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Design & Analysis of Spokes of Non-Pneumatic Tyre on Hatchback, Sedan and SUV Tyres

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Abstract: The Non-Pneumatic Tyre (NPT) is a type of tyre that does not rely on air to maintain the weight. Although solid rubber tyres are available, they lack compliance and will not give a soft ride when utilised in conventional automobiles. Non-pneumatic tyres (NPTs) have two advantages over pneumatic tyres: they are flat-proof and do not require air-pressure maintenance. The static contact behaviour of NPTs with hexagonal honeycombs is researched as a function of vertical tension in this study, while additional advantages of NPTs are investigated. Several research projects are underway across the world to develop NPT as a viable alternative to standard pneumatic tyres. This publication compiles a summary of the research that was conducted to create and enhance NPT.

I. INTRODUCTION

When it comes to autos, the engine, transmission, and other powertrain components are only as good as the tyres. Pneumatic tyres have been the dominant choice for usage in automobiles subjected to various operating circumstances since its creation in 1888 by Dunlop, owing to a number of advantages, including: Low energy waste while rolling. Cushioning effect due to low vertical rigidity. Contact pressure is low, and Low mass. Even while a pneumatic tyre has various advantages that have led to its broad acceptance, it has the potential to run flat during operation, which is its greatest negative to date. Solid tyres are used on vehicles that are subjected to harsh circumstances, such as tractors, to eliminate this problem, however this degrades ride quality. Researchers have been working on a non-pneumatic tyre (NPT) with suitable robustness since the 1920s. Researchers were able to develop NPTs with appropriate compliance thanks to advances in material science and production technology. The wheel and tyre are combined into a single component in modern NPT designs. The NPT is divided into three sections. Deformable spokes that support vertical weight, a stiff hub Rubber tread and reinforced shear band that comes into touch with the surface. By changing the size or materials used to make NPT, may change its qualities such contact pressure, rolling resistance, and load bearing capacity.

II. RESEARCH METHODOLOGY

The Research paper “Design and Analysis of non-pneumatic hexagonal tyre”. Which is published by M. Venego, Pal Reddy, P. Harshita, S. Sreshta. Their objective of this work is to design and analyze hexagonal honeycomb spokes for non-pneumatic tyre which can withstand static conditions of an all-terrain vehicle (ATV) under macro-scopic uniaxial loading conditions. Three types of honeycomb spokes models are analyzed using ANSYS finite element analysis to study about the deformation and stresses developed. The parts which are used for non-pneumatic tyres includes HUB material is A17075-T6, POLYURETHANE SPOKES, Shear Band material is AISI4130, Thread Band material is Synthetic rubber. There are various types of spokes to design and analyze. The types of spokes are Honeycomb Structure, Spoke tyre Structure, Triangular Structure, Diamond Structure. Honeycomb Spokes Structure was chosen because it has the best shape, with low rolling resistance, a low mass valve, a lower and more uniform contact pressure distribution, and the ability to take von-mises stresses on its spokes. Their design calculation was shaft design, key dimensions, design of rim, design of hub, etc. They take three different types of no-pneumatic tyre are modeled namely type A, B, and C are in the variation of Dimensions of the honeycomb spokes and the other material properties remain same. They calculated the stresses like deformation and von-mises stresses into the ANSYS Software and their static structural analysis was conducted comparing the three types of tyre dimensions the conclusion can be drawn to a point that the type B has shown desired results for the static loading condition of an ATV.

T. Prabhurama, S. C. Meenakshi Sundarama, S. Jegadeeswers, and V. Sathish Kannan published a paper titled "Static study of varied spoke structure of airless and conventional tyre." The goal of this project is to undertake a static study of an airless tyre using a variety of 3D printing materials and spoke configurations. They use multiple 3D printing materials to conduct finite element analysis on an airless tyre. Honeycomb, diamond, and triangle spoke structures were investigated for this investigation. For their 3D printing experiment, they used ABS+PC, PET, and HIPS. Traditional tyres are made of neoprene rubber. The static analysis is carried out using ANSYS. The boundary conditions for modelling and analysis of airless tyres are considered design characteristics, such as a load of 3193 N and a mesh element size of 50mm. For airless tyres, the hub is considered fixed support, but for conventional tyres, the rim is considered fixed support. It compares and contrasts the three materials used in airless tyres. As a consequence, they conclude that the diamond spoke structure modal outperforms the other spoke modal. Similarly, the diamond spoke structure performs better under varied material restrictions for all three materials. As a result, the diamond spoke structure airless tyre is more robust and durable for the given boundary condition and applied stresses.

The research paper "design and analysis of non-pneumatic tyre with honeycomb spoke's structure" which is published by umesh G C, Amit kumar. This paper shows that we can replace conventional tyres (pneumatic tyres) by non-pneumatic tyre. Traditional tyres have long dominated the global market due to their superior ride quality and durability. However, it has drawbacks such as bursting while driving, the need to maintain internal pressure, and the compound production procedure. A cutting-edge technique is being developed to leverage one-of-a-kind mixtures of materials and geometry that do not require compressed air to support the load. As a result, non-pneumatic tyres were developed. A non-pneumatic tyre is a cellular flexible spoke component that replaces the air in a standard tyre. The flexible spoke construction is used to replace the traditional alloy wheel in this article. They used uni-axial load to study hexagonal honeycomb along spokes developed for non-pneumatic tyres.The spokes experience tension as well as compression while they are rolling. So spokes required to have stiffness and rigidity.

III. Problem Statement

The non-pneumatic tyre mostly had high rolling resistance and gives less suspension than similar shaped and sized pneumatic tyres. The other problems for non-pneumatic tyre is that the heat generated that occurs when they are driven. The non-pneumatic tyres are covered with compressed polymers (plastic). Taking the non-pneumatic tyre, the spokes of non-pneumatic tyre undergoes various stresses during the tyre rolls. And with different vehicles loads the stresses are defined. The Stresses are Deformation, Shear Stress, Von-mises, and Strain etc. Therefore, it is most important to minimize these stresses of spokes that is the spoke should be stress resistant. In the non-pneumatic tyre, the stresses mostly affect the spokes of the non-pneumatic tyre, so while designing the non-pneumatic tyre the most important part is the spoke and there are various spokes structures that can resists high stresses that are Plate spoke, diamond spoke, triangular spoke, and honeycomb spoke etc. And also, it need to design taking various loads conditions as there are different loads of different vehicles and also analysing the non-pneumatic tyre to find out the stresses using ANSYS Software.

IV. CAD Model

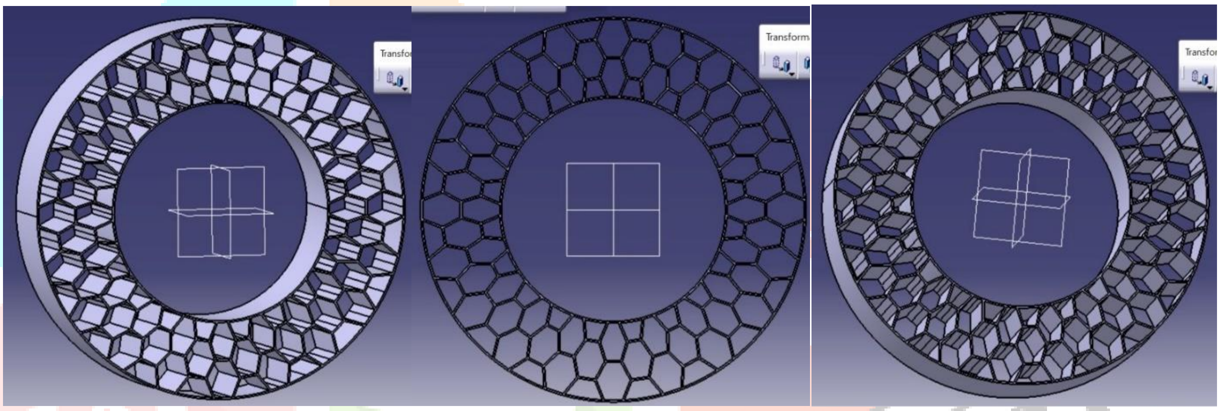

Figure no.01: CAD Model

The Above figure present the cad model which was designed on the Catia Saoftware with the Given Dimensions.

