IJARSCT

ISSN (Online) 2581-9429

Impact Factor: 6.252

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

Volume 2, Issue 6, May 2022

Modeling, Finite Element Analysis, and Optimization of Non-Pneumatic Tyre (NPT)

Prof. B. M. Mariyappalavar[1], Mayur Thakare[2], Atharva Chowkidar[3],
Bhushan Chavhan[4], Mayur Kashid[5]
Professor, Department of Mechanical Engineering[1]
Student, Department of Mechanical Engineering[2,3,4,5]
JSPM's Rajarshi Shahu College of Engineering, Pune, Maharashtra, India

Abstract: *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 exist, they don't have enough compliance and will not provide a supple ride if used in normal vehicles. Non-Pneumatic tyres are introduced to overcome the disadvantages of pneumatic tyres. They are introduced with a compliant cellular solid spoke component which functions as air of a pneumatic tyre. The objective of this work is to design and analyse honeycomb spokes for NPT tyre which can withstand static conditions of an All Terrain Vehicle (ATV) under macroscopic uni-axial loading condition. Three types of honeycomb spokes models are analysed using ANSYS finite element analysis to study about the deformation and stresses developed.*

Keywords: Non-Pneumatic Tyre (NPT), Static analysis of Non-Pneumatic Tyre, Design approach of Non-Pneumatic Tyre(NPT), Honeycomb Structure, Airless tyres

I. INTRODUCTION

Airless tyres or non-pneumatic tyres are the tyres which are not supported by air pressure. They are more convenient, durable and they provide a safer space in the driving medium. These tyres are also called as T wheel which are a merger of the words tyre and wheel. This is because the T wheel does not use a traditional wheel and hub assembly. The 'Term non-pneumatic tyre' should be understood as a structure that transmits using the rim the vertical and tangential force that provides directional control of the vehicle and the attainment of those properties does not depend on the pressure of any gas or fluid inside the tire. The rim (which task is to connect the NPT structure with the vehicle hub) is usually made of a material characterized by a high value of Young's modulus (compared to the other elements of the NPT), the most commonly used materials are steel or aluminum alloys. The main task of the tread is to provide proper cooperation of its blocks with the ground and provide protection of reinforcement layers against damage resulting from the impact of roads' obstacles. The flexible spokes and shear band are the components that support the load acting on an NPT like air in the case of a pneumatic tyre. Several researches are going on to optimize the design of spokes and shear band of an NPT and some of them are discussed below. Akshay Narasimhan et al [4] 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.

II. HONEYCOMB STRUCTURE

Honeycomb structures have been widely used in the aircraft industry to construct lightweight sandwich structures having high out of plane stiffness. As mentioned before, the magnitude of in-plane stiffness of honeycomb cellular structures are less. Triangular and kagome structures are known to be extension dominant structures whereas hexagonal and square structures have good flexibility. The hexagonal structures exhibit greater flexibility under both axial and shear loading conditions. The advantage of hexagonal structures is that desired in-plane properties can be achieved by changing cell parameters like cell angle, cell length and wall thickness. Effective in-plane moduli of hexagonal honeycombs were developed using beam theory and are collectively called cellular material theory (CMT). The effective moduli according to this theory are given by the following equations,

DOI: 10.48175/568

III. DESIGN OF NON-PNEUMATIC TYRE

3.1 Structure and Material

An NPT integrates wheel and tire into a single unit and different parts of an NPT are made of different materials. CAD models of 3 NPTs were made which is discussed in the next section. The NPT concept described consists of a composite ring, with at least two circumferential reinforcements separated by a radial distance. The composite ring is called a shear beam and it has a low modulus material sandwiched between the reinforcements. During rolling, the material between the reinforcements is subjected to shear loading and deforms primarily in pure shear. A uniform, yet discrete, distribution 2 of spoke pairs is designed to connect the ring to the hub of the wheel and they deform due to buckling. The hubs of all three NPTs are made of 10mm thick aluminium alloy. The flexible honeycomb spokes NPT is made of polyurethane and is attached to the rigid hub. The shear band is provided to have a uniform contact patch and the shear rings help to keep the tyre in the shape when it is deformed.

