. It fulfils the role of air in this tyre.

OBJECTIVES

- To sustain the vehicle's weight.
- To protect the car from uneven surfaces.
- To offer enough traction for braking and driving.
- To offer sufficient steering stability and control.
- To stop tyre blowouts or air leakage.
- To make recycling easier.
- To continue to move around even if some of the spokes are broken or missing.
- To enhance Long Life & Durability.
- To get rid of the tube.

2. PREVIOUS STUDY

The primary goal of this work is to use ANSYS Workbench to perform Finite Element Analysis on flange coupling. First, a SOLIDWORKS model of the flange coupling is created and saved in Ansys format. The flange coupling file in Ansys format is then imported into the ANSYS workbench. Plots of the stress and deformation contours have been made. Then, random designs are created using dimension changes, material optimisation, and analysis the solid works software-created model of the flange coupling is subjected to design optimisation in an effort to lighten it. Solid Works is a 3D parametric design tool used to create a wide range of items, including toys, hoover cleaners, cell phones, furniture, electrical assemblies, marine equipment, aeroplane components, autos, marine equipment, furniture, and electrical assemblies. Designing mechanically functional assemblies with fewer than 200 pieces commonly uses Solid Works. So we created a non-pneumatic tyre with the aid of this Solid Works software. Design of spokes structure: The entire structure of the honeycomb is separated into cells during design. To generate the entire structure, a single cell is first created and then patterned. The figure displays the single cell conceptions' dimensions. Hexagonal honeycomb's geometric characteristics As shown in Figure 4.1, hexagonal honeycombs are created using the cell wall thickness, t, the vertical cell length, h, the inclined cell length, l, and the cell angle,. These dimensions are included in Table 4.1 for the honeycomb cells. Depending on the cellular geometry, the honeycombs' efficient stress-strain curves are different. Under uni-axial pressure, cellular structures lose flexibility because to an increasing cell angle (). Lower local stresses are shown by the honeycomb spokes with improved cell angle magnitude, which is great for a fatigueresistant spoke design. There are numerous configurations when designing a honeycomb with various cell angles, heights, and lengths. However, the honeycomb spoke dimensions used in this investigation were determined at random. For the design of the honeycomb spokes, the following dimensions were used.

3. LITERATURE SURVEY

Design and Analysis of Non-Pneumatic Tyre (NPT) With Honeycomb Spokes Structure

A conventional tyre is made up of air enclosed rubber packed by means of compressed air. Conventional tyres over period have been dominating the world marketplace because it exhibits ride excellence and robustness. But it has disadvantaged such as burst out while driving, compound manufacturing method, the necessity to keep interior pressure. An innovative technology is under advancemen t to exploit only one of its kind blends of materials and geometry that does not need compressed air to hold up the load. Hence non - pneumatic tyres were introduced. Non-pneumatic tyre is a submissive of cellular flexible spoke component which acts as air of a traditional tyre. In this project we replace conventional alloy wheel by flexible spoke structure. We investigated hexagonal honeycomb along spokes designed for non-pneumatic tyre by applying uni-axial load. The spokes experience tension as well as compression while they are rolling. So spokes required to have stiffness and rigidity. Non-pneumatic tyre are designed in ANSYS Workbench, (1) honeycomb tyre. ANSYS finite element analysis is worn to find deformation and stress in. Honeycomb tires are established to be superior in terms of fatigue resistance and durability

Design and analysis of non-pneumatic tyre

Non-Pneumatic Tyre (NPT) as the name suggests is a type of tyre that doesn't use air to support the load. Even though tyres made out of solid rubber exists, they don't have enough compliance and will not provide a supple ride if used in normal vehicles. The NPT discussed here consists of mainly three parts. A rigid hub, Deformable spokes that support vertical load, Reinforced shear band and tread made out of rubber which comes into contact with the surface. The properties of NPT like contact pressure, rolling resistance and load carrying capacity can be varied by altering the dimensions or materials used to manufacture NPT. Several researches are being carried out all over the globe to make NPT an alternative to the conventional pneumatic tyre. This paper consolidates an overview of the research works that were carried out to develop and improve NPT.