4.1 Design of Spokes Structure

Table no.01: Dimensions of Spoke Structure with different types vehicle

Type of Vehicle	L (mm)	H (mm)	Ø (degree)	T (mm)	E1 (mpa)	E2 (mpa)	G (mpa)
Hatchback	26	36	15	3	0.08087	0.0168	0.00217
Sedan	29	28	30	3.5	0.02493	0.02379	0.0065
SUV	37	16	45	4	0.00940	0.0244	0.0350

Where L, H, Ø, & T are the Single Cell Length, Inclined Cell Length, and Cell Angle Average Values.
Where E1, E2, & G are the Modulus of Elasticity.

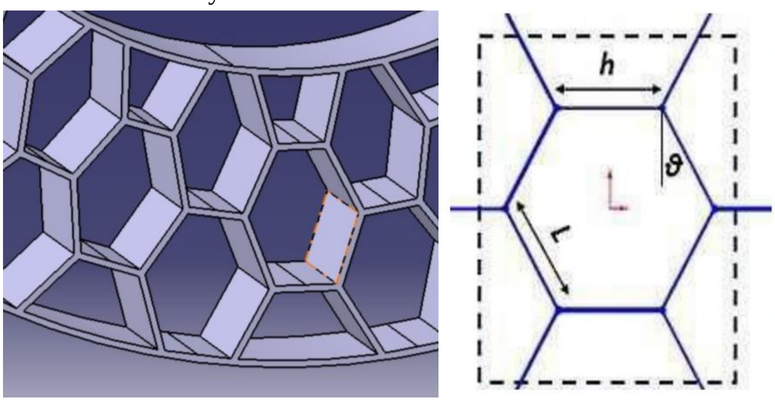

Figure no.02: Spoke Structure of Single Cell

To Design the Non-pneumatic tyre for honeycomb Structure First we had to Design the Single Cell of the Honeycomb Structure. The Single cell is taken by dividing no. of cells in the honeycomb structure. To design the single cell by finding the exact dimensions such as Length, Inclined length of the cell, and Angle of cell. And also, the modulus of Elasticity.

4.2 Geometrical Aspects

The Wheel Size: - "665*260*165"
The Hub or Rim Diameter: - 620 mm
The Hub thickness: - 165 mm
The Outer ring diameter: - 665 mm
-620 mm outer diameter,
-inner diameter of the Hub: - 360 mm

4.3 Theoretical Calculations: -

1)STRESS=F/A
2)E1=Es(t/l)3 * COSØ/(h/l+SINØ)*SIN2Ø
3)E2=Es(t/l)3 * (h/l + SINØ) /COS3 Ø
4))G=Es(t/l)3 * (h/l)+SINØ /(h/l)2 (1+2h/4 l)*COSØ
WHERE E1 & E2 are effective in the young's plane moduli of the honeycomb core in the material system of co-ordinates.
G = Honeycomb core effective in plane shear moduli in material coordinate system.
The solid cell wall material's Young's modulus is Es. (Material is polyurethane.) Es=6 Mpa)

Table no.02: Stress Calcuations

Type	Outer Dia. (D)	Inner Dia. (d)	Thickness (t)	Force	Area (A)	Stress (σ)
Hatchback	**620**	**360**	**165**	**2200**	**0.0098175**	**$224*10^3$**
Sedan	**620**	**381**	**185**	**2700**	**0.01165**	**$232*10^3$**
SUV	**775**	**431**	**265**	**5300**	**0.01888**	**$281*10^3$**

