MODELING AND ANALYSIS OF NON-PNEUMATIC TYRES WITH DIFFERENT DESIGN STRUCTURES USING FEM METHOD

[1]Mr. M. Mallesham, [2]Kudikala Suryateja
[1]Assistant Professor,[2]B.Tech Student
Department Of Mechanical Engineering
Sree Chaitanya College Of Engineering

ABSTRACT

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 advancement 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 different flat Spoke structure, curved spoked structure, and triangle structure 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 SOLIDWORKS workbench and analysis using ANSYS workbench finally find out the stresses, strains, deformations, shear stresses than after find out the suitable design for non - pneumatic tyres.

INTRODUCTION

A tyre is most important part of any vehicle. Tyre is a rubber member which provides cushioning effect as well as provides clearance to vehicle. The rubber member is mounted on wheel rim. In tube tyre, tube is present inside the tyre while in tubeless tyre there is no tube. A tire is a ring shaped component that was mounted on a wheel's rim to transfer the vehicle's load from the axle. Tyre which is used in automobile, bicycle, motorcycle is pneumatically inflated structures which provide a good rolling, cushioning effect. Such tyre is using numbers of year and they are developing. Some companies are trying to develop tyre which are airless that means they are non pneumatic. Michelin and Bridgestone are the tyre which are firstly design, they are non pneumatic. So begins an article discussing the development of air less tires, something that has become more prevalent in the past few years. Honeycomb tyre are also a typr of non pneumatic tyre.

Figure 1flat structure car wheel

In recent years, with the increasing of vehicle velocity and the expansion of the running environment, the criterions for the tire are very high. While the ordinary pneumatic tire has the following several problems: 1.It is easy to tie the thorn and burst and the burst may cause fatal accidents. 2. The air pressure inside should be maintained right.3. The manufacturing process is complex. In military application, the ordinary tire cannot bear attack from light weapons and landmines, so that affecting the tasks. In view of the above, pneumatic rubber tire has developed in the aspect of safety and several types of safety tire have been used[1-2], but with two characteristics of pneumatic and rubber the protection ability of ordinary tire is difficult to be improved, and the performance parameters become significantly lower after

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the loss of tire pressure. Therefore, new structures of the tire are explored and non-pneumatic tire appears

Figure 2 honeycomb structure nomenclature

TYPES OF TYRES:

- PNEUMATIC TYRE
- NON - PNEUMATIC TYRE

PNEUMATIC TYRE:

Pneumatic or air filled tyre is tyre which is made up of hard rubber and work on compressed air. A tread, usually reinforced with steel belting or other materials, covers this inner core and provides the contact area with the road. The pressure of the air inside the tyre is more than atmospheric air pressure, so the tyre remains inflated even with the weight of a vehicle resting on it. The tyre air pressure provides resistance against forces that try to deform the tyre, but it gives to a certain degree of cushioning effect as the tyre hits bumps in the road.

Figure 3 pneumatic tyre

NONPNEUMATIC TYRE:

The patent-pending design mimics the precise; six sided cell pattern found in a honeycomb and best duplicates the "ride feel" of pneumatic tyres, according to the developers. The goal was to reduce the variation in the stiffness of the tyre, to make it transmit loads uniformly and become more homogenous, and the best design, as nature gives it to us, is really the honeycomb.

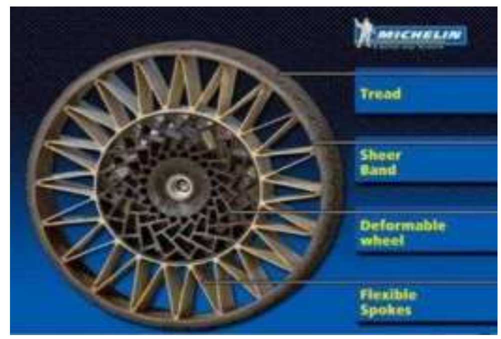

Figure 5 construction and working

COMPARISON BETWEEN PNEUMATIC AND NON PNEUMATIC TYRE:

Sr.no.	Parameter	Pneumatic Tyre	Non pneumatic Tyre
1.	Life	Life of tyre is less.	Life of tyre is long as it was made of polymer.
2.	Efficiency	More efficiency about 80%	Less efficiency about 40%
3.	Cost	cheaper	High costlier.
4.	Air	Air is essintional factor	No need of air
5.	Air valve	Valve is needed	No need of valve
6.	Puncture	Occurred	No puncture occurred

LITERATURE REVIEW

Masters IG and et al. (1996), presented a model about the elastic deformations in honey combs [1]. A theoretical model has been developed for predicting the elastic constraints of honeycombs based on the deformation of the honey comb cells by flexure, stretching ad hinging. The model has been used to derive expressions for the tensile moduli, shear moduli and Poisson's ratios. Examples are given of Structures with a negative Poisson's ratio. Tonuk E. and et al. (2001), constructed a

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detailed finite element model of a radial automobile tyre and its characteristics are studied [2]. The stress strain relationship of rubber is modeled. Validity of various simplifications is checked. Balawi S and et al. (2008), investigated different properties of honeycomb structure [3].

