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DESIGN AND ANALYSIS OF NON-PNEUMATIC TYRES

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Abstract: *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.*

I. INTRODUCTION

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 power train 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

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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 Homes. 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.

The NPT is made composed of a rubber tread, a shear band, a rigid hub, and flexible spokes. When the NPT structure is taken into account, the spokes experience cyclic tension compression loading as the tyre rolls thus, it's critical to reduce spoke local stresses when driving with cyclic loading. In other words, the importance of fatigue-resistant spoke design increases. The term "honeycomb" refers to periodic micro structured two-dimensional prismatic cellular materials. In lightweight sandwich structures where a high out-of-plane stiffness is sought, honeycombs have predominantly been utilised. Using this kind of tyre has environmental advantages as well. Airless tyres won't need to be thrown away and replaced as frequently as pneumatic tyres because they never get flat and may be re-treated. This will considerably reduce the volume of landfills. Due of the advantages. I think it's crucial to maintain and expand the study into and manufacturing of airless tyres. 4 This kind of innovation should be encouraged by engineers worldwide because it harmonises nicely with many engineering codes of ethics. People use cars every day, thus any advancement over current models would have a significant impact on the lives of the majority of people. So, I think learning about such a subject is quite valuable, especially for us recent engineering graduates. Researching subjects with such deep significance can produce fruitful outcomes that are advantageous to society.

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.

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Fig-1.1 Pneumatic tyre

The deformation that takes place during rotation is a major justification for employing pneumatic tyres. The car's weight pressing down on the tyre as it rolls causes the tyre to somewhat flatten. This results in the tyre having more of its surface area in contact with the ground, which improves traction. Moreover, it provides a modest cushioning affect that makes tripping over tiny rocks or other debris imperceptible. 5 You can appreciate the difference a pneumatic tyre makes if you've ever ridden in a vintage carriage with wooden wheels. The capacity of pneumatic tyres to absorb the unevenness of the ground is one of their greatest advantages. As a result, there will be less shaking and bouncing during the ride. Also, they will have thicker tyres, which offer traction for driving on slick and uneven terrain. They do, however, also have some drawbacks. Because they frequently result in serious accidents, the danger of a blowout or flat (when air is released unexpectedly from the tyre) is a big issue. Because of these drawbacks, tyre manufacturers are interested in creating airless tyres.

II LITERATURE SURVEY

Aravind Mohan et al. [1] 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.

N. Pavan et al. [2] 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.

Muhammad Ali et al. [3] 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.

Jithendar Gouni et al. [4] Non-pneumatic tyre design is modelled with

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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 Aluminium Alloy (Al: 7075-T6) and the spokes with the Polyurethane (PU) and the outer reinforcement are made with the high strength steel (AISI-4340).

Akshay Narasimhan et al. [5] studied the effect of material properties on static behaviour of an NPT having radial spokes and shear band made of polyurethane and concluded that increase in shear modulus increased the stiffness of the NPT. Hysteresis loss due to the viscoelastic nature of rubber accounts for 90 % of energy loss. The spokes and shear band of NPT are usually made of polyurethane which also exhibits viscoelasticity

Mohammad Fazalpour et al. [6] developed and studied the characteristics of NPT with shear band having cellular structure which is made of elastic material. Conventional materials don't exhibit high stiffness with good resilience. In order to achieve desired properties, the shear band was made into a cellular structure as cellular structures of desired properties can be made by optimizing the cell geometry. Cellular structures are also used for construction of spokes of an NPT.

Jaehyung Ju et al. [7] studied the properties of NPTs having spokes made of both regular and auxetic honeycombs and mentioned that the behaviour of regular and auxetic honeycombs differ much as far as deflection under axial loading is concerned.

Kwangwon Kim et al. [8] studied the static behaviour of NPT with hexagonal spokes by comparing their designs with a pneumatic tyre of similar dimension and observed that NPT has less contact pressure than a pneumatic tyre. This project aims to study the static contact behaviour of NPTs having regular hexagonal honeycomb spokes with different cell geometries having same thickness.