V. Ansys Modelling

5.1 Hatchback Ansys Model

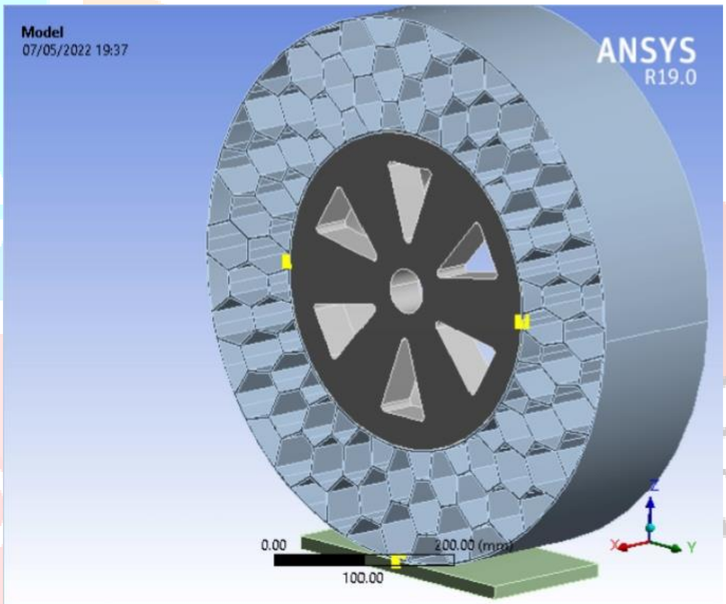

Figure no.03: Hatchback Ansys Model

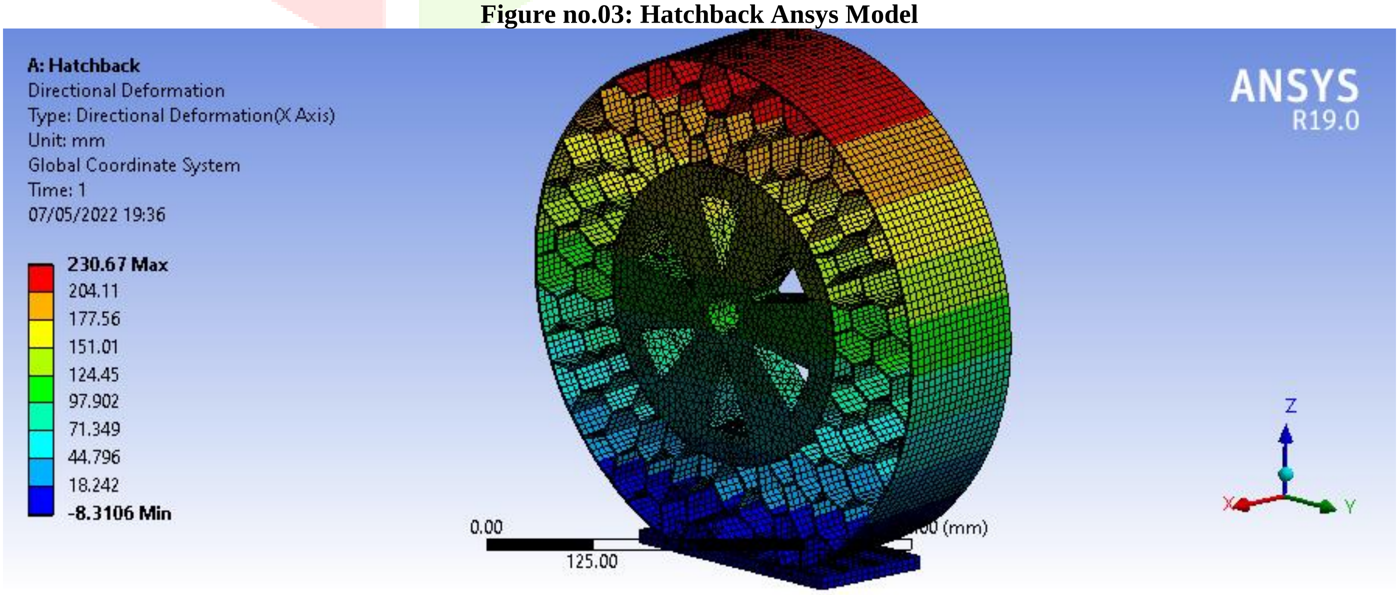

Figure no.04: Hatchback Directional Deformation

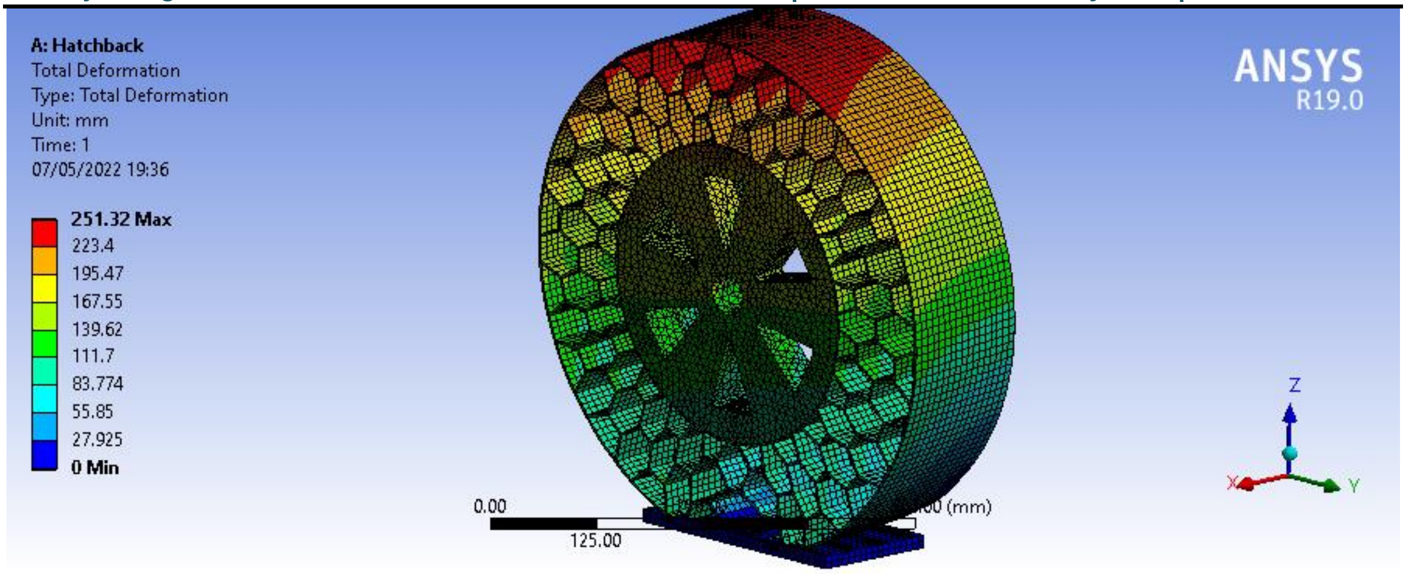

Figure no.05: Hatchback Total Deformation

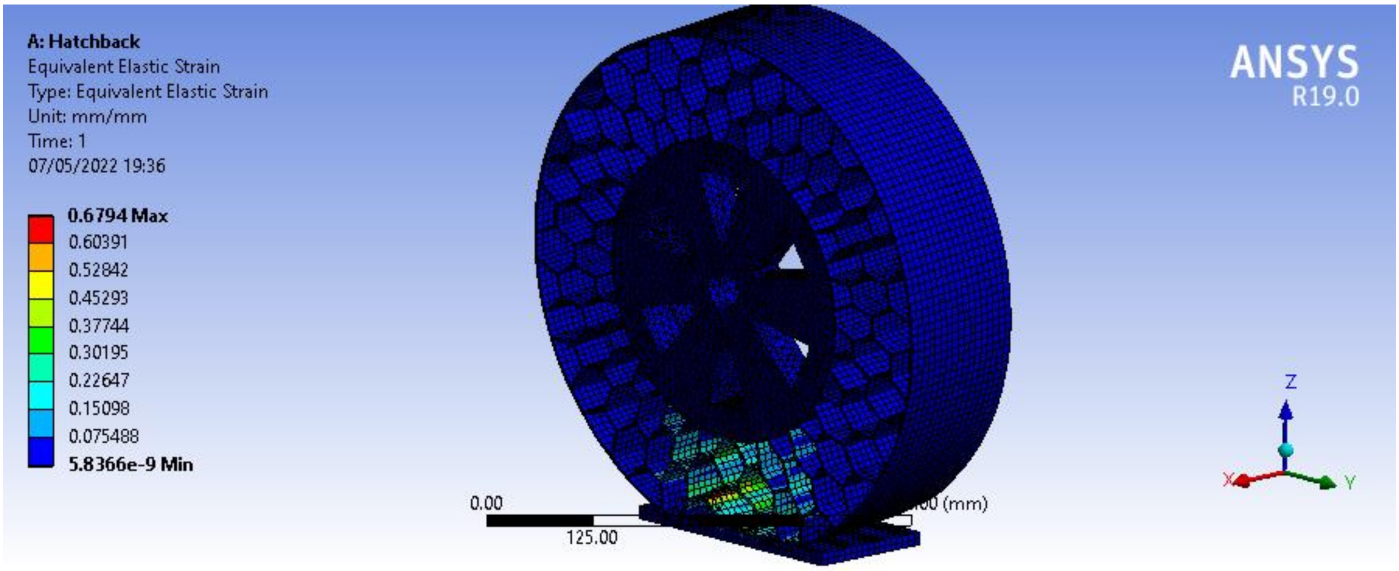

Figure no.06: Hatchback Equivalent Elastic Strain

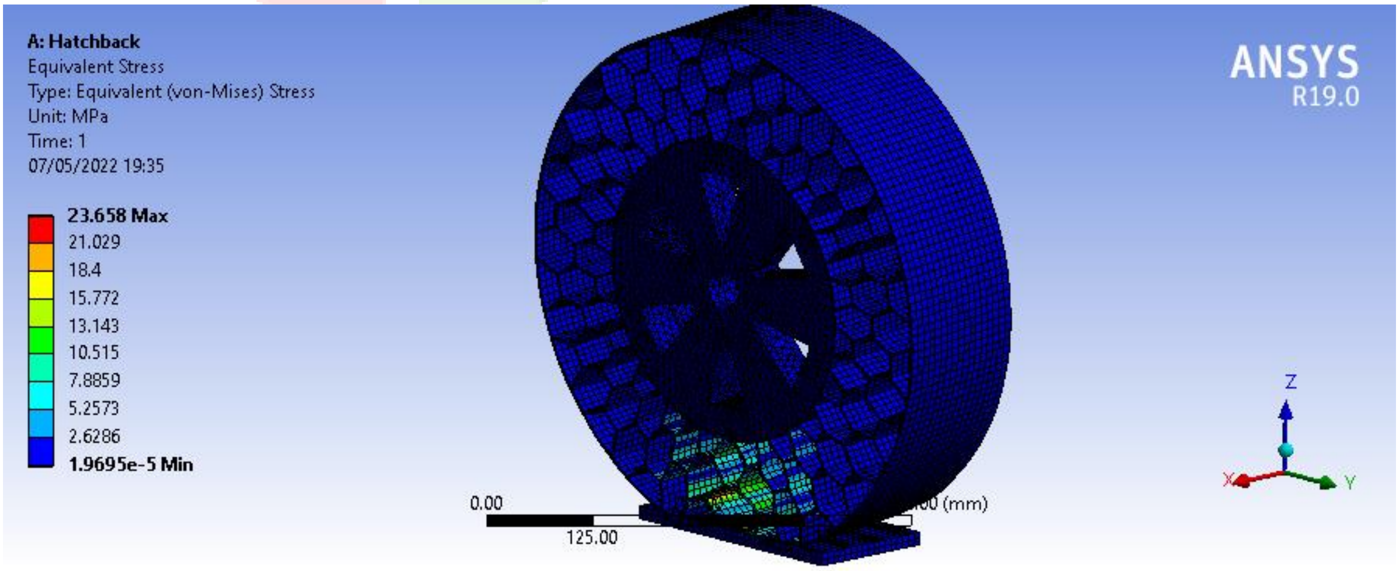

Figure no.07: Hatchback Equivalent Stress

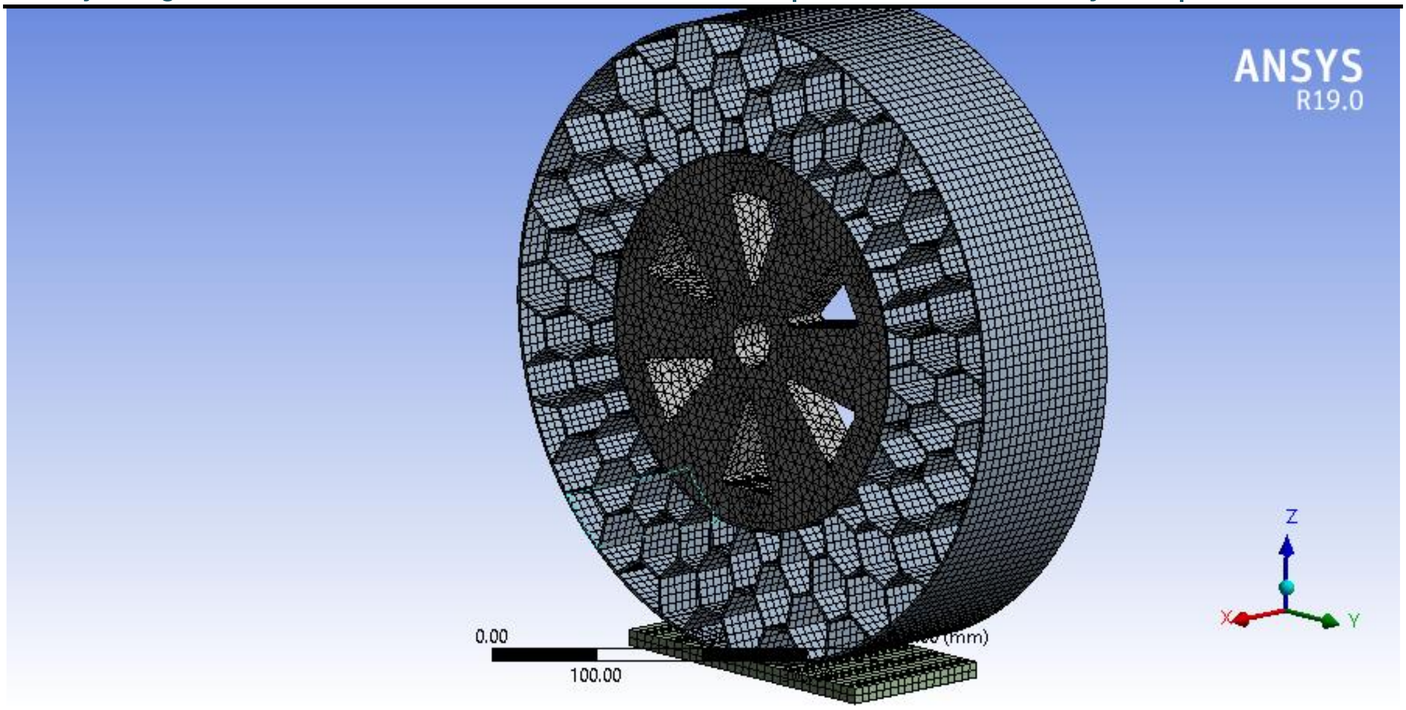

Figure no. 08: Hatchback Meash

