PIEZOELECTRIC POWER GENERATION IN AUTOMOTIVES BY USING HONEYCOMB STRUCTURE TYRES

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Abstract - *Piezoelectric energy harvesting technology has received a great attention during the last decade and the objective of this project is to get the Static and Dynamics analysis of the Non-Pneumatic Tire (NPT) with hexagonal honeycomb structure design which was first developed by the French tire company Michelin. Its significant advantage over pneumatic tires is that it does not use a bladder full of compressed air and therefore it cannot burst or become flat. The modelling of honeycomb spoke structure was done in Solid works modeling software. The design deals with the stresses induced due to force applied on the tire and rolling (RPM) of the tire. To analyze it ANSYS has been used as a tool. The static and dynamic structural analysis was performed on the designed tire. Our project discuss the use of piezoelectric material PZT, within a commercial vehicle's No pneumatic honeycomb structured tire to harvest power that can be used for power sensors or even run on board devices*.

Key Words: Piezoelectric energy harvesting technology, Non-Pneumatic Tire (NPT), Static Analysis, Dynamic Analysis, 3D Modelling, Power production, vehicle.

1. LITERATURE REVIEW

1. Modeling and Analysis of Non-Pneumatic Tires with Hexagonal Honeycomb Spokes. (Assistant Professor, Mechanical Department, Saintgits college of Engineering, Kerala, India) –ISSN: 2349-7947

In this project it investigates the hexagonal honeycomb spokes for NPT tire under macroscopic uniaxial loading. The spokes of an NPT undergoes tension-compression cycle while the tire rolls. The spokes of an NPT is required to have both stiffness and resilience, which are conflicting requirements. Three types of honeycomb spokes are designed in AUTOCAD, namely A, B and C. Three dimensional models are created in CATIA. The mass of the designed tires are found out. ANSYS finite element analysis is used to study about the deformation and stresses developed in different type of honeycomb spokes. Type C honeycomb spokes are found to be better considering both fatigue resistance and lower mass design.

2. Design and Analysis of Non-Pneumatic Tire (NPT) With Honeycomb Spokes Structure (Umesh G C,Amith Kumar S N PG student, Assistant ProfessorDr. Ambedkar Institute of Technology Bengaluru, India)

In this, they used an innovative technology 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. Non-pneumatic tire is a submissive of cellular flexible spoke component which acts as air of a traditional tire. In this project we replace conventional alloy wheel by flexible spoke structure. We investigated hexagonal honeycomb along spokes designed for non-pneumatic tire 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. Here they designed & done analysis the non pneumatictire in Ansysworkbench. The static analysis of honeycomb tire had been carried out. The equivalent stress value obtained in static analysis for honeycomb tire is 76.344 MPa which is under permissible limits of material properties. So the structure is safe. The deformation value of honeycomb tire is 4.9839 mm.

3. Bowen, C. R. and Arafa, M. H. (2015) Energy harvesting technologies for tire pressure monitoring systems. Advanced Energy Materials, 5 (7). ISSN 1614-6832

In the paper we came to know the importance and use of piezoelectric materials and how much it generates the voltage. Following are the values we came across to use in out project. Piezoelectric- Compatible with MEMS, No external voltage source, Voltages of 2 – 10 V.

4. PIEZOELECTRIC POWER GENERATION IN AUTOMOTIVE TIRES (2- 4 November 2011), Montreal, Quebec, Canada. Faculty of Engineering and Applied Science, University of Ontario Institute of Technology 2000, Simcoe St N, Oshawa, Ontario, Canada L1H7K4

In this project three different methods of power generation were used utilizing PZT and PVDF were evaluated based on various performance criteria. for PZTthey used pzt bender bonded to tire it is brass reinforced elements have a total thickness of 0.23 mm with a 0.1 mm thick circular ceramic plate of 25 mm diameter is used. And for PVDF dimension 15 x 40 mm (3 pieces) with area of 1800 0.23 generates power of 0.23mw. PZT element generate a voltage peak with each revolution with maximum voltage of 45.5V A maximum of 4.6 mW of power can be extracted from the element bonded to the tire at a load resistance of 46 kΩ and a rotational wheel speed of 80 revolutions per minute roughly equal to 9 km/h. but in PVDF it generates 0.82mw so in this paper it tells that pzt material can generate more output voltage than PVDF with different harvesting methods.

5. Power Enhancement for Piezoelectric Energy Harvester (Sutrisno W. Ibrahim, and Wahied G. Ali)

In this paper they taken PZT and PVDF this paper investigates the necessary conditions to enhance the extracted AC electrical power from the exciting vibration energy using piezoelectric material. The effect of tip mass and its mounting position on maximum power extraction are investigated theoretically and experimentally. The optimal load impedance is also investigated to maximize the output power.

2. INTRODUCTION

For more than 100 years, vehicles have been rolling along on cushions of air encased in rubber. Sometimes, we get so used to a certain product that no true changes are ever really made for years, decades even. So begins an article discussing the development of airless tires, something that has become more prevalent in the past few years. A few tire companies have started experimenting with designs for non-pneumatic tires including Michelin and Bridgestone, but neither design has made it to mass production.