The modeling of the effective properties of these honeycomb cores is of key importance to predict the overall mechanical response of the sandwich structures. In particular, the in-plane elastic moduli were studied by analytical and numerical means and correlatedwith experimental results for aluminum hexagonal or regular honeycombs. It is found that the flexibility of the honeycomb increases with cell angle. Stefano Gonella and et al. (2008), conducted a study about the equivalent in-plane properties for hexagonal and auxetic lattices, through the analysis of partial differential equations associated with their homogenized continuum models [4]. The adopted homogenization technique interprets the discrete lattice equations according to finite differences formalism, and it is applied in conjunction with the finite element description of the lattice unit cell.

PROBLEM IDENTIFICATION

Non-pneumatic tyres usually have higher rolling opposition and offer much less suspension than on the contrary shaped and sized pneumatic tyre. Additional troubles for airless tyre contain8dissipating the heat built-up that arises when they are driven. Non-pneumatic tyres are often packed with compacted polymers, relatively to air. Bearing in mind the non-pneumatic tyre structure, the spokes experience compression and tensions under cyclic loading while the8tyre rolls. In this project work, the non-pneumatic tyre has been studied with V-structure spokes. Non- pneumatic tyres are the tyres that are not supported by air pressure. They overcome many disadvantages over conventional tyre like possibility of a catastrophic damage, required maintenance of proper internal air pressure and complex manufacturing procedure. Therefore, it is essentials to reduce the localized stress of spokes i.e., the spokes must be fatigue resistance.

METHODOLOGY:

- Solid Modeling of three different Structures for Non-Pneumatic Tyre with the Help of SOLIDWORKS software
- Study of Non-Pneumatic Tyre
- Using static analysis
- Analyzing the Von-misses Stresses, Strains, Deformations , shear stresses
- Finally concluded the suitable structure

MATERIAL PROPERTIES:

The Non-pneumatic tyre is designed using following constituent parts, which are hub, honeycomb spokes, outer ring and thread. The function of hub is to provide a rigid support to the honeycomb spokes. The honeycomb spokes are the key component of the NPT, which replaces the air filled pneumatic tyres. The spokes of an NPT should have both stiffness and resilience under cyclic compression loading. The function of outer ring is to enforce the thread rubber to be deformed by shear. The thread provides the necessary traction between the road and the vehicle.

Part	Hub	Spokes	Outer ring	Shear band
Material	UNS A97075	Polyurethane	AISI 4140	Syntactic rubber
Yield strength, (MPa)	503	145	480	18.2
Elastic modulus, E (MPa)	75000	35	210000	14
Poisson's ratio, (υ)	0.33	0.48	0.3	0.48
Density, (ρ) Kg/m³	2180	1210	7810	1050
Shear modulus, G (MPa)	32000	11.18	80000	3.5

Table 1 material properties table

GEOMETRICAL ASPECTS:

- The wheel size is 24.6” ×6.5”×9.8”
- The hub or rim diameter is = 250 mm.

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- Inner hub diameter =200mm
- Hub thickness is = 25 mm.
- The outer ring diameter is = 605 mm.
- The outer diameter of the wheel is =625 mm.
- The width of the wheel is = 165.1 mm.

GEOMETRIC DIMENSIONS:

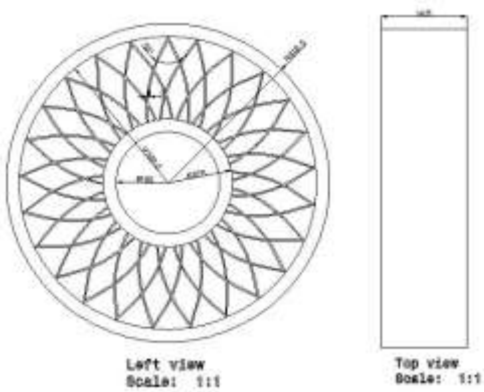

Figure 6 triangle shape

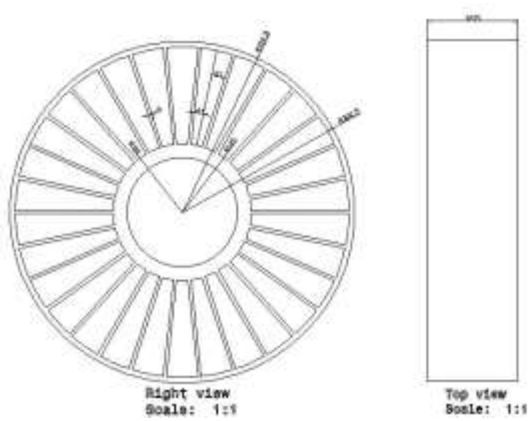

Figure 7 plate spokes

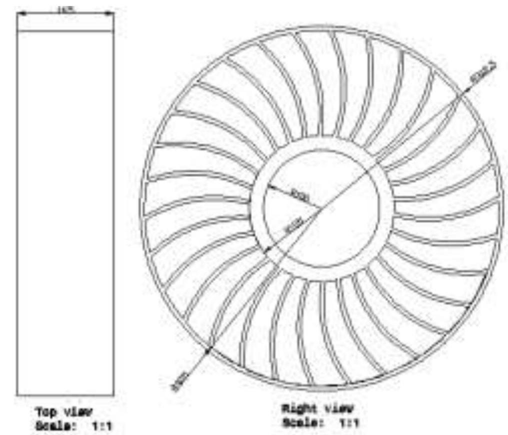

Figure 8 curved structures

- **DESIGN PROCEDURE IN SOLIDWORKS WORK BENCH:**

Dimensions were chosen for designing triangular spokes.

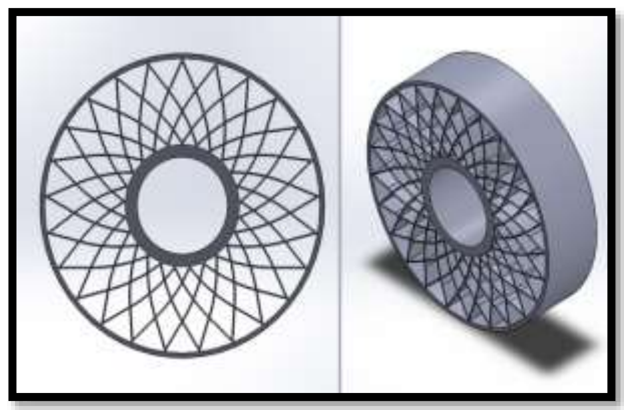

Figure 9 triangle shape structure

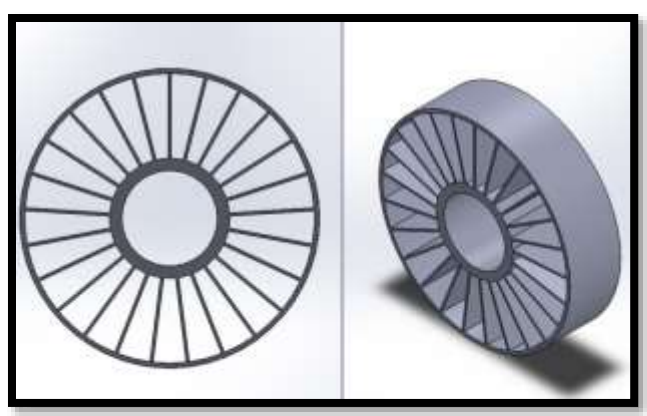

Figure 10 plates spoke structure

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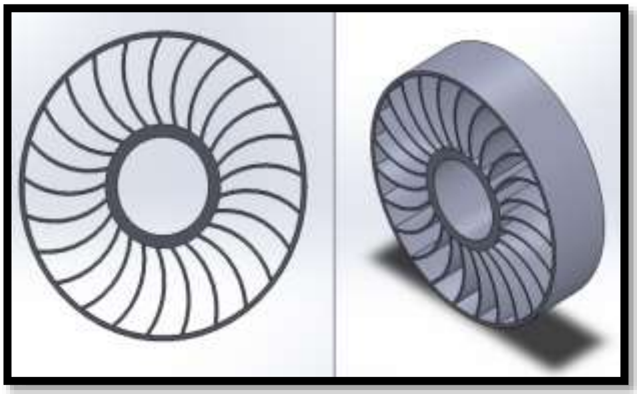

Figure 11 curved spokes

MESH AND BOUNDARY CONDITIONS:

The total number of nodes in the meshed model is triangle shape =151614, plate shape spokes=14591, and total number of elements honeycomb shape= 3248, triangle shape =78210, plate shape spokes=2156.