5.2 Sedan Ansys Madel

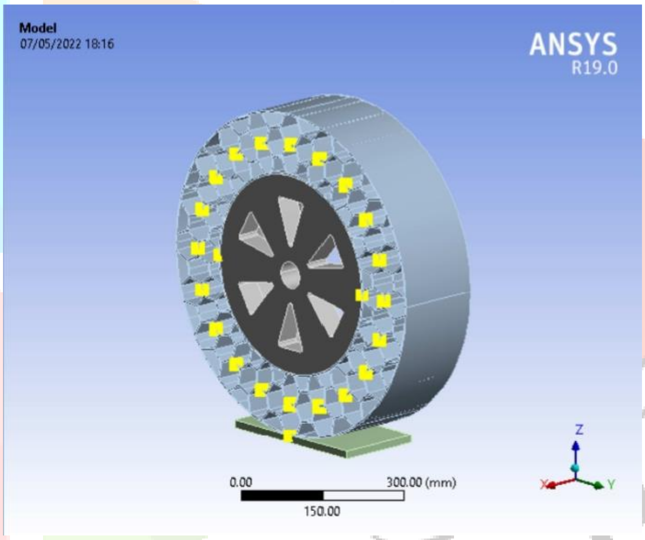

Figure no.09: Sedan Ansys Model

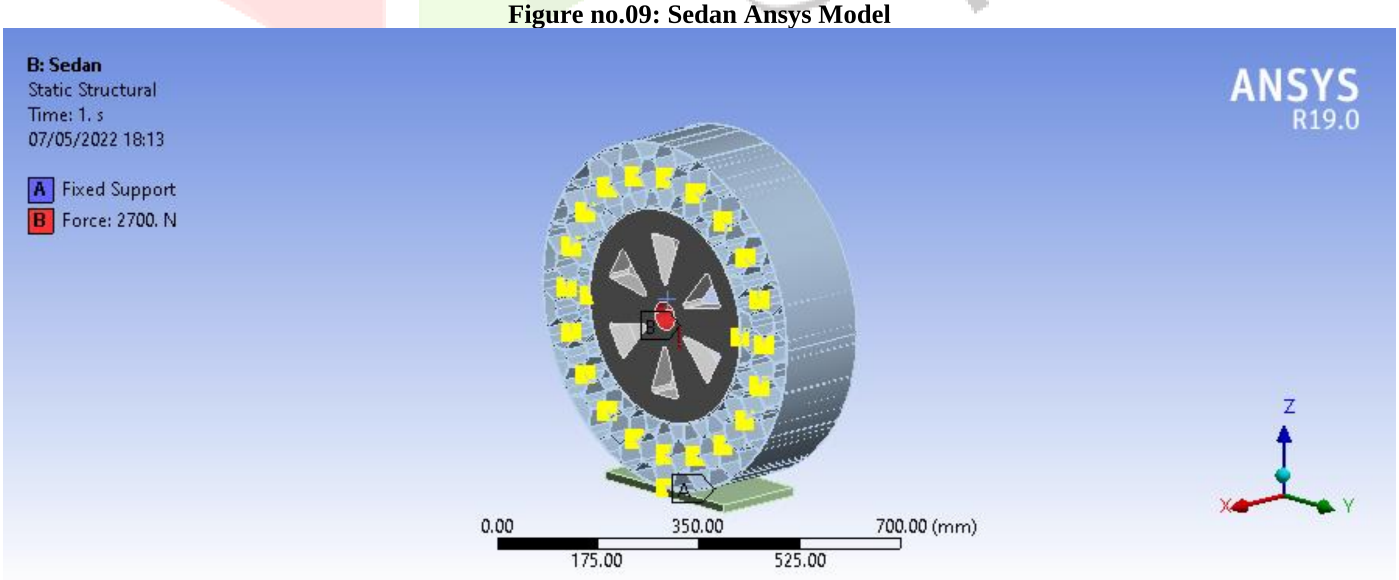

Figure No.10: Static Structure

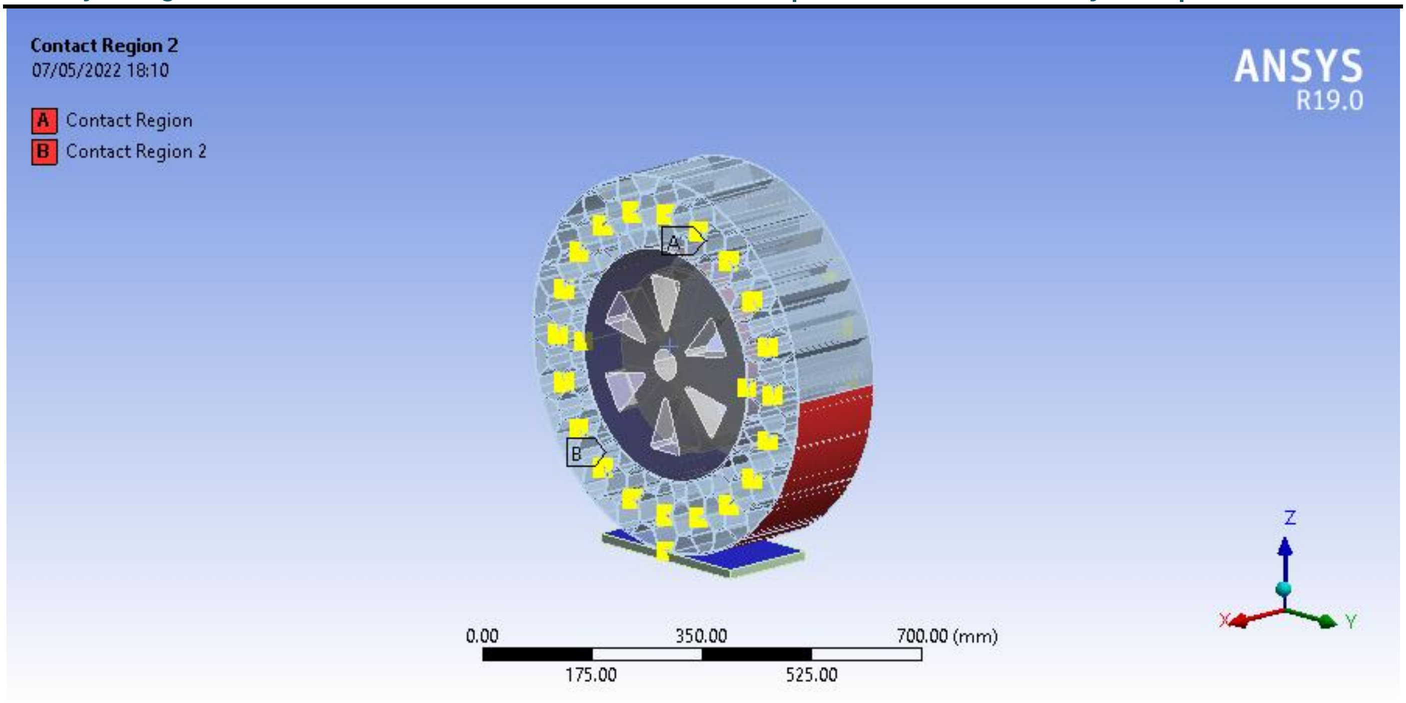

Figure No.11: Contact Region

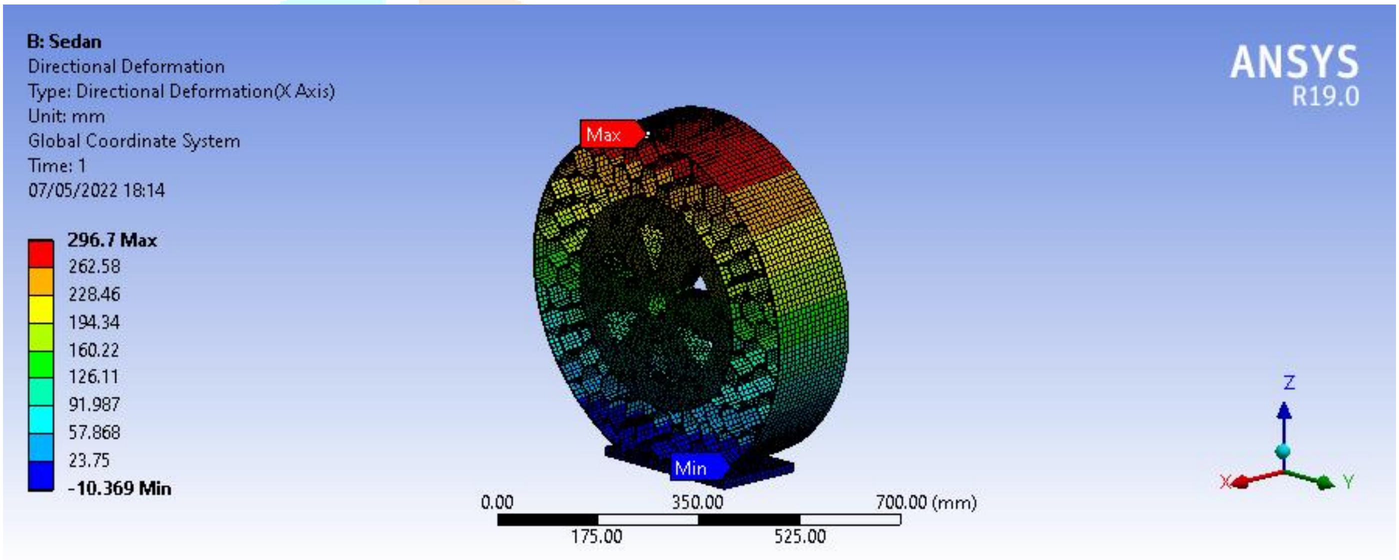

Figure No.12: Directional Deformation

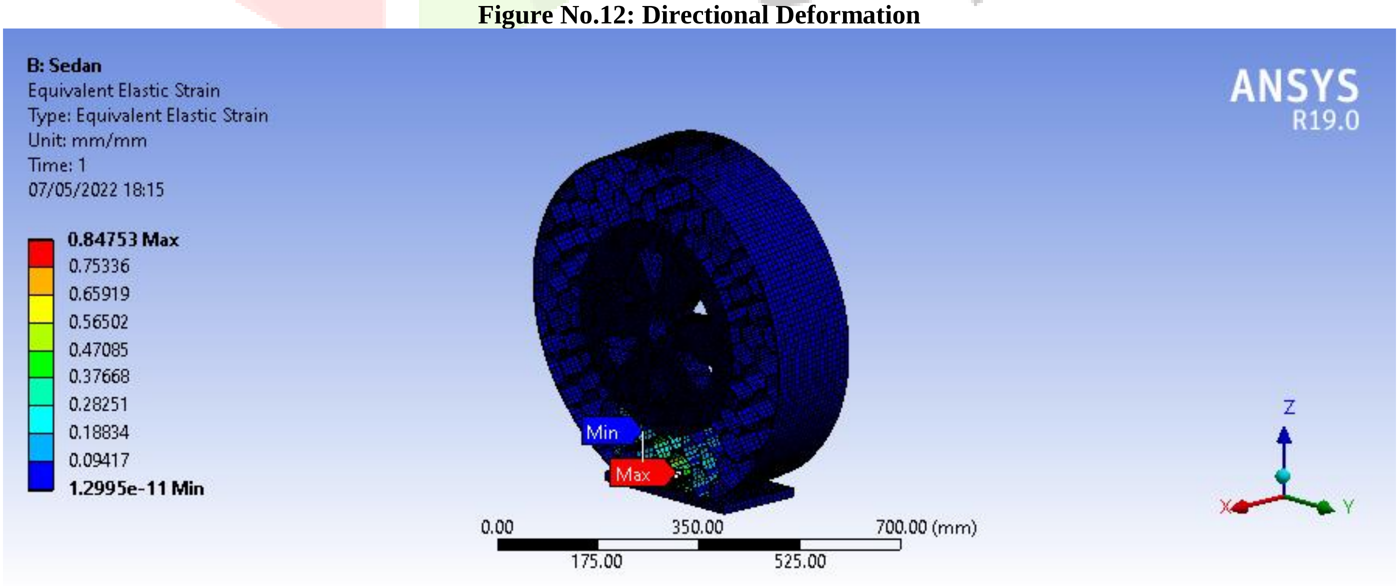

Figure No.13 Equivalent Elastic Strain

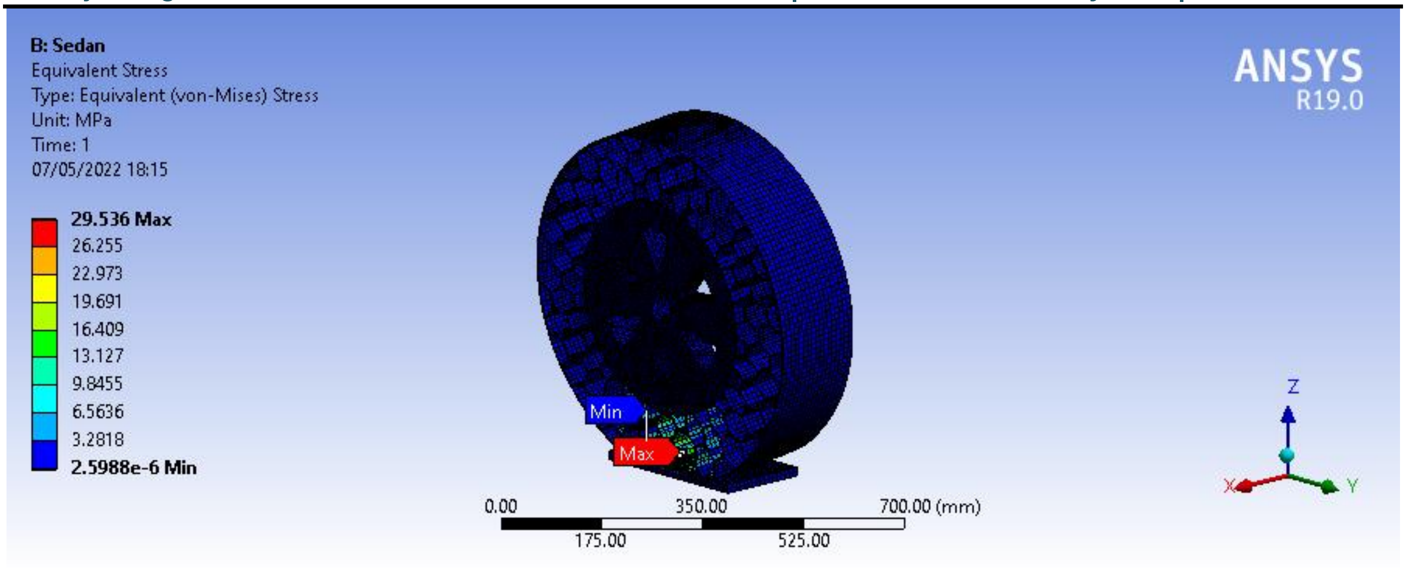

Figure No.14: Equivalent Stress

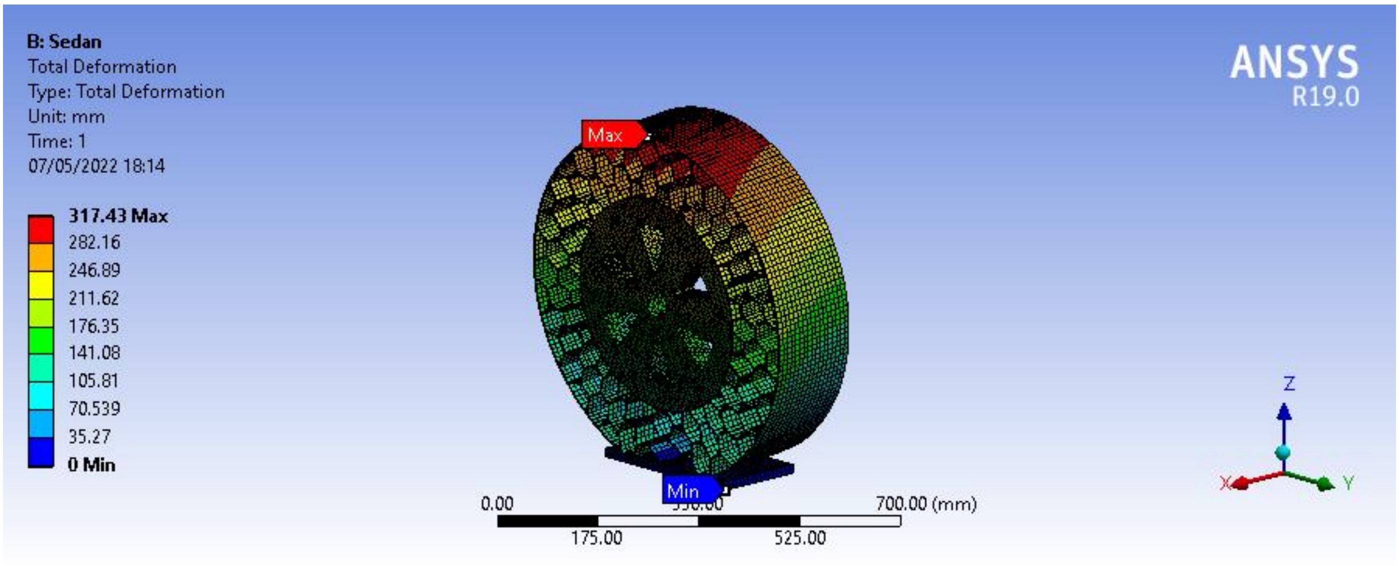

Figure No.15: Total Deformation