Creating a new non-pneumatic design for tires has more positive implications than one might think. For one thing, there are huge safety benefits. Having an airless tire means there is no possibility of a blowout, which, in turn, means the number of highway accidents will cut significantly. Even for situations such as Humvees in the military, utilizing non pneumatic tires has a great positive impact on safety. Tires are the weak point in military vehicles and are often targeted with explosives. If these vehicles used airless tires, this would no longer be a concern. There have been recent innovations with respect to airless tires; Non Pneumatic Tires have emerged consisting of flexible polygon spokes and an elastomer layer having inner and outer rings. Considering the NPT structure, the spokes undergo tension–compression cyclic loading while the tire rolls. Therefore, it is important to minimize the local stresses of spokes when under cyclic loading while driving. In other words, fatigue resistant spoke design takes on greater importance. Two dimensional prismatic cellular materials of periodic microstructures are called honeycombs. Honeycombs have been primarily used in lightweight sandwich structures for which a high out-of-plane stiffness is desired.

There is also an environmental benefit to using this type of tire. Since they never go flat and can be re-treaded, airless tires will not have to be thrown away and replaced nearly as often as pneumatic tires. This will cut down landfill mass significantly. This type of innovation works well in conjunction with several engineering codes of ethics, and thus should be embraced by engineers everywhere. Cars are things that people use every day, so any improvements over existing designs would affect the lives of the majority of people

3. HISTORY OF TIRES

Going back in history, initially a craftsman known as wheelwright forged bands of iron & steel, tying the wheel segments together as the metal contracted around the wheel. Hence the name, tire, as it tied the wheel together. This was then placed on wooden wheels of carts and wagons.

Explorers had seen Indians using sheets of rubber for waterproofing and in the 1800's, Charles McIntosh was experimenting with this latex – sap from a tree in the Amazon. It had its problems as the cold weather caused it to be brittle whilst in hot weather they became sticky. However, in 1839, Charles Goodyear discovered that by adding Sulphur to the melted latex it gave elasticity and strength. This vulcanized rubber was used to as cushion tires for cycles.

John Dunlop, trying to make his son's bicycle more comfortable to ride on, managed to invent the pneumatic tire. Another person, Robert Thomson, had already patented the idea of a pneumatic rubber tire so the Dunlop Rubber Company was established and won a legal battle with Thomson. In 1891, the detachable pneumatic tire was invented by two brothers, Michelin, consisting of a tube bolted on to the rim.

In 1948, Michelin revealed the first radial tire was developed and this was a revolutionary achievement as it used steel-belted radial tires. The advantages meant longer life and increased mileage for the vehicle. However, it required a different suspension system and so was slowly adopted. This was the tire along with Dunlop's invention, which gives us the tire we have today. We have seen heavy tire development, especially in motorsport, however we are yet to see anything as revolutionary as previous key points in history. There have been concepts, with a major one being the Michelin Tweel announced in 2005.

4. PNEUMATIC TIRES

The basic design of all pneumatic tires is very similar, even though there are many different types. They all include an inner core that holds pressurized air which is then covered with a layer of rubber that comes in contact with the road, called a tread.

Fig 1 – Pneumatic tires

The tread helps keep traction with the road and prevents slipping and skidding. The tread has the tendency to wear down over time, so if the tire has not gone flat, a person will usually replace it at this point the main reason for using pneumatic tires is the deformation that occurs during rotation. As the tire rolls, the weight of the car pushing down on it causes the tire to flatten slightly. This in turn, causes the tire to have a larger surface area to be in contact with the ground, which makes for better traction. It also gives a slight cushioning effect, making running over small rocks or debris unnoticeable.

5. NON-PNEUMATIC TIRES (NPT)

Airless tires or Non-pneumatic tires (NPT), are the tires that are not supported by air pressure. These tires are also called as 'Tweel' which is a merger of the words tire and wheel. This is because the Tweel does not use a traditional wheel hub assembly. The Tweel concept was first announced by Michelin back in 2005. Its structure is a solid inner hub mounted onto the vehicles axle that is surrounded by polyurethane spokes. This forms a pattern of wedges, which help to absorb the impacts of the road. These spokes look similar to the ones found on bicycles and plays the shock-absorbing role of the compressed air as in a traditional tire. A sheer band is then stretched across the spokes, which forms the outer edge of the tire. It is the tension of the band and the strength of the spokes that replaces the air pressure used on traditional tires. When a vehicle drives over an obstacle, a hump for example, the tread and shear bands give way as the spokes bend, before they quickly bounce back into shape.

Fig-2: Non-Pneumatic Tire Parts

MAIN PARTS OF NON-PNEUMATIC TIRES

The Four main parts of the non-pneumatic tires includes:

5.1 HUB: The hub is generally made up of Steel or Aluminum alloy. The average weight of the hub if its made of steel is roughly 4 Kg and of Aluminum alloy (AL7075-T6) is 2.5 Kg. It is a rigid structure and cannot deform while running. The frame of the vehicle is connected to the hub using nuts and bolts just like the hub used in the Pneumatic tires. It is the component in the Non-Pneumatic tire which has the longest life than any other component.