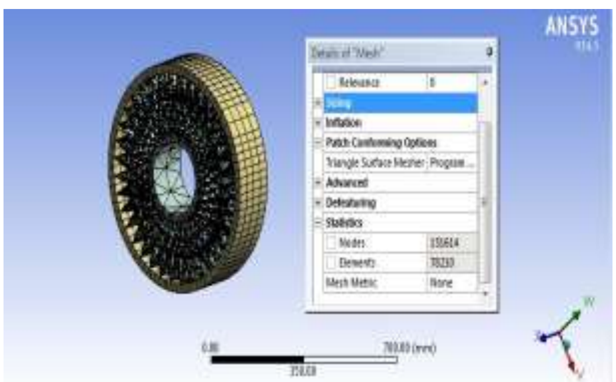

Figure 12 meshing of triangle structure

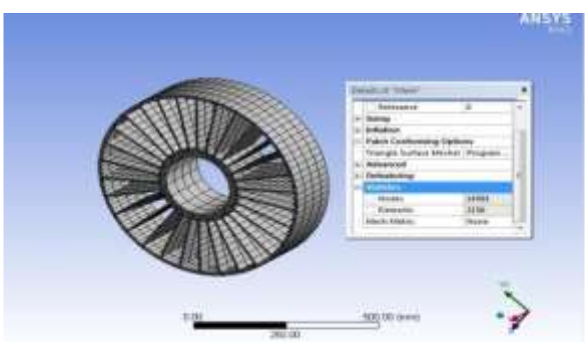

Figure 13 meshing of plate spoke structure

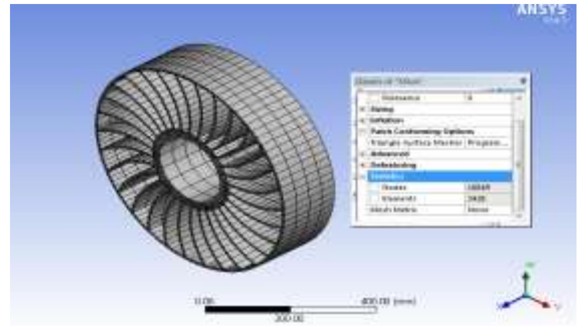

Figure 14 meshing of curved structure

BOUNDARY CONDITIONS:

The load applied on top surface honeycomb structure 3000 N is applied centre of honeycomb structure apply displacement in the Negative y-direction at the inner surface of the wheel Rotational velocity apply 5000 rpm.

TRAINGLE SHAPE STRUCTURE:

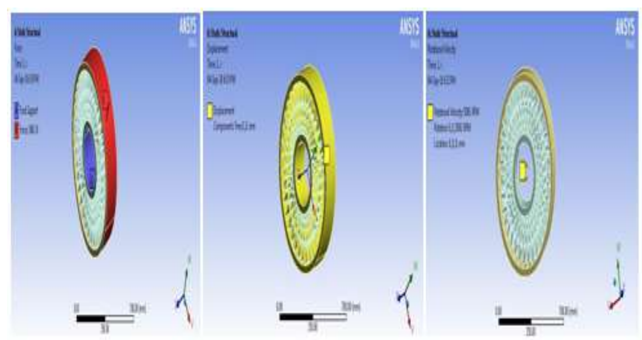

Figure 15 boundary condition load applying on top surface 3000n and rotational velocity 5000

PLATE SPOKE STRUCTURE:

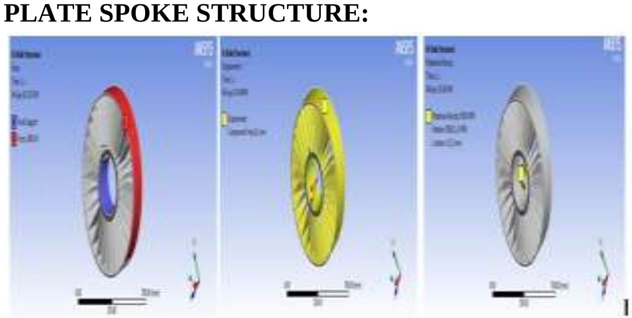

Figure 16 boundary condition load applying on top surface 3000n and rotational velocity 5000.

CURVED SPOKE STRUCTURE:

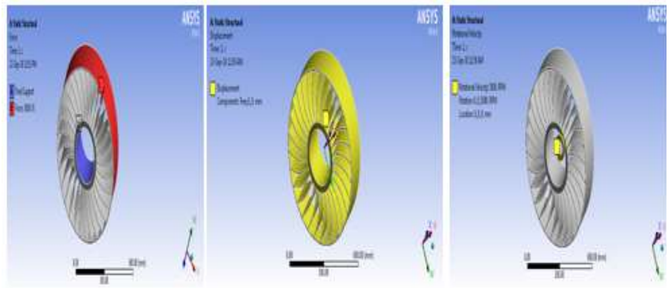

Figure 17 boundary condition load applying on top surface 3000n and rotational velocity 5000.