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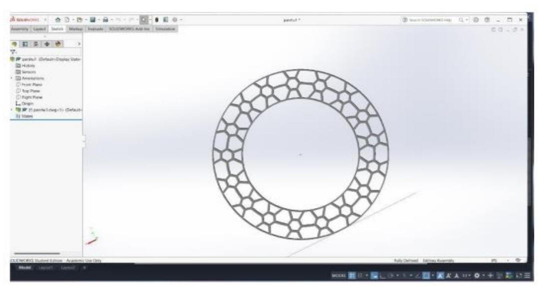
Design and analysis on non-pneumatic tyres with different design structures and assorted loads

Non-pneumatic tyre design is modeled with SOLIDWORKS. with spoke structures as honeycomb and linear plate spokes. The models were analyzed in ANSYS workbench, where hub of the non-pneumatic tyre is made with the Aluminum Alloy (Al:7075-T6) and the spokes with the Polyurethane (PU) and the outer reinforcement are made with the high strength steel (AISI-4340). The factors such as total deformation of the non-pneumatic tire, von misses stress and the von misses' strain, maximum principal stress, shear stress of the non-pneumatic tyre is considered and analysis is carried out by applying various loads at the top surface of the outer ring as 3000N, 4000N and 5000N respectively. Then finding out the suitable design for non-pneumatic tyres by comparing the results

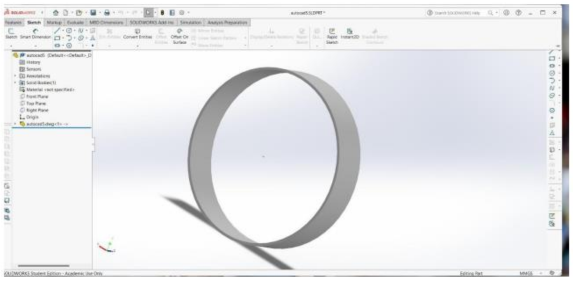
4. METHODOLOGY

Hexagonal honeycomb's geometric characteristics As shown in Figure 4.1, hexagonal honeycombs are created using the cell wall thickness, t, the vertical cell length, h, the inclined cell length, l, and the cell angle,. These dimensions are included in Table 4.1 for the honeycomb cells. Depending on the cellular geometry, the honeycombs' efficient stress-strain curves are different. Under uni-axial pressure, cellular structures lose flexibility because to an increasing cell angle (). Lower local stresses are shown by the honeycomb spokes with improved cell angle magnitude, which is great for a fatigueresistant spoke design. There are numerous configurations when designing a honeycomb with various cell angles, heights, and lengths. However, the honeycomb spoke dimensions used in this investigation were determined at random. For the design of the honeycomb spokes, the following dimensions were used.

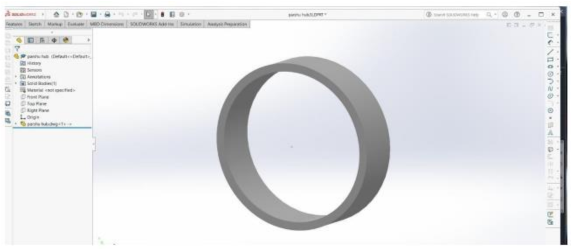
DESIGN OF NON PNEUMATIC TYRE:



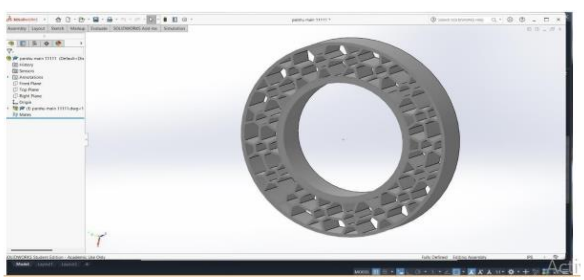
OUTER RING

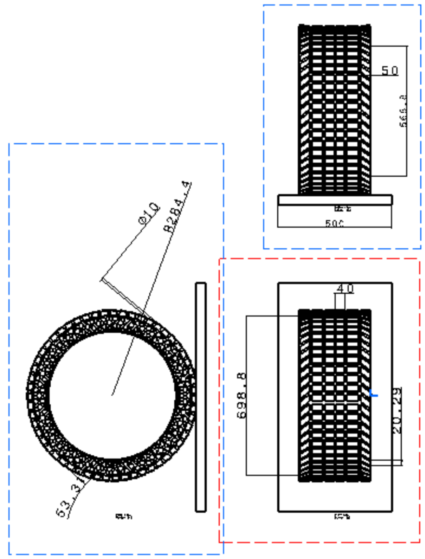


HUB



FINAL ASSEMBLY OF NON PNEMATIC TYRE





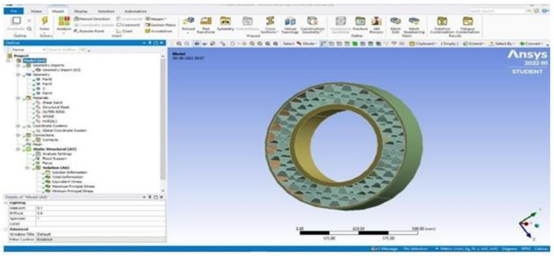
STRUCTURE ANALYSIS OF NON PNEUMATIC TYRE USING ANSYS SOFT WARE

Part	Hub	Honeycomb Spoke	Outer Ring	Shear or Tread Band
Material	Aluminum alloy	Polyurethane	AISI -4340 High Steel	Synthetic Rubber
Young's Modulus (Mpa)	72 Gpa	32 Gpa	210000	11.9
Poisson's Ratio v	0.33	0.49	0.24	0.49
Density kg/m^3	2800	1200	7800	1043
Yield Strength (Mpa)	500	140	470	16

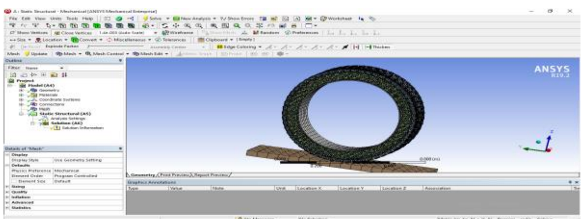
Material used

Aluminum alloy, Structural steel, Titanium alloy

IMPORT GEOMETRY

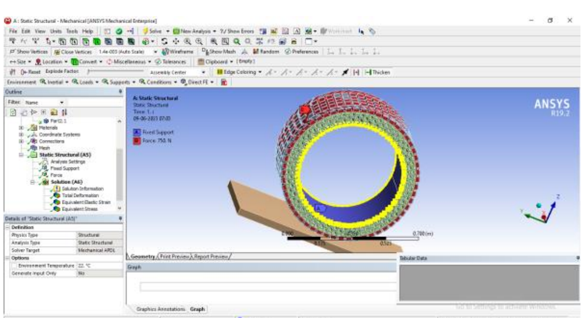


MESHING

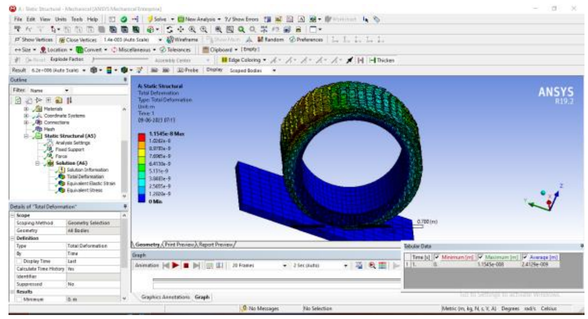


BOUNDARY CONDITIONS

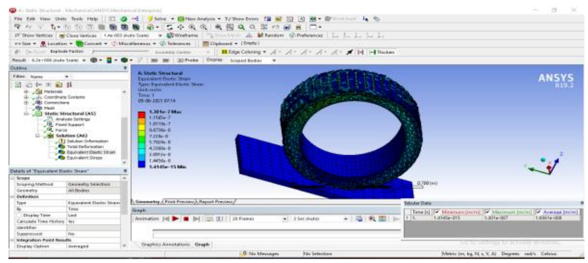
After completion of the meshing, boundary condition and loads are applied. User can define constraints and loads in various ways. This helps the user to keep track of load cases. The boundary condition is the collection of different forces, supports, constraints and any other condition required for complete analysis. Loading conditions force 750N and fixed support are applying outer and inner surfaces respectively as shown in figure.