Fig-3- Steel hub

5.2 POLYURETHANE SPOKES: The discovery of polyurethane [PU] dates back to the year 1937 by Otto Bayer and his co-workers at the laboratories of I.G. Farben in Leverkusen, Germany. The initial works focused on PU products obtained from aliphatic diisocyanato and diamine forming polyurea, till the interesting properties of PU obtained from an aliphatic diisocyanato and glycol, were realized. With the decades, PU graduated from flexible PU foams to rigid PU foams (polyisocyanurate foams) as several blowing agents, polyether polyols, and polymeric isocyanate such as poly methylene diphenyl diisocyanato (PMDI) became available. These PMDI based PU foams showed good thermal resistance and flame retardance.

5.2.1MANUFACTURING OF POLYURETHANE

The manufacturing process involves the reaction of a pre polymer with a curative. The pre polymer consist of two parts, Polyols and Diisocynate. The Polyols are mainly Polyesters or Polyether's and the Diisocynate are Toluene Diisocynate or Methylene Diphenyl Diisocynate. The reaction of the Polyols and Diisocynate is an exothermic reaction. The pre polymer will be at a temperature of about 60 degree Celsius in the molten state.

The reaction of this pre polymer with a curative, which is a butadiene held at 40 degree Celsius will form the polyurethane. The solidification of this polyurethane will occur at 100 degree Celsius in about 4 hours.

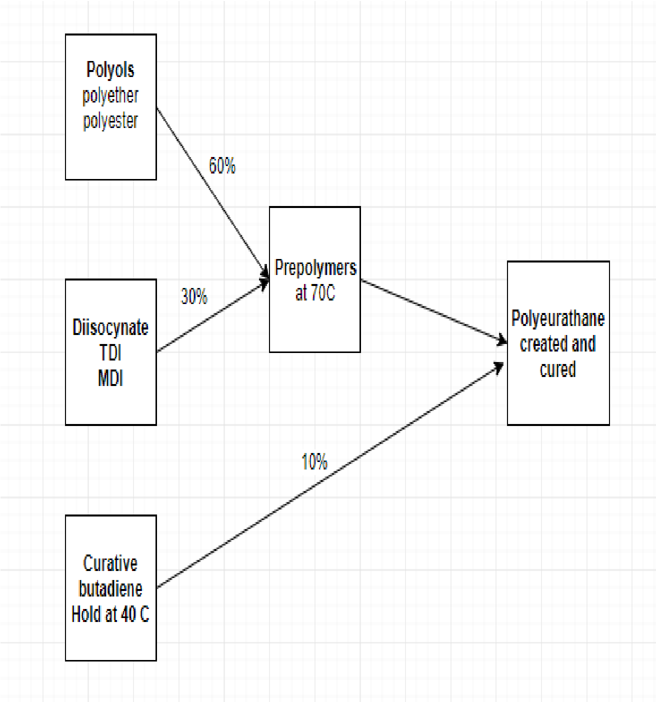


Fig-4: Block diagram of polyurethane formation

6. FABRICATION OF AIRLESS TIRES

Non-Pneumatic tires are produced in three steps: tread and shear band making, hub making, and assembling the former with polyurethane spokes. In the first step, the tread is constructed by a similar method as the tire tread manufacturing process. The tread on a NonPneumatic tire is exactly the same as a pneumatic tire and is extruded in the same way. It is then mated to layers of belts in the same manner as conventional tires. The process of rolling plies onto a drum to achieve the correct diameter currently is performed manually, but the same basic process that is performed on tires will be mimicked when the non-pneumatic tire production is fully automated. In this fairly simple process, rectangular sheets of rubber and steel cord are rolled onto a steel drum, and the excess material from each sheet is removed. Once the desired base thickness is achieved in this manner, the extruded tread is rolled onto the top, and the entire assembly is vulcanized. The second step is the making of the 4-kg steel hub casting or the aluminum alloy casting. The process is similar to ordinary casting process where the molten metal is poured into the mold and solidified.

In the third step, the hub and the tread are secured concentrically and polyurethane is poured into a spoke and shear band mold while the entire assembly spins so that the polyurethane will sufficiently fill the mold in the radial direction. The energy needed to spin the non-pneumatic tire assembly and polyurethane mold for just 5 minutes while the polyurethane is poured is considered irrelevant compared to the large amount of energy required to heat and pressurize the ovens needed to cure the shear band and then cure the entire assembly after the polyurethane is poured. Before the pouring process occurs though, all the surfaces that contact the polyurethane are cleaned and covered with either an adhesive or a mold release for the shear band and spoke mold, respectively.

The adhesives used are Ethyl acetate, Chemlok 7710, Stoner M-804 etc. The polyurethane pre-polymers and curative are stored separately until they are heated and combined at this point in the manufacturing process. The combination of the heated pre-polymers and curative could be considered in this Tweel manufacturing section, but in order to organize the impacts of the raw materials it is treated as part of the raw material production of polyurethane.