A. Material properties

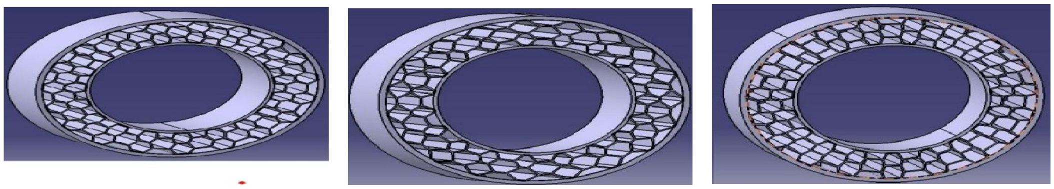
1) Aluminium Alloy 7075- T6
   -Density 2800 Kg/m3
   -Young's modulus 72 Gpa
   -Yield stress 503 Mpa
   -Poisson's Ratio 0.33

2) Polyurethane
   -Density 1200 Kg/m3
   -Young's modulus 32 Gpa
   -Yield stress 145 Mpa
   -Poisson's Ratio 0.49

3) High Strength Steel
   -Density 7800 Kg/m3
   -Young's modulus 210 Gpa
   -Yield stress 710 Mpa
   -Poisson's Ratio 0.29

4) Rubber
   -Density 1043 Kg/m3
   -Young's modulus 11.9 Gpa
   -Yield stress 16 Mpa
   -Poisson's Ratio 0.49

B. CAD model of NPT



Types	l	h	Theta	T
Type A	37	16	137	4
Type B	29	28	121	4
Type C	26	36	105	4

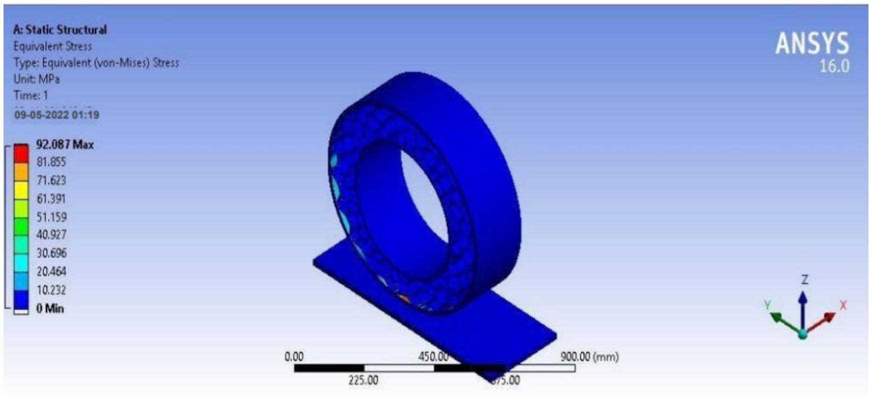
The design of spokes influences the stiffness and resilience of an NPT. The dimensions of other components were kept as a constant and the dimensions of cells of the spokes were varied to generate different designs. The overall diameters of all the three designs are 654mm. The Cell angle θ, inclined cell length l, vertical cell length h and wall thickness t are the parameters that influence in-plane properties of a honeycomb structure. The cells were designed to have a uniform thickness of 4mm. Since the hexagonal cells are of non-regular type, the dimensions of each cell vary slightly and the average dimensions of a cell of each type is mentioned in Table. The effective in-plane moduli for different spoke designs were calculated using CMT. Cell angle and the ratio of inclined length to cell height (l\h) are the critical factors that determine the flexibility of the structure.