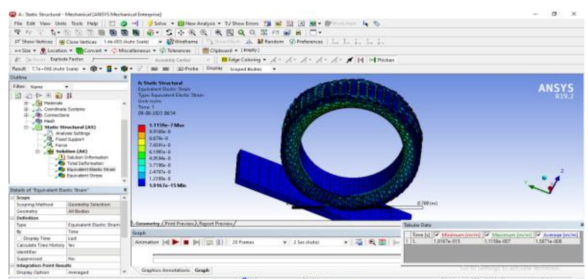
TOTAL DEFORMATION



STRESS

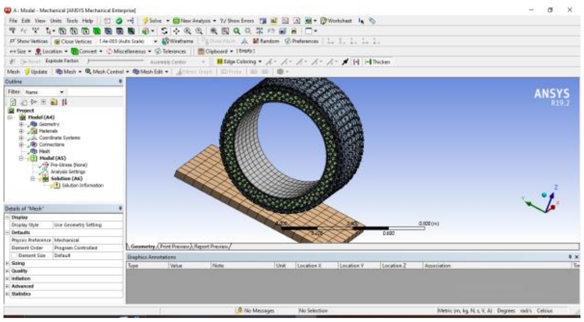


STRAIN



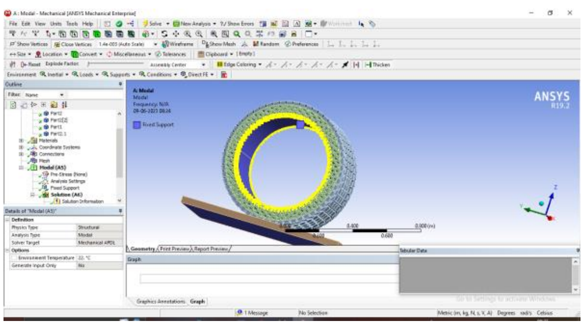
MODAL ANALYSIS OF NON-PNEUMATIC TYRE

MESHING

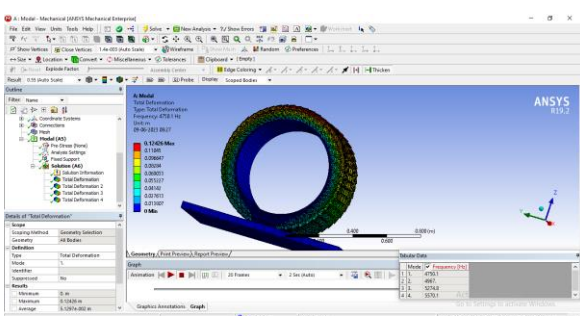


Boundary condition

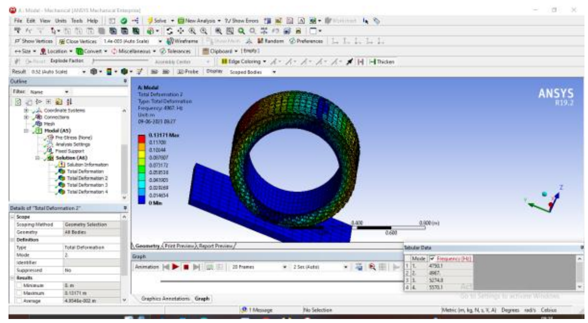
Fixed support



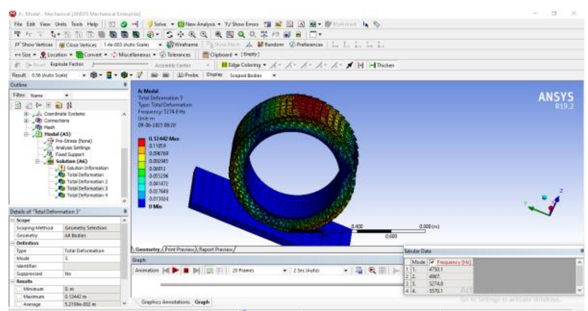
TOTAL DEFORMATION 1



TOTAL DEFORMATION 2



TOTAL DEFORMATION 3



RESULT TABLE

STATIC ANALYSIS

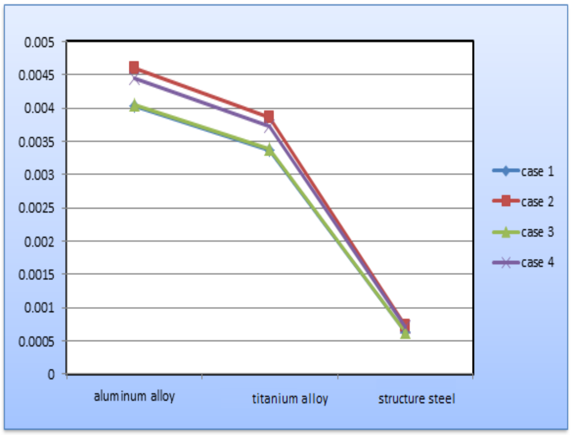
Material	Deformation(mm)	Stress (N/mm^2)	Strain
Structural Steel	$1.1545e^{-8}$	26270	$1.1159e^{-7}$
Aluminum alloy	$1.6183e^{-8}$	27620	$2.128e^{-7}$
Titanium alloy	$1.4406e^{-8}$	27207	$1.6578e^{-7}$