After the polyurethane is poured and the assembly is allowed to stop spinning, the entire Tweel tire is placed into another oven. This final curing occurs at 100°C degrees for 4 hours so that the desired polyurethane properties are obtained and to assure all the components are securely bonded together. The properties of the materials used for making non-pneumatic tires are given in table 1The energy inputs for rubber curing presses have been recorded and analyzed by tire manufacturers, and the average tire curing process requires about 1.1 kWh of energy for a tire weighing 10 kg, which means roughly 0.11 kWh of energy is needed to vulcanize 1 kg of rubber.

At the early stages of Tweelmanufacturing, Michelin is using the same type of press that is used to cure radial tires, so it is assumed in this analysis that the same energy will be required to cure 1 kg of rubber in a Tweel tire as 1 kg of pneumatic tire rubber.

The thickness of rubber in these two products varies slightly, but the curing temperature and time is close enough to assume the same energy requirements per kg of rubber. So, the required energy to cure the shear band in the Tweel is roughly (6.35 kg)*(0.11 kWh/kg), which equals 0.7 kWh. The energy required to heat, mix, and cure the polyurethane is allocated to the raw material production of polyurethane, so this 0.7 kWh is all the energy that is needed in the Tweel manufacturing inventory

Table-1: Material properties of non-pneumatic tire

Part	Hub	Spoke	Outer Ring	Tread
Material	AL-7075-T6	Polyurethane	AISI 4340	Rubber
Density in kg/m3	2800	1200	7800	1043
Youngs modulus E (GPa)	72	32	210	11.9

Poisson's Ratio v	0.33	0.49	0.29	0.49
Yield Strength Mpa	500	140	470	16

Table 2: NPT material composition in wt%

	Carcass	**Tread**	**Total tire**	**Hub**	**Total**
Raw Material	**Wt %**	**Wt %**	**Wt %**	**Wt %**	**kg**
Synthetic rubber	15.78	41.72	24.17	**0**	1.15
Natural rubber	24.56	3.53	18.21	0	0.10
Carbon black	23.40	9.54	19.00	0	0.26
Silica	0.80	28.07	9.65	0	0.77
Sulphur	1.60	0.80	1.28	0	0.02
ZnO	1.83	0.91	1.58	0	0.03
Oil	4.02	10.64	6.12	0	0.29
Stearic acid	0.87	1.47	0.96	0	0.04
Recycled rubber	0.60	0	0.50	0	0
Coated wires	17.2	0	11.4	0	0.62
Textiles	7.0	0	4.7	0	0
Steel	0	0	0	100	4.00
Polyurethane	90	0	100	0	8.44
Total wt%	**100**	**100**	**100**	**100**	
Weight[kgs]	**7.25**	**2.75**	**10.0**	**4.0**	**15.75**

7. GEOMETRICAL ASPECTS OF TIRE

The wheel size is 25"*6.5" *15"

The hub or rim diameter is =380.1mm

Hub thickness is=25 mm

The outer ring diameter is =605mm

The outer diameter of the wheel is =625mm

The thickness of shear band is =15mm

The width of the wheel is =165.1m

7.1 MODELLNG OF HONEYCOMB STRUCTURE IN SOLDWORKS

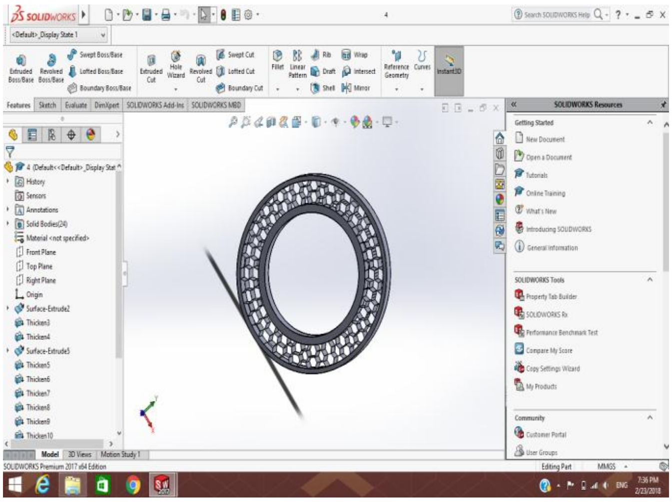


Fig-5: OVERVIEW OF MODEL.

While designing the honeycomb structure, whole structure is divided in to cell. The single cell is created first and patterned to create entire structure. The dimensions of single cell notions are shown in the figure6, 7.