RESULTS AND DISCUSSIONS

The constructed honeycomb different structures like Triangle structure, plate structure, curved shape structure in SOLIDWORKS is analyzed using ANSYS 14.5.0 we observed results stresses, strains, shear stresses, total deformations as shown below figures.

- **TRIANGLE SHAPE STRUCTURE**

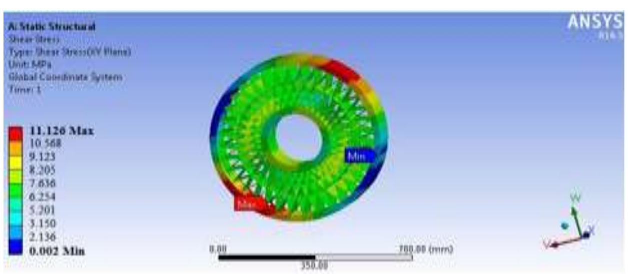

Figure 18 von-misses stress of triangle shape structure top surface 3000n

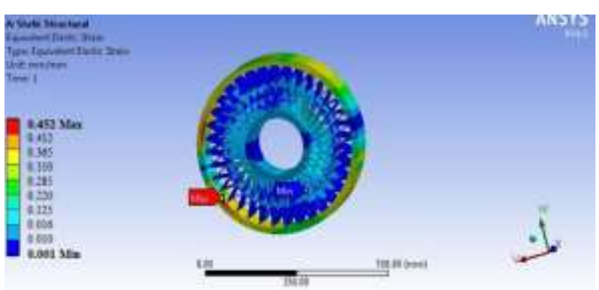

Figure 19 strain of triangle shape structure

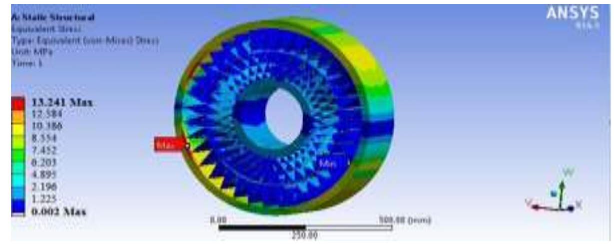

Figure 20 shear stress of triangle shape structure

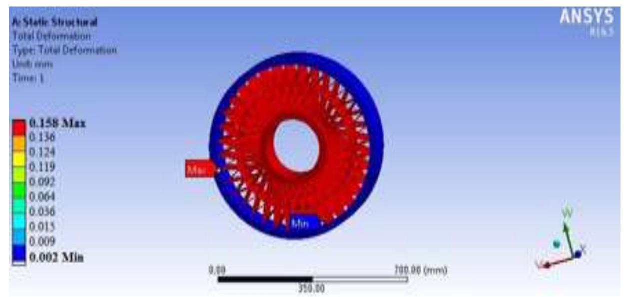

Figure 21 total deformation of triangle shape structure

- **ROTATIONAL VELOCITY WHEN 5000 RPM:**

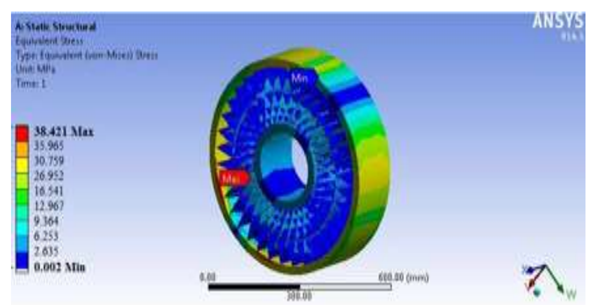

Figure 22 von-misses stress of triangle shape structure

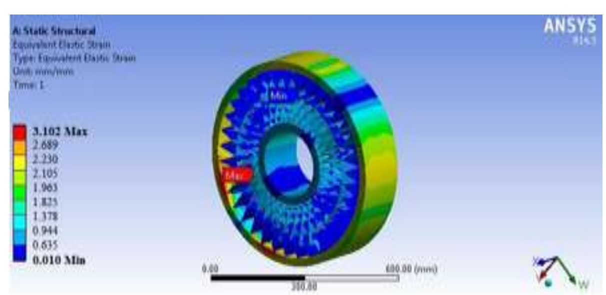

Figure 23 strain of triangle shape structure

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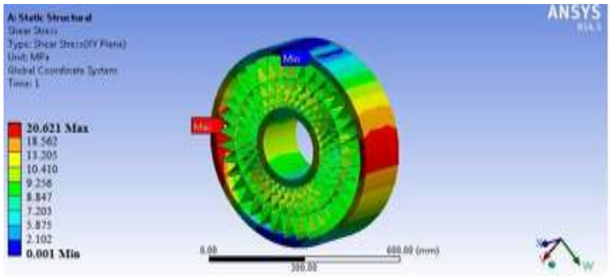