MODAL ANALYSIS

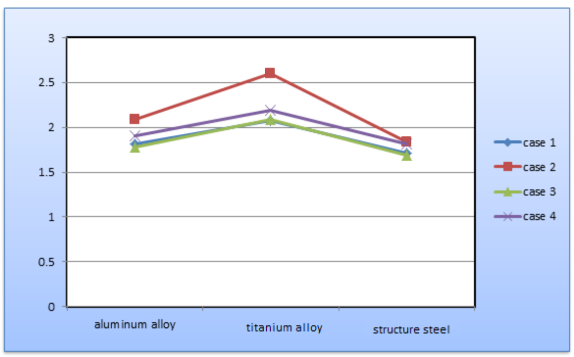
Material	Total Deformation 1(mm)	Total Deformation 2(mm)	Total Deformation 3(mm)	Total deformation 4 (mm)
Structural Steel	0.12426	0.13171	0.12442	0.21782
Aluminum alloy	0.15336	0.16495	0.15327	0.15655
Titanium alloy	0.14177	0.15292	0.14337	0.14662

GRAPHS

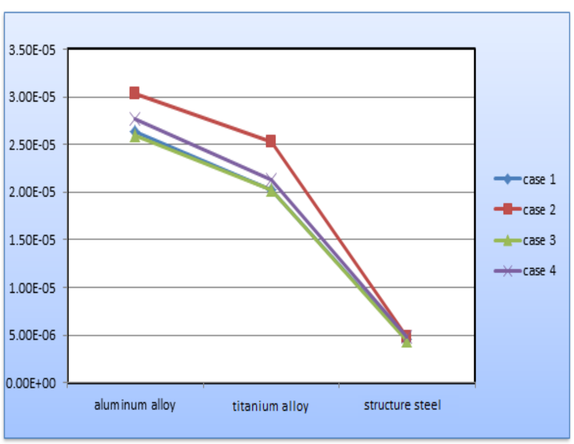
DEFORMATION PLOT



STRESS PLOT



STRAIN PLOT



4. CONCLUSION:

The possibility of a lower cost per tyre, which is always welcomed by the buyer, exists because these tyres can also be withdrawn. Engineering standards of ethics, which will guarantee that the development is carried out in a way that is responsible and fair, are also supported by and guiding this unique project. It's crucial to consider how a technology like this will affect society. In a sense, this is re-inventing the wheel. Because of the benefits this tyre offers and the variety of uses it can be put to, this kind of innovation will become more and more important in the future. The hexagonal honeycomb spokes of an NPT to replace the air in a pneumatic tyre was suggested as a 61 structural application of the flexible in-plane capabilities of hexagonal honeycombs. Using the compliant cellular design concept, cellular spoke shapes for an NPT were examined using normal and auxetic honeycomb spokes. In this thesis the design takes care of the strains brought on by the force placed on the tyre and the tyre's rolling (RPM). ANSYS was utilised as a tool to analyse it. The static and modal analysis was performed on the designed tyre. modifying non pneumatic tyre modelling done in SOLIDWORKS software structural analysis done in Ansys software structural analysis is determine the total deformation, von- misses strain, von -misses stress for different materials at applying force 750N.

Aluminum alloy, structural steel, titanium alloy materials used for non - pneumatic tyre. The design takes care of the strains brought on by the force placed on the tyre and the tyre's rolling (RPM). ANSYS was utilised as a tool to analyse it. The static and dynamic structural analysis was performed on the designed tyre. By observing structural analysis stress and strain values are less for titanium alloy compare to the aluminum and structural steel. By observing modal analysis total deformation is less for titanium alloy compare to the structural steel and aluminum alloy. So we conclude that titanium alloy is better for non-pneumatic tyre.

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