Table-3: Geometric dimensions of honeycomb spokes

Geometric Parameters	L1	L2	L3	L4
mm(degree)	21	19.30	18.5	20

Table-4: Geometric dimensions of honeycomb spokes

Geometric Parameters	H1	H2	ϴ1	ϴ2	ϴ3
mm(degree)	25	25	15	20	30

Geometric parameters of Hexagonal Honeycomb Hexagonal honeycombs are designed with the cell wall thickness, t, the vertical cell length, h, the inclined cell length, l, and the cell angle, θ, as shown in Figure a. Table 4 incorporates the dimensions of the honeycomb cells. The efficient stress– strain curves of the honeycombs differ depending on the cellular geometry. An elevated cell angle, θ, cause cellular structures to comprise flexibility under uni-axial loading. The honeycomb spokes with a superior cell angle magnitude illustrate lower local stresses, which is excellent for a fatigue resistant spoke design. While modeling honeycomb, number of configuration are available with different cell angle, cell height h, and cell length l. But the dimensions of honeycomb spokes for this analysis are chosen randomly. The following dimensions were chosen for designing honeycomb spokes

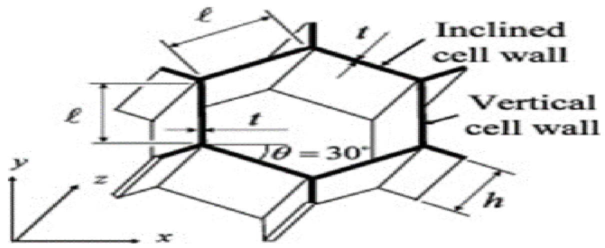


Fig 6 Honey comb Cell Structure.

8. STATIC STRUCTURAL ANALYSIS OF HONEYCOMB SPOKE

The FEM (finite element method) is a numerical technique used to resolve problems which is described by differential equations (partial differential equations) or can be resolved as functional minimization. In finite elements approximating functions are determined with the help of nodal values of a continuum which is sought. The continuum or physical problem is converted into a discretized small finite element problem with unknown nodal values. FEM is a computer program utilize to analyze a material and to find how stresses will affect the design or material for the applied load. Meshing is carried out using ansys software. Hear we used tetrahedral element for meshing. These tetrahedral elements are 3D elements which are having 3 degree of freedom at each node. Tetrahedral (solid187) element captures complete behavior of components by creating appropriate mathematical model during analysis. The total number of nodes in the meshed model is 15339 and total number of elements is 8256.

Material properties of honeycomb tire: The materials used in this analysis for honeycomb tire are aluminium alloy, polyurethane, steel, syntactic rubber. The main reason for selecting these materials is because they pose wide range of mechanical properties like high stiffness and resilience, high flexibility, hyperelastic, high temperature resistance etc. Standard materials have been selected and the properties are shown in the tables below.

Table 6(i): Material properties for honeycomb tire

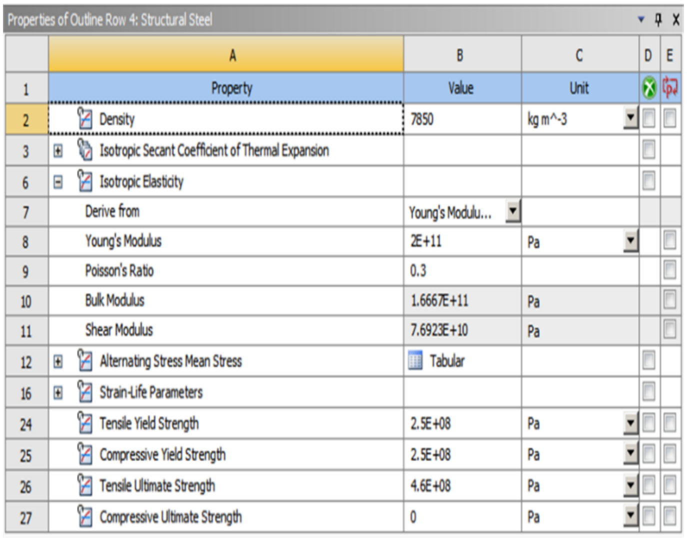
Part	Hub	Honeycomb Spoke
Material	Aluminum alloy	Polyurethane
Young's Modulus E (GPa)	72	32
Poisson's Ratio v	0.33	0.49
Density kg/m3	2800	1200
Yield Strength (Mpa)	500	140

Table 6(ii): Material properties for honeycomb tire

Part	Outer Ring	Shear or Tread Band
Material	AISI-4340 High Steel	Synthetic Rubber
Young's Modulus E (GPa)	210	11.9
Poisson's Ratio v	0.24	0.49
Density kg/m3	7800	1043
Yield Strength (Mpa)	470	16