Figure 24 shear stress of triangle shape structure

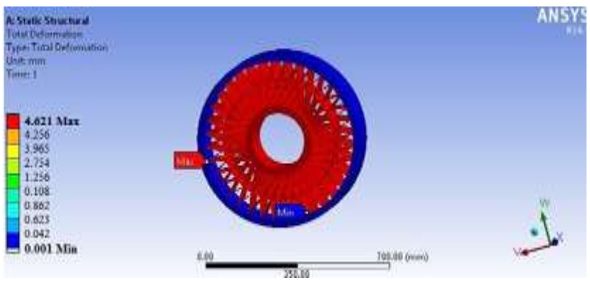

Figure 25 total deformation of triangle shape structure

- **ROTATIONAL VELOCITY OF PLATE SPOKES WHEN 5000 RPM:**

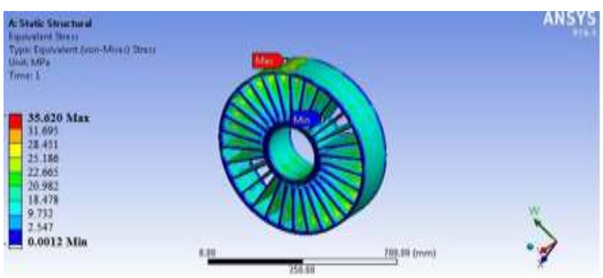

Figure 26 von-misses stress of plate spoke structure

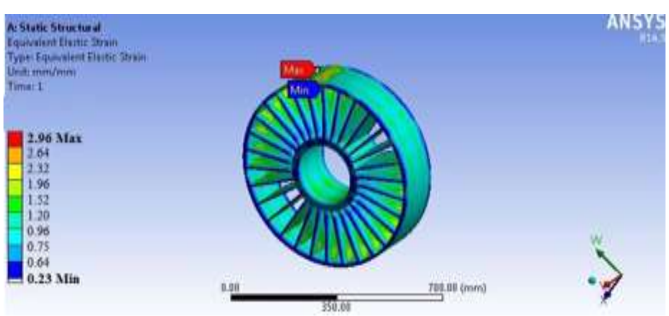

Figure 27 strain of plate spoke structure

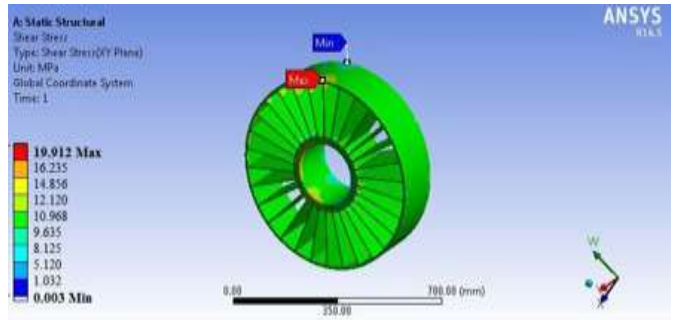

Figure 28 shear stress of plate spoke structure

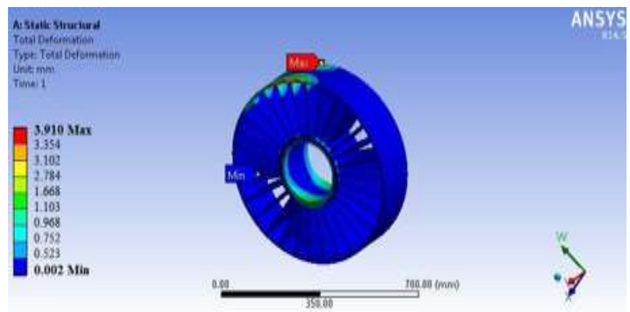

Figure 29 total deformation of plate spoke structure

SPOKE SHAPES	*VON MISSES STRESSES (MPa)*		*EQUIVALENT STRAIN*		*SHEAR STRESS (MPa)*		*TOTAL DEFORMATION (mm)*	
BOUNDARY CONDITIONS	*3000 N*	*5000 RPM*	*3000 N*	*5000 RPM*	*3000 N*	*5000 RPM*	*3000 N*	*5000 RPM*
TRIANGULAR	11.126	38.421	0.452	3.102	13.241	20.621	0.158	4.621
FLAT	12.962	35.620	0.321	2.96	10.901	19.912	0.075	3.910
CURVED	12.736	36.093	0.425	2.8771	10.23	19.468	0.736	4.509