III METHODOLOGY

The methodology is composed of deep literature research from previous work on pneumatic and NPTs to design and analyse new polyurethane spoke structures according to standard (GBT 2977-2008) which have least amount of deformation, stress, and strain energy values. The material properties of all the metallic parts of the tyre were taken from previous research work including the non-linear material data of polyurethane and synthetic rubber. A honeycomb NPT (NPT-A1) was taken as a standard design to set the

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boundary and mesh parameters in ANSYS and compare the results of the stress analysis of HC-A1 based on Mooney-Rivlin (MR) hyper-elastic material model, with the previous research of NPT-A1, by applying a point load at the centre of the aluminium hub. After the stress results of HC-A1 matched with the stress results of NPT-A1 with minimum error, then the same boundary and mesh parameters were used for the newly designed spoke structures. The newly designed NPTs spoke structures dimensions were also designed as per standard (GBT 2977-2008) and only the designs of spoke structures were changed by keeping the mass of the spoke structures almost constant. These include the three positive cell angle honeycombs (HC-A1, HC-A2, and HC-A3), simple straight spoke type, and trapezoid type NPTs spoke structures. In this paper, the non-linear static structural analysis of NPTs with different spoke structures was numerically analyzed and simulated. The deformation modes, stress distribution in treads and spokes, and the strain energy parameters of different designs of NPTs were studied thoroughly.

IV DESIGN

Solid Works is a 3D parametric design tool used to create a wide range of items, including toys, how over 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 no 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.

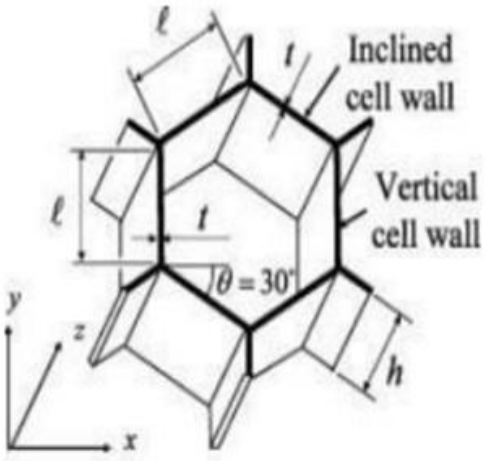

Fig-4.1 Length & Angle of cell wall

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

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in Table 4.1 for the honeycomb cells. Depending on the cellular geometry, the honeycombs' efficient stress-strain curves are different. Under unit-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 fatigue resistant 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.

HONEYCOMB SPOKE IN SOLIDWORKS

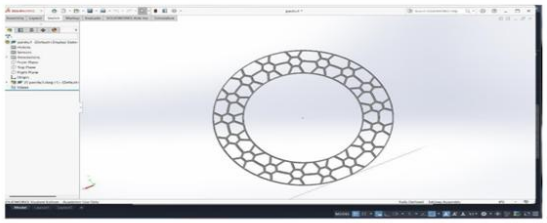

Fig-4.2 Structure of honeycomb spoke

In this fig honey comb spoke is designed in solid works software by using solid works modules. In solid works we have mainly 4 modules

The modules are:

1. Sketcher3. Assembly

2. Part4. Drafting

V STRUCTURAL ANALYSIS

IMPORT GEOMETRY IN ANSYS FROM SOLIDWORKS

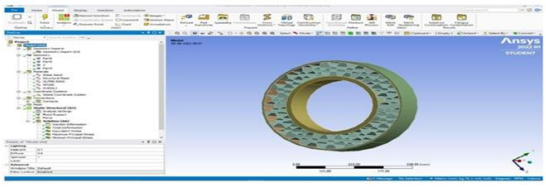

Fig-5.1 Part design

The model is designed with the help of solid works and then import on ANSYS for Meshing and analysis. The analysis by static analysis is used in order to calculating pressure profile and deformation stress and strain.