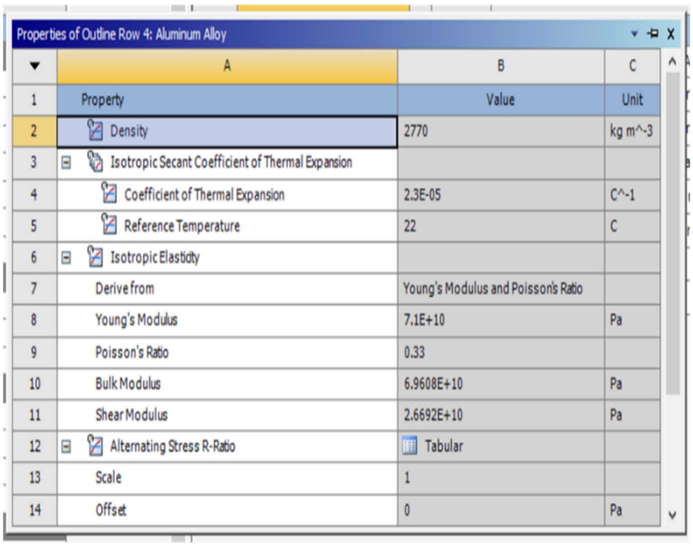
8.1 PROCEDURE FOR ANALYSIS IN WORKBENCH

8.1.1. Engineering data


Properties of Outline Row 4: Structural Steel

	A	B	C	D	E
1	Property	Value	Unit		
2	Density	7850	kg m^-3		
3	Isotropic Secant Coefficient of Thermal Expansion				
6	Isotropic Elasticity				
7	Derive from	Young's Modulu...			
8	Young's Modulus	2E+11	Pa		
9	Poisson's Ratio	0.3			
10	Bulk Modulus	1.6667E+11	Pa		
11	Shear Modulus	7.6923E+10	Pa		
12	Alternating Stress Mean Stress	Tabular			
16	Strain-Life Parameters				
24	Tensile Yield Strength	2.5E+08	Pa		
25	Compressive Yield Strength	2.5E+08	Pa		
26	Tensile Ultimate Strength	4.6E+08	Pa		
27	Compressive Ultimate Strength	0	Pa		

Fig7: For structural steel


Properties of Outline Row 4: Aluminum Alloy

	A	B	C
1	Property	Value	Unit
2	Density	2770	kg m^-3
3	Isotropic Secant Coefficient of Thermal Expansion		
4	Coefficient of Thermal Expansion	2.3E-05	C^-1
5	Reference Temperature	22	C
6	Isotropic Elasticity		
7	Derive from	Young's Modulus and Poisson's Ratio	
8	Young's Modulus	7.1E+10	Pa
9	Poisson's Ratio	0.33	
10	Bulk Modulus	6.9608E+10	Pa
11	Shear Modulus	2.6692E+10	Pa
12	Alternating Stress R-Ratio	Tabular	
13	Scale	1	
14	Offset	0	Pa

Fig-8: For aluminum alloy

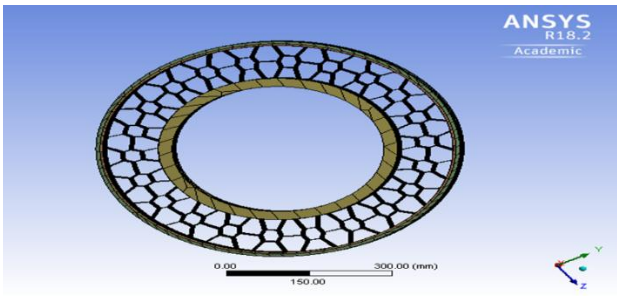


Fig-8: Meshing

8.2. STATIC ANALYSIS

8.2.1 STRESS AND DISPLACEMENT RESULT WHEN 750N

FORCE IS APPLIED

Fixed support is the surface where tire usually travel and

load/weight acts on center of the tire i.e, hub. And image

results of Total deformation and Equivalent (Von-Mises)

Stress show below for various loads.