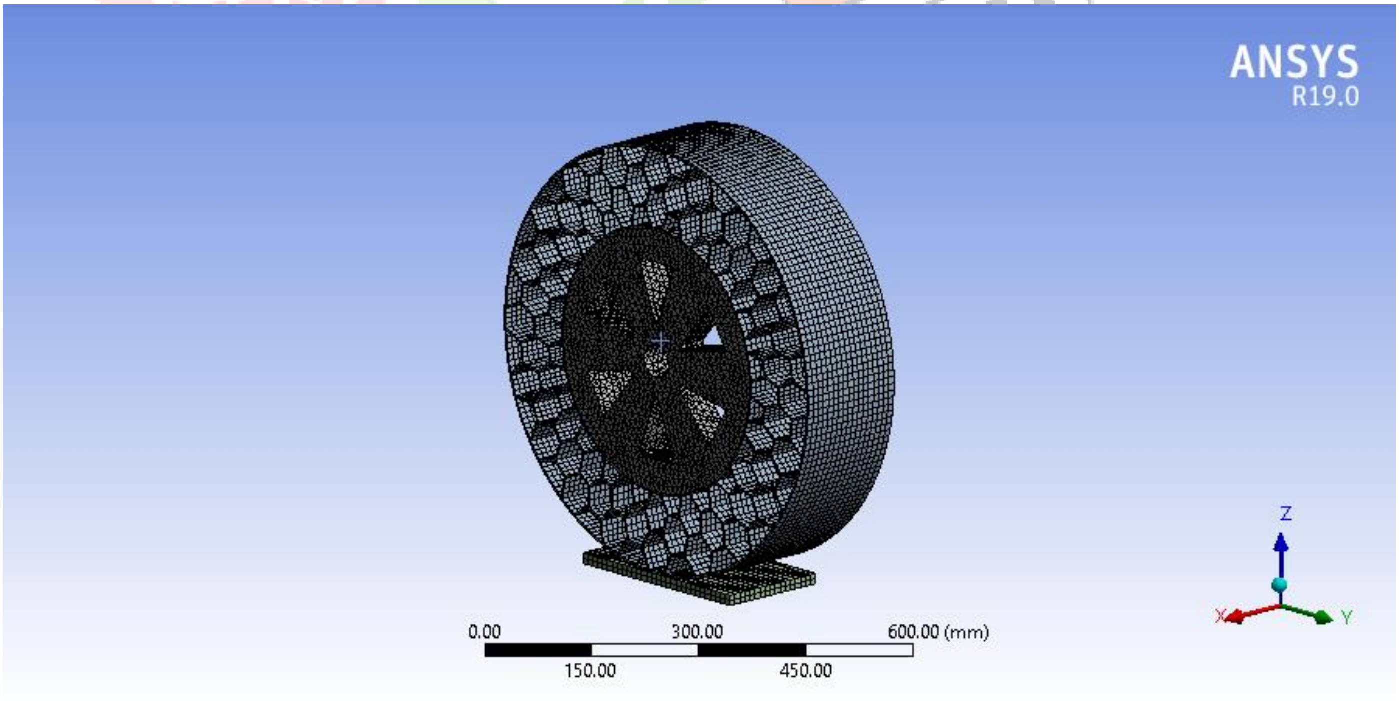

Figure No.16: Sedan Mesh

5.3 SUV Ansys Model

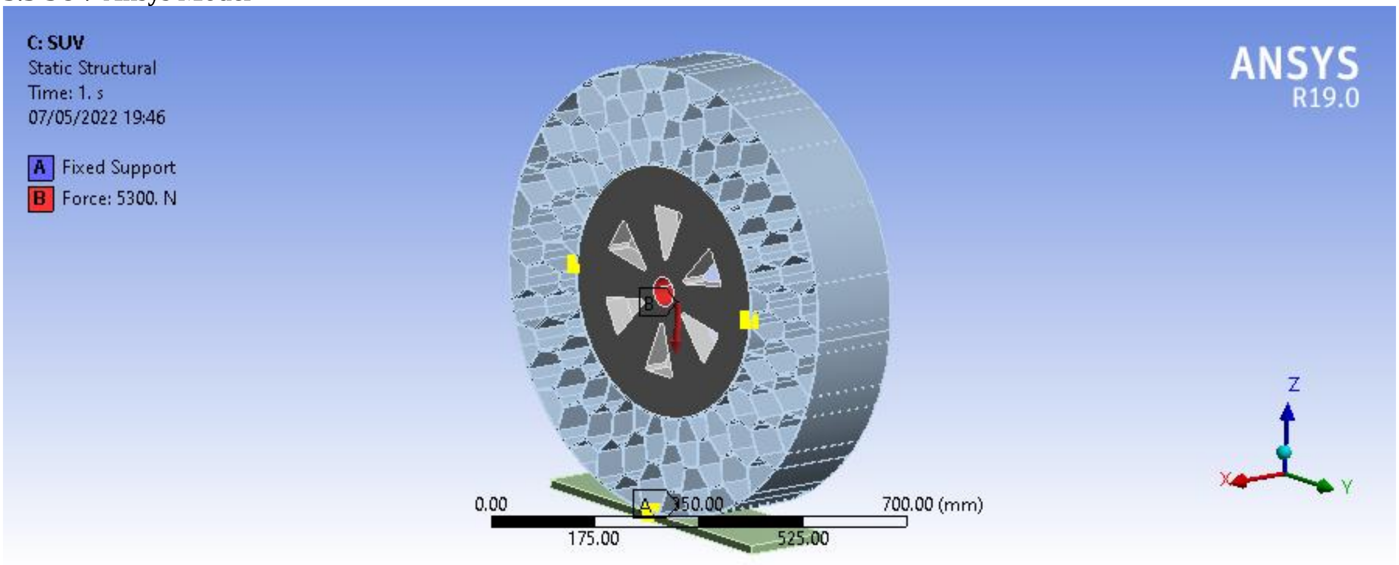

Figure No.17: SUV Ansys Model

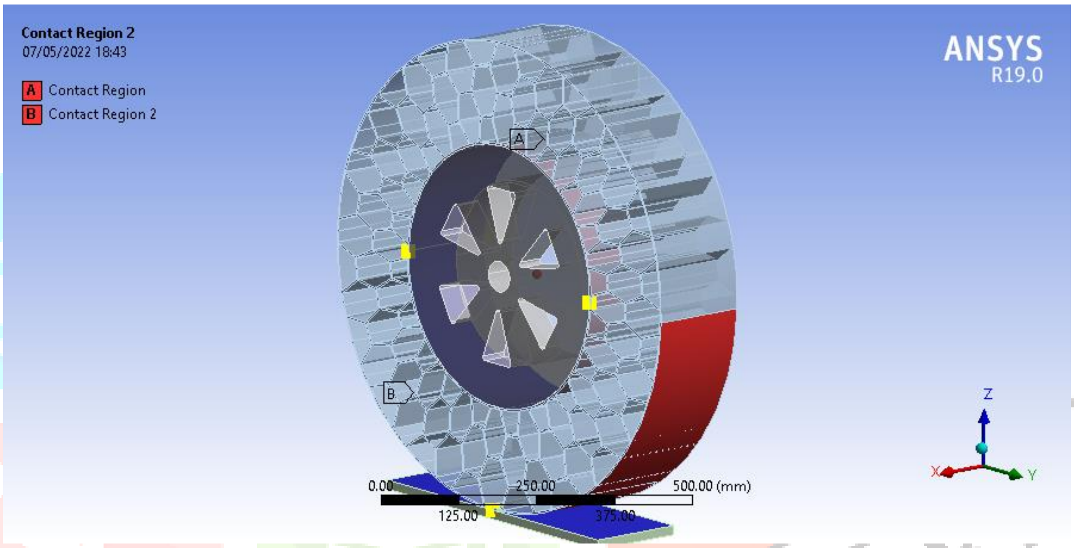

Figure No.18: Contact Region

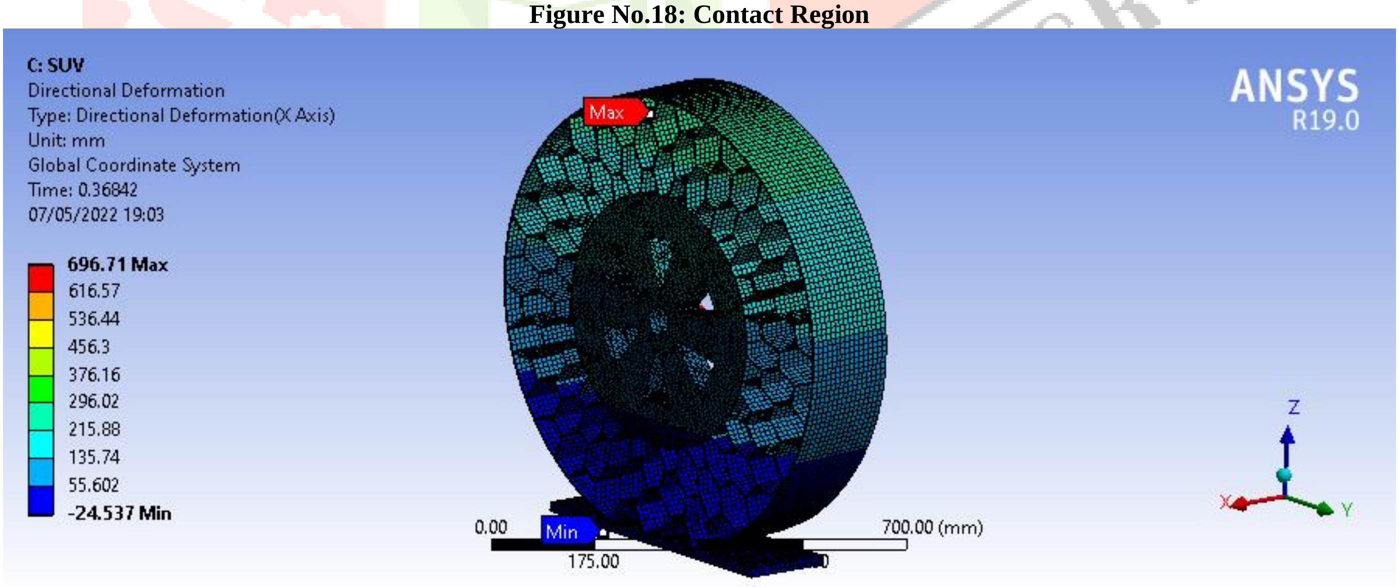

Figure No.19: Directional Deformation

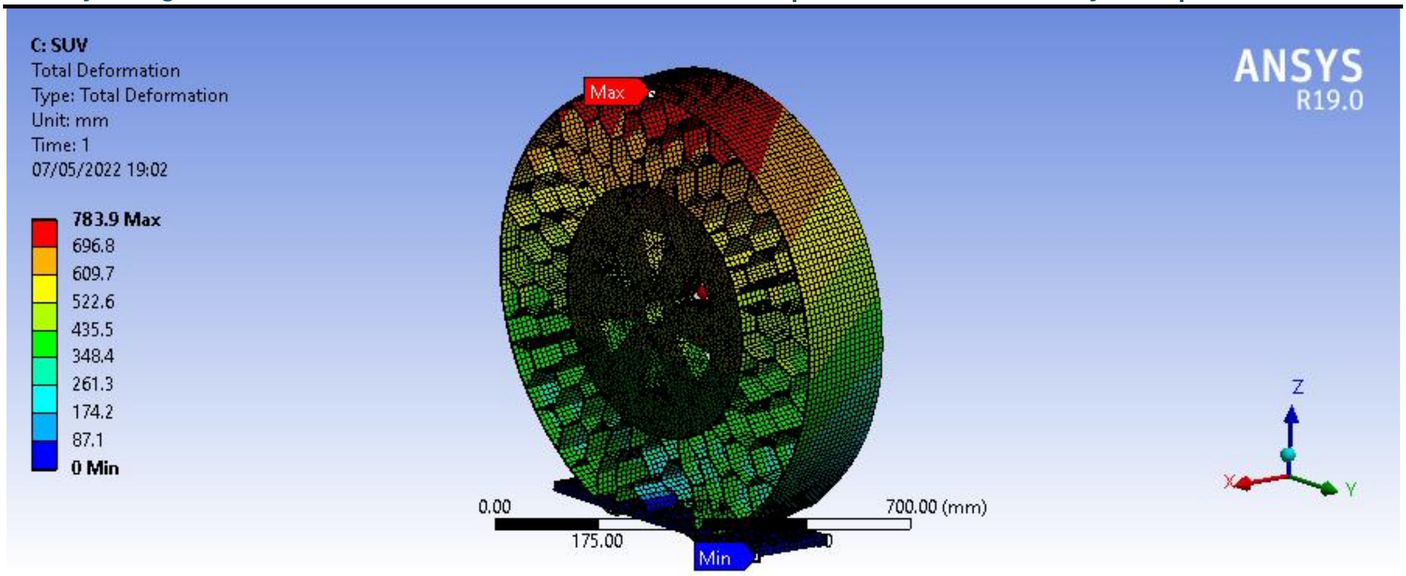

Figure No.20: Total Deformation

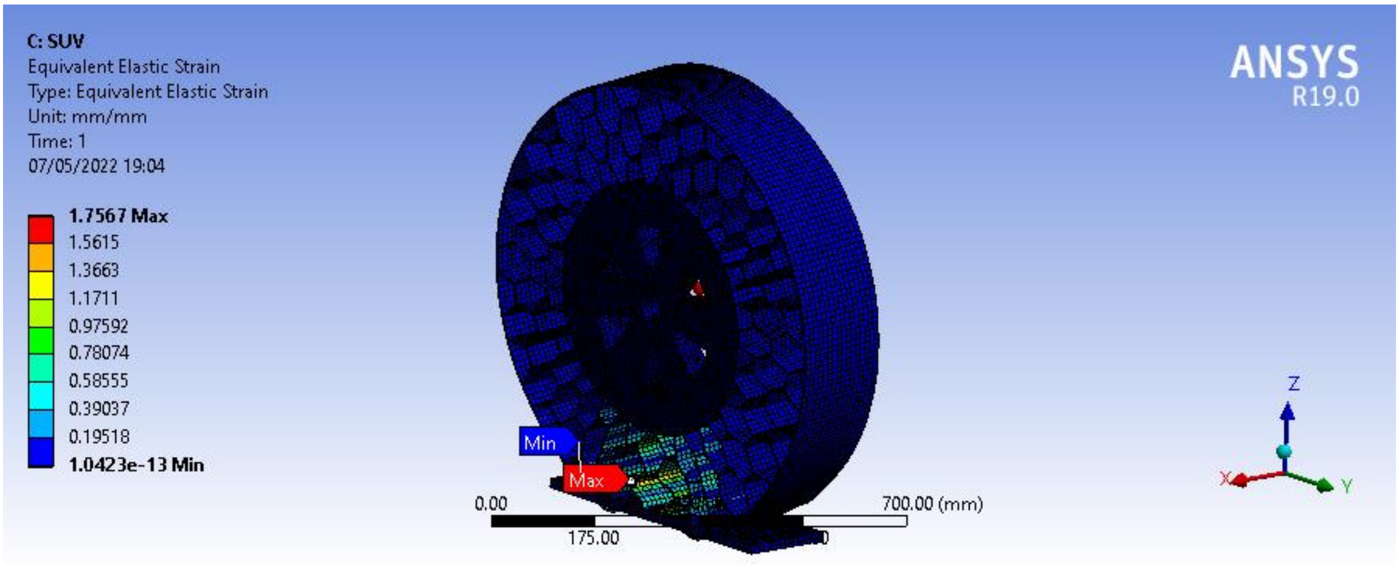

Figure No.21: Equivalent Elastic Strain

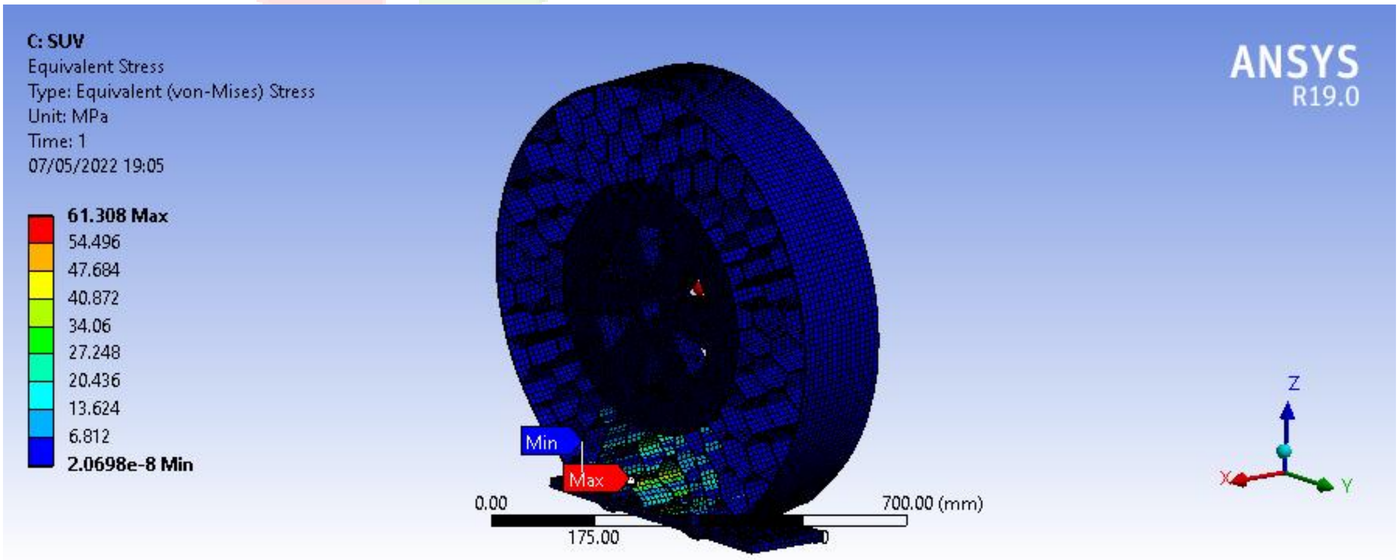

Figure No.22: Equivalent Stress