Table 2 static structural analysis results

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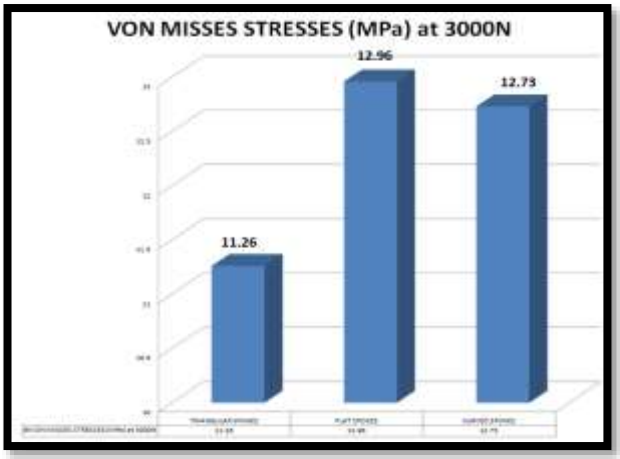
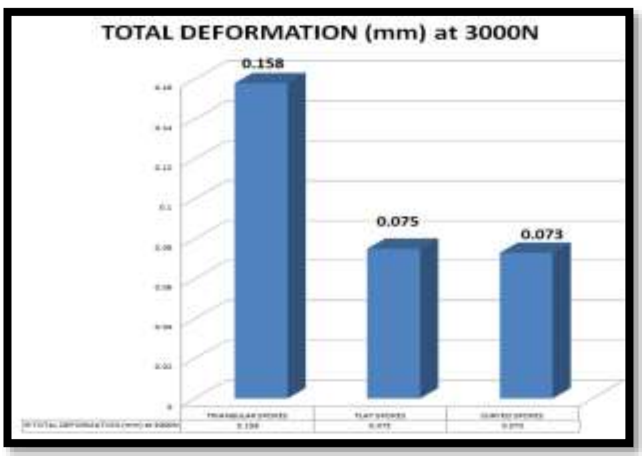
GRAPHS:

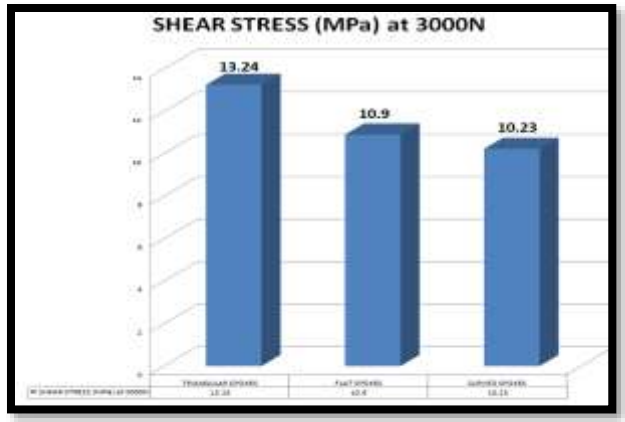
- **SURFACE LOAD 3000N**



Graph 1 von-misses stress graph

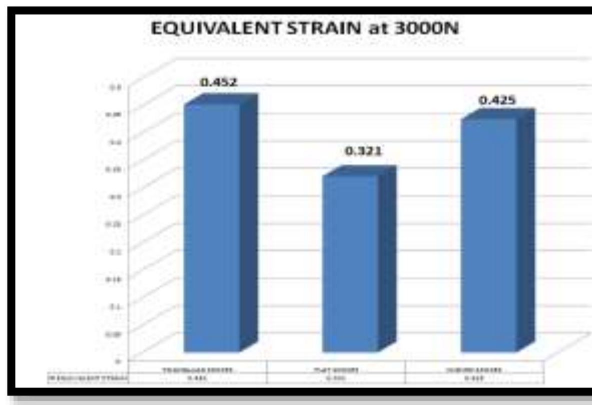


GRAPH 2 TOTAL DEFORMATION GRAPH



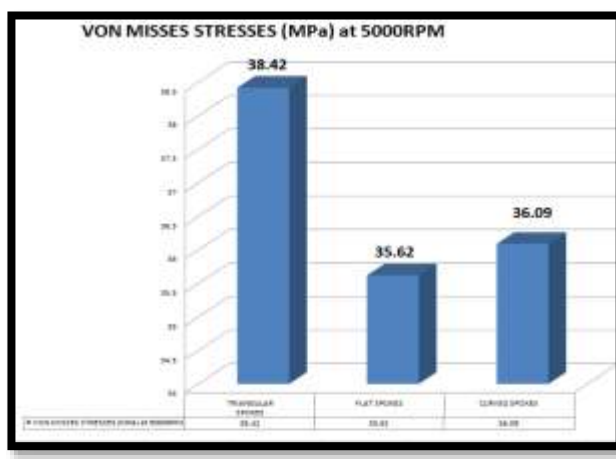
GRAPH 3 SHEAR STRESS GRAPH

- **TOP SURFACE 3000N**

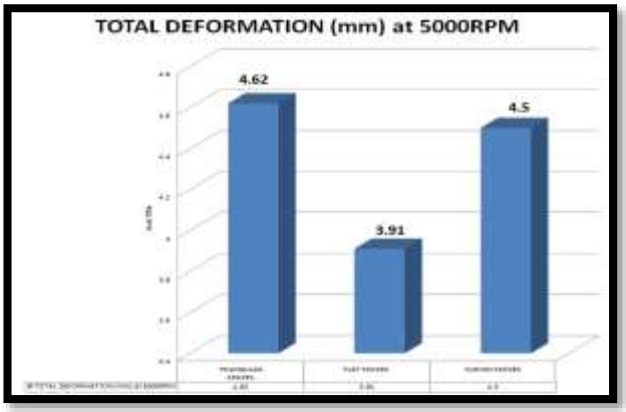


Graph 4 strain graph

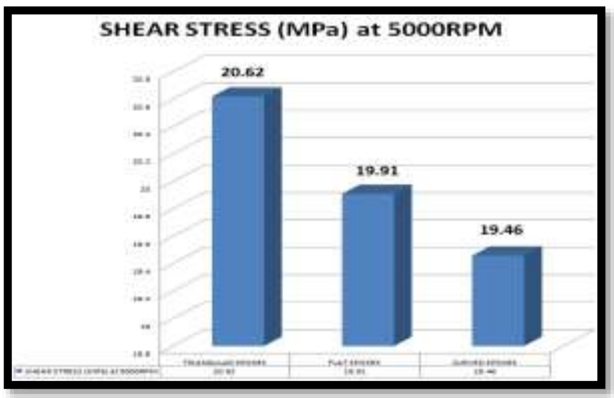
- **ROTATIONAL VELOCITY 5000RPM**



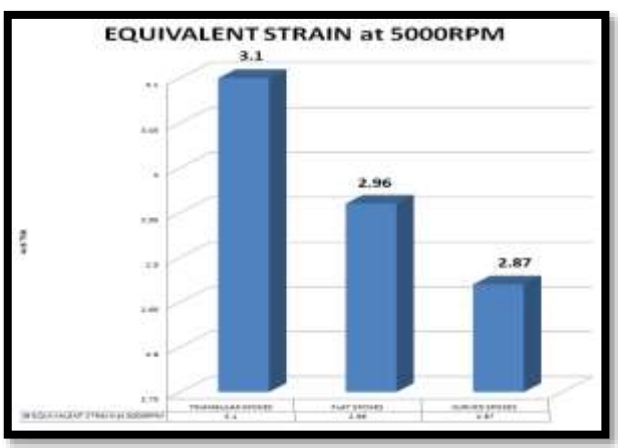
Graph 5 von-misses stress graph



Graph 6 total deformation graph



Graph 7 shear stress graph



Graph 8 strain graph

CONCLUSION

Modelling and analysis of the non-pneumatic tyres are done tyre is generated in SOLIDWORKS and this is imported to ANSYS (18.0) for processing work. An amount of load acting on the wheel 3000N is applied along the circumference of the tyre made Up of hub material is made up of UNSA97075 ,spokes material is poly urethane, outer ring is AISI 4140, Shear band is Syntactic rubber Following are the conclusions from the results obtained.

- We are taking totally three designs triangle shape structure; plate spoke structure, curved spokes.
- Finally find out the suitable design for the tyre above three designs.
- Concluded based on the von-misses stress, strain, total deformation, shear stress values.
- Curved structure is the suitable design because of low stresses, Strains, shear stress, total deformation.
- Hence it is the best suitable design for manufacturing is curved structure, it is a good strength, fatigue life (endurance limit), reliability and reduces the overall weight and cost.

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