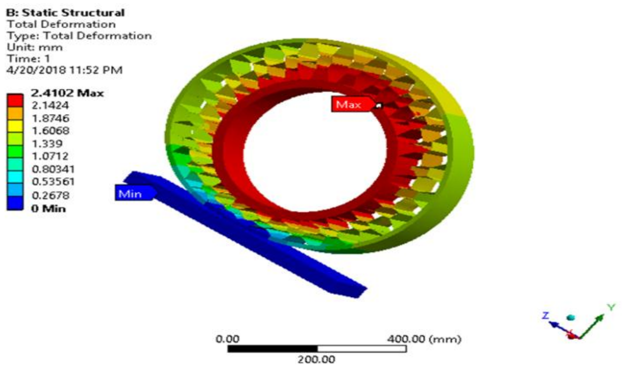


Fig-9: Total deformation at load 750 newton

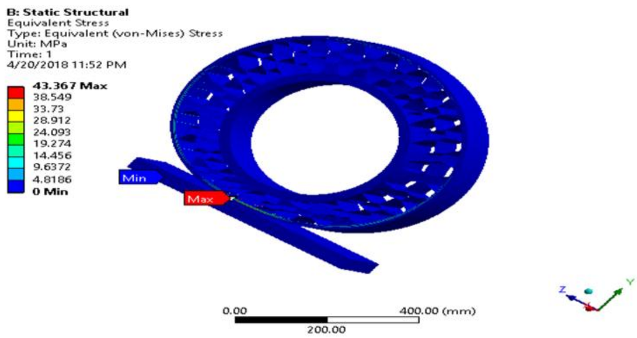


Fig-10: Equivalent (Von-Mises) Stress at load 750 N Force

8.2.2 STRESS AND DISPLACEMENT RESULT WHEN 1550N FORCE IS APPLIED.

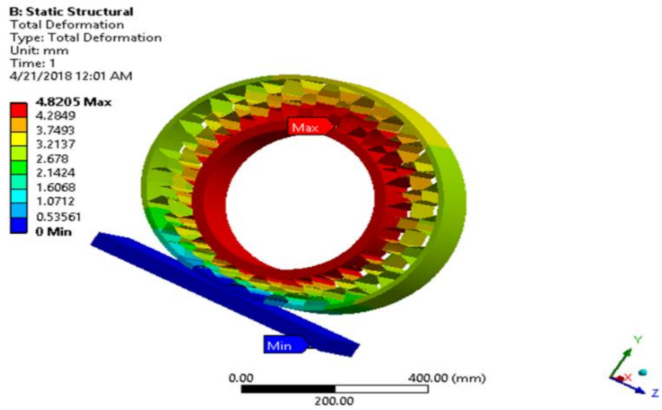


Fig-11: Total deformation at load 1550 N Force

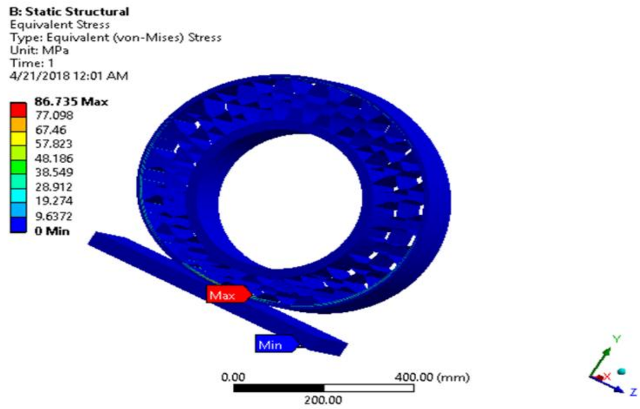


Fig-12: Equivalent (Von-Mises) Stress at load 1550 N Force

8.2.2 STRESS AND DISPLACEMENT RESULT WHEN 3200N FORCE IS APPLIED.

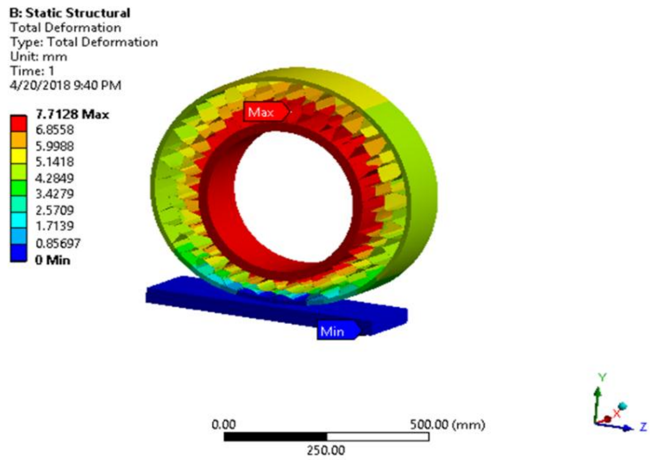


Fig-13: Total deformation at load 3200 N Force

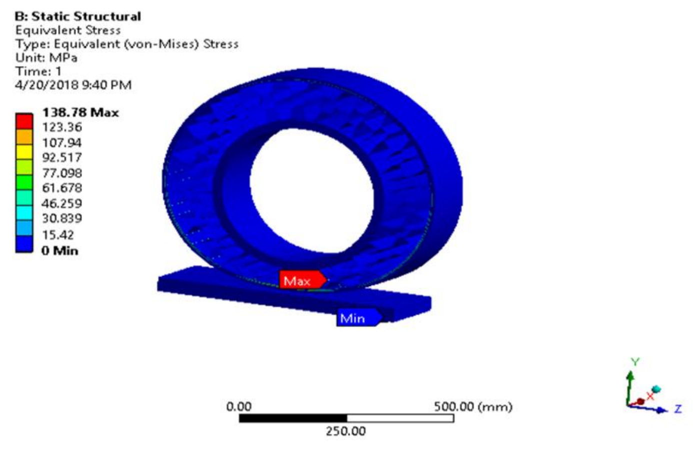


Fig-12: Equivalent (Von-Mises) Stress at load 3200 N Force

9. DYNAMIC ANALYSIS

9.1 MODAL ANALYSIS

The Modal Analysis is performed to evaluate the natural frequency of the non-pneumatic tire and its mode shape. The natural frequencies of the non-pneumatic tire should not fall between the operating frequency ranges to avoid the structure failure due to resonance. In this project we conducted model analysis to determine different natural frequency and mode shapes. This occurs for the applied static load of 750 N and 5000 rpm rotation applied in the z-direction. Mass of the tire is calculated using volume and density. Since volume of tire is known while modeling tire and density is found using material properties. If we know mass and load we can calculate natural frequency of the component. The natural frequency of tire is 554.68 Hz. Hear attempt is made just to depict different mode shapes for applied load.