5.1.1 Meshing

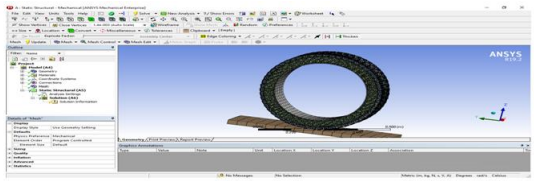

Fig-5.2 Meshing

For meshing, the load ring is divided into two connected volumes. Then all thickness edges are meshed with 360 intervals. A tetrahedral structure mesh is used. So the total number of nodes and elements is 6576 and 3344

5.1.2 BOUNDARY CONDITIONS

After completion of the meshing, boundary condition and loads are applied. User can

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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.

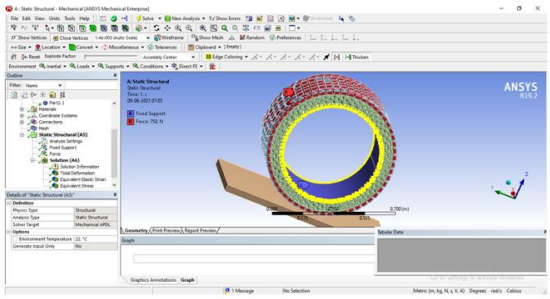

Fig-5.3 Structural conditions

The following results are obtained

1. Total deformation
2. Von-Mises equivalent stress
3. Von- mises equivalent strain

VI RESULT

Research into airless tyres contradicts the common perception that tyres are an insignificant component of automobiles that cannot be improved. This innovative technology will improve environmental sustainability while also enhancing vehicle safety. The possibility of a lower cost per tire, 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.

Structural analysis results

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	$1.6578e^{-7}$

Table no-7.1

Modal analysis results

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

Table no-7.2

GRAPHS

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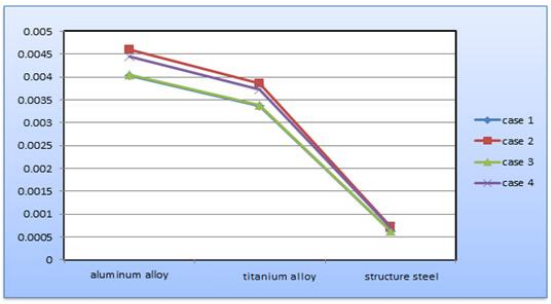
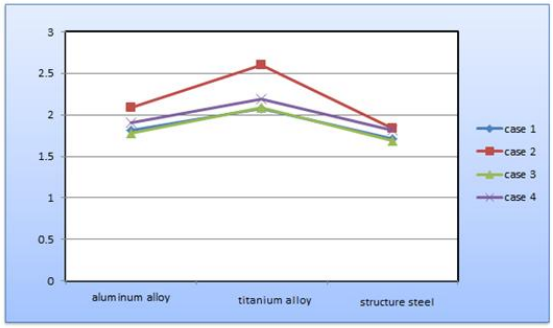
DEFORMATION PLOT OF THREE METALS



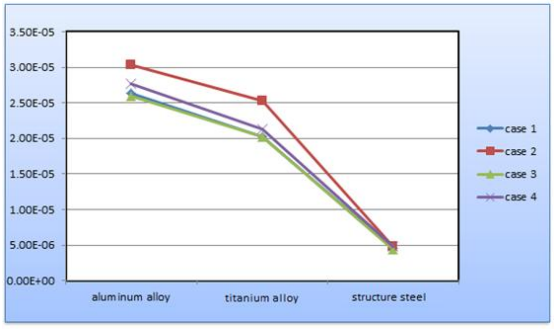
Graph-1

STRESS PLOT OF THREE METALS



Graph-2

STRAIN PLOT OF THREE METALS



Graph-3

VII 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.

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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.

Aluminium 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.

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