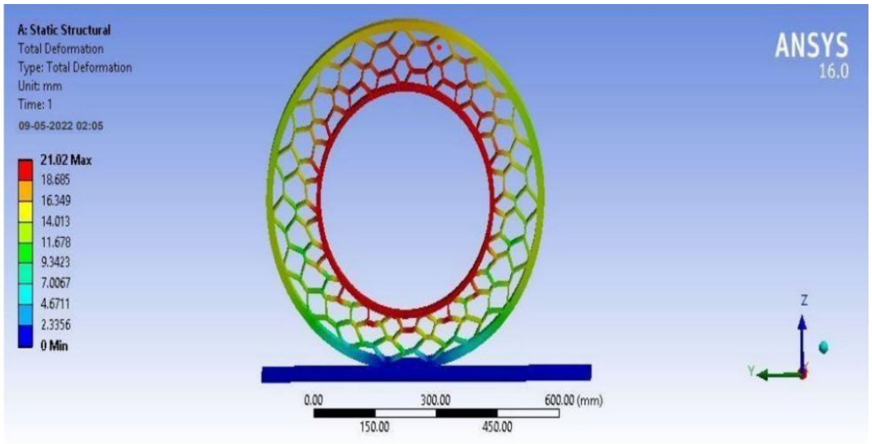
C. Finite Element Analysis

Meshing was done in Ansys Workbench and tetrahedral elements were used for meshing. Tetrahedral elements have 3 degree of freedom at each node and can completely capture the behavior of component by creating appropriate mathematical model while analyzing.

D. Boundary Conditions and Loading

In order to perform static analysis on NPTs designed, the CAD model is imported into Ansys Workbench and material properties for each element of NPT were assigned. The tread and shear band with rings, the shear band and spokes, the spokes and aluminium hub were tied together using bonded constraint. Frictional type contact was used to define the nature of contact between road surface and the tread. The movement of NPT was arrested in all directions except the vertical and load varying from 1000N to a maximum of 4000N was applied at the center of the hub and corresponding total deflection in vertical direction and equivalent stresses developed in spokes were noted. Contact tool is used to get the value of contact pressure generated between the tread and road surface when the load is applied.





DOI: 10.48175/568

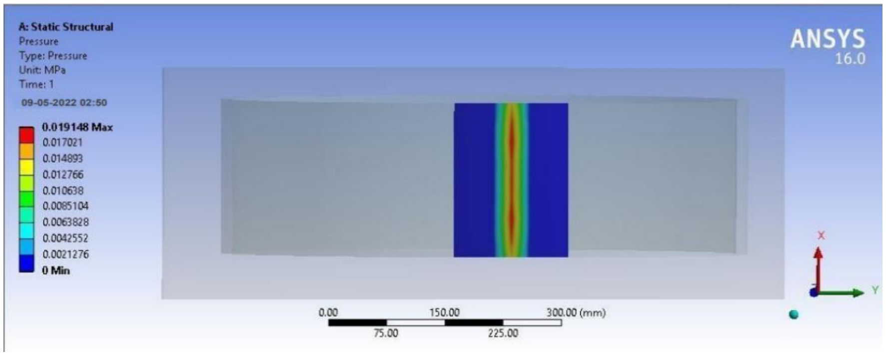


Figure 3. Ansys test results for Type A at maximum load showing Von-Mises Equivalent stress, Deformation, and Contact pressure in order