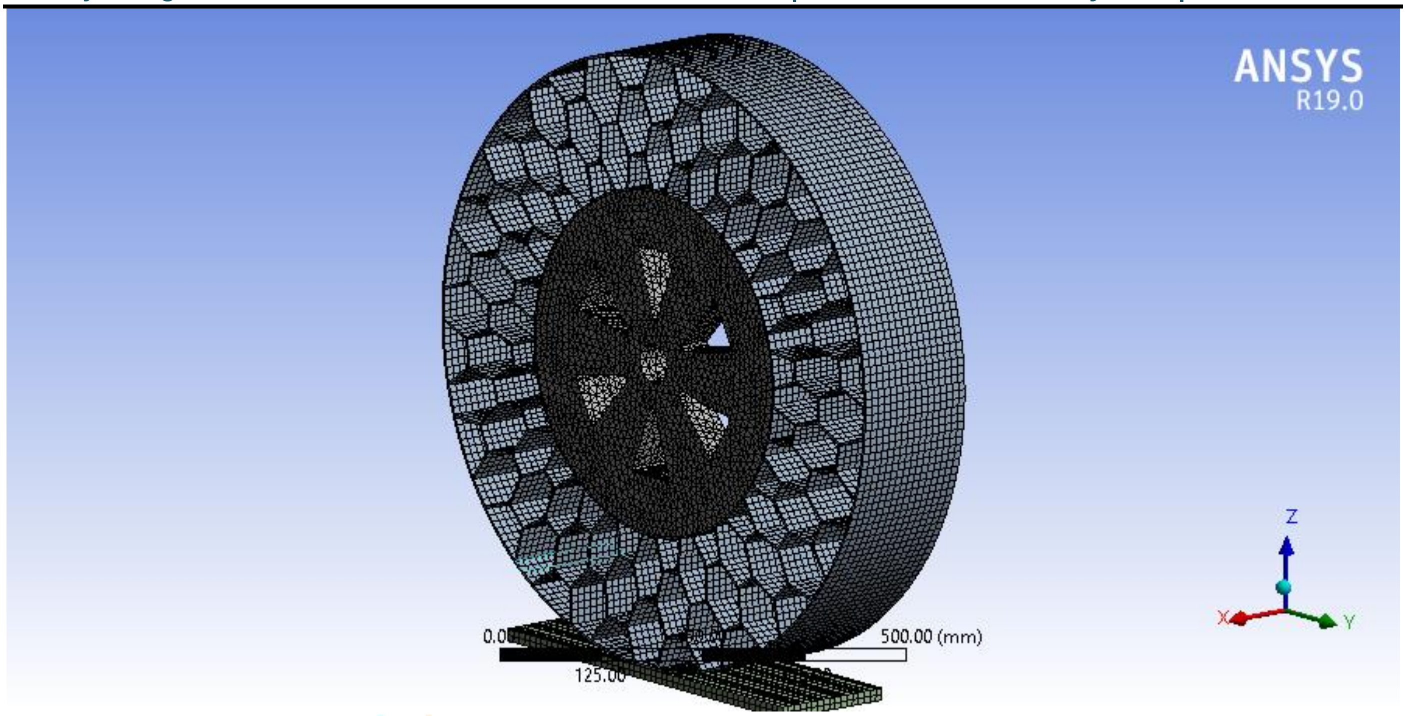

Figure No.23: SUV Mesh

VI. Results and Discussions: -

The static analysis on the three different vehicle types was performed using Ansys Software, and the directional deformation, total directional deformation, equivalent stress, equivalent strain induced in spokes, and contact pressure developed for all three types of vehicle were determined, and the results are shown in the table.

Table no.03: Direction Deformation, Total Deformation, Equivalent Stress and Strain, and Contact pressure

Type	Load	Max. Directional Deformation (mm)	Max. Total Deformation (mm)	Equivalent Stress (mpa)	Equivalent Strain (mpa)
Hatchback	2200	230.67	251.32	23.658	0.6794
Sedan	2700	296.70	317.43	29.536	0.8475
SUV	5800	696.71	783.90	61.308	1.7567

VII. Conclusions

The primary goal of this article was to create a tyre that was not pneumatic with honeycomb spokes that could handle the static loading conditions of an All-Terrain Vehicle with Directional Deformation, Equivalent Strain, Equivalent Stress, and Total Deformation in the honeycomb spokes. Honeycomb spokes of various diameters were modelled in An and a static structural study was carried out on them. The flexibility of the honeycomb structure under axial loading is determined by the design of spokes that take a single cell. The contact pressure of a non-pneumatic tyre with a honeycomb construction is lower. A structural analysis of a non-pneumatic tyre with honeycomb spokes is carried out under various load circumstances for different vehicle classes such as Hatchback, Sedan, and SUV.

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