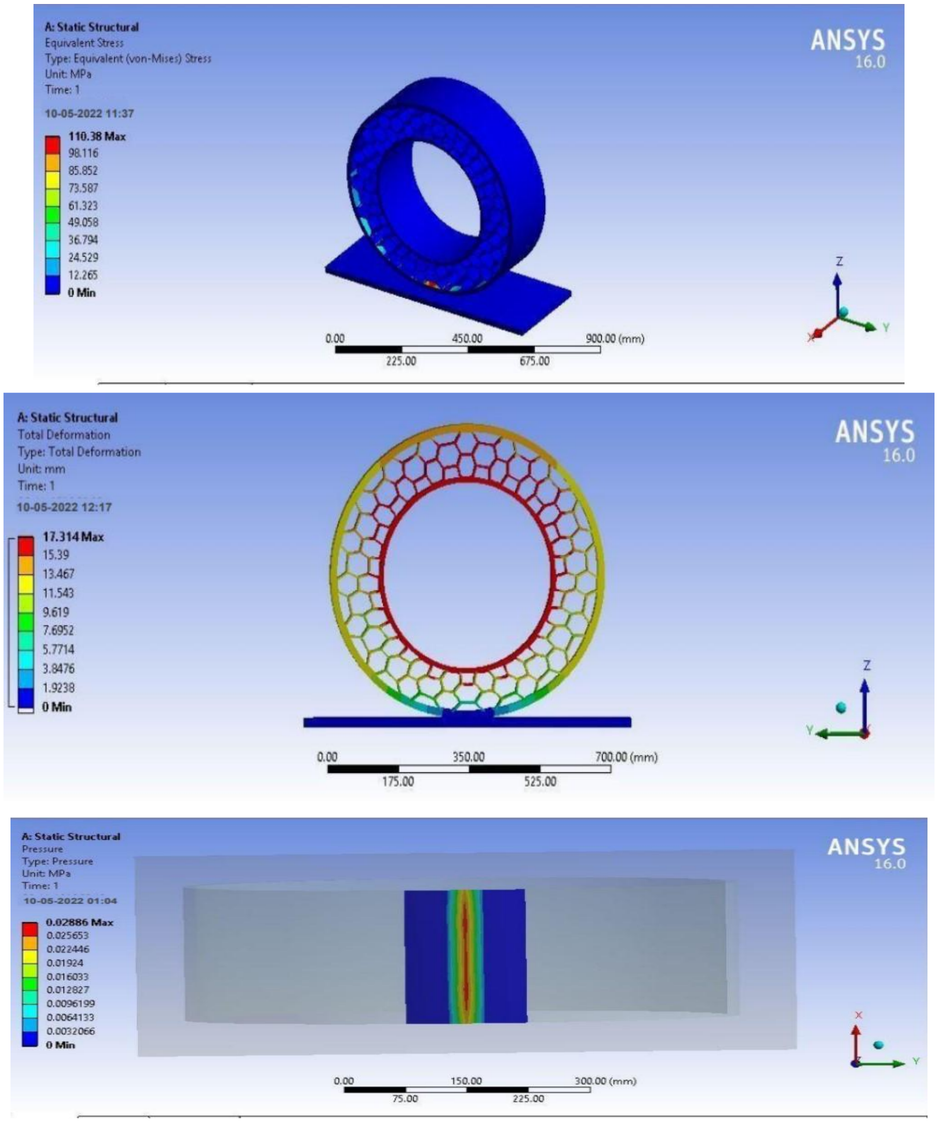


Figure 4. Ansys test results for Type B at maximum load showing Von-Mises Equivalent stress, Deformation, and Contact pressure in order.

DOI: 10.48175/568

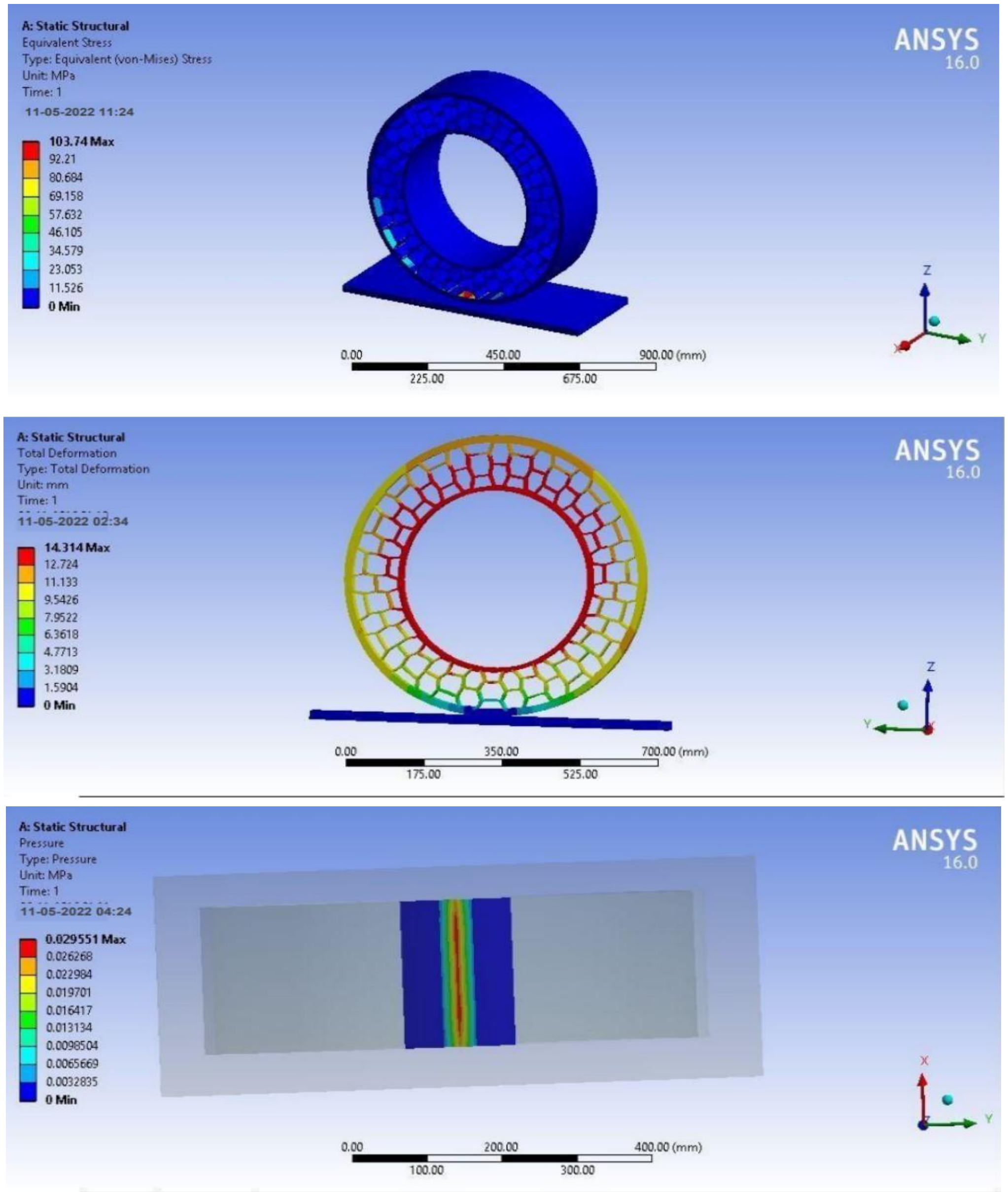


Figure 5. Ansys test results for Type C at maximum load showing Von-Mises Equivalent stress, Deformation, and Contact pressure in order.

Load (n)	Type	Maximum Deformation (mm)	Von mises Stress (mpa)	Maximum Contact pressure (mpa)
1000	A	12.55	54.06	0.013
	B	10.21	63.47	0.017
	C	7.15	49.48	0.016
2000	A	13.56	58.74	0.018
	B	12.24	76.62	0.018

	C	9.22	64.65	0.019
3000	A	16.78	73.08	0.017
	B	15.29	96.96	0.028
	C	11.28	80.38	0.026
4000	A	21.06	92.09	0.016
	B	17.34	110.36	0.026
	C	14.34	103.78	0.027

IV. CONCLUSION

NPT with honeycomb spokes with larger cell angle showed minimum stress concentration which is important for fatigue resistant designs. Ratio of inclined cell angle to cell height is an important factor which determines the flexibility of honeycomb structure under axial loading. Larger ratio induces high flexibility to structure. Due to decreasing vertical stiffness with load, NPTs with hexagonal spokes exhibit lower contact pressures. Type A designs having the largest cell angle among the three designs exhibit least stress, maximum deflection and minimum contact pressure and performance best under static conditions. Thus we have to work on improvement of design to optimize rolling resistance.

REFERENCES

[1]. Static analysis of airless tyres by C. Manibaalan , Balamurugan. S , Dr. Joshi. C. Haran
[2]. Thermo-mechanical Analysis of Non-pneumatic Rubber Tyres by Stephen Harwood
[3]. Airless Tyre Project SciTech Industries (2012). (Video) http://vimeo.com/41741265
[4]. B.Mattmiller. (2008). Airless Tyre Project May Prove a Lifesaver in Military Combat. University of Wisconsin News Archive (Online article). http://www.engr.wisc.edu/news/archive/2008/Jul08.html p. 1
[5]. Study on 3D printed auxetic structure-based non-pneumatic tyres (NPT'S) By Narasimhulu Andriya
[6]. Optimisation of geometry and material properties of a non-pneumatic tyre for reducing rolling resistance by Mallikarjun Veeramurthy, Jaehyung Ju, Lonny L. Thompson and Joshua D. Summers
[7]. CFD study of aerodynamic performance of non-pneumatic tyre with hexagonal spokes by Daksh Bhatia, Praneeth KR, Babu Rao Ponangi.

DOI: 10.48175/568