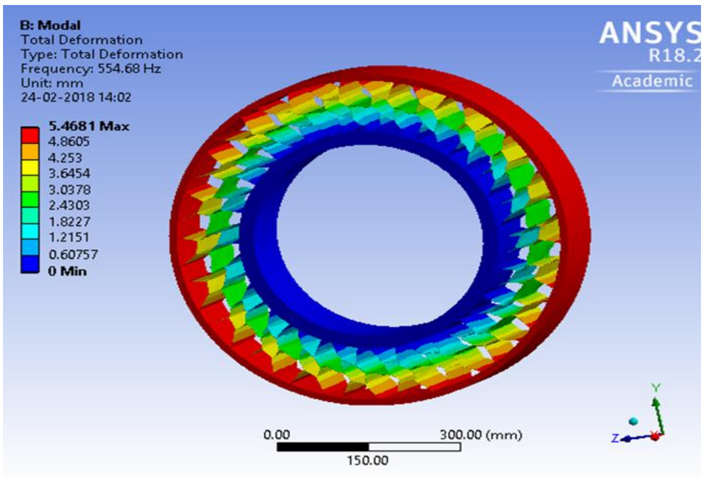


Fig-14: Total Deformation For Mode Shape 1

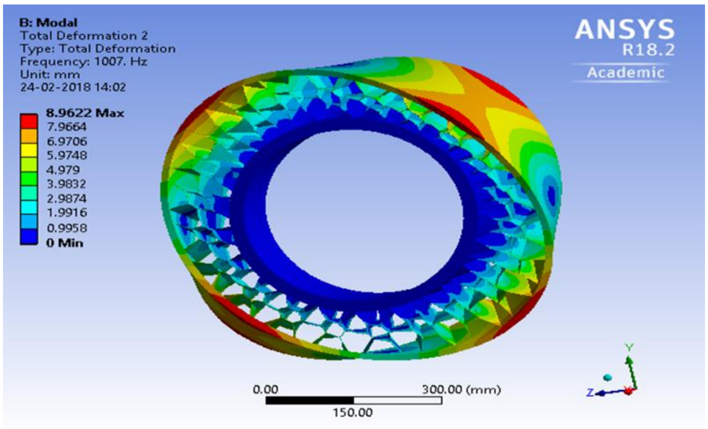


Fig-15: Total Deformation For Mode Shape 2

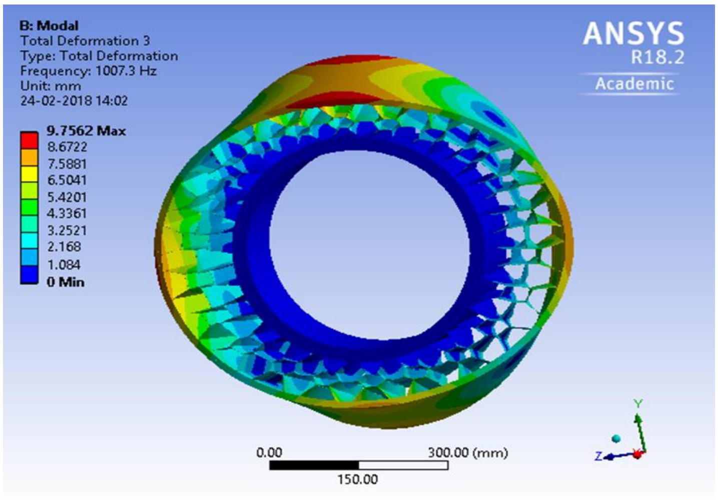


Fig-16: Total Deformation For Mode Shape 3

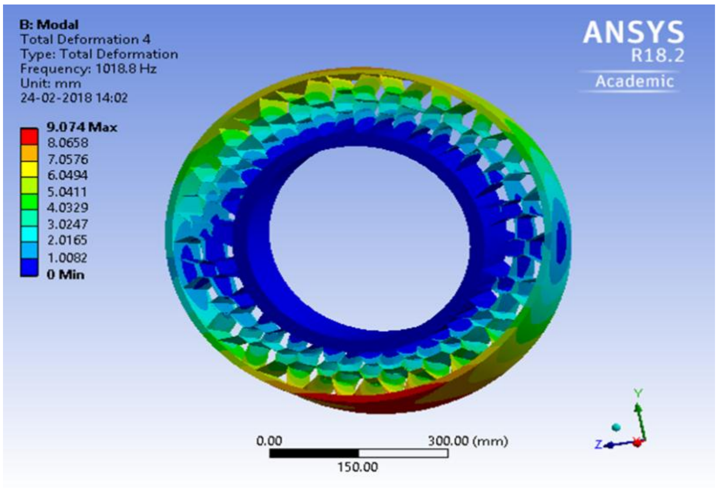


Fig-17: Total Deformation For Mode Shape 4

10. RESULTS

Tires may seem to be a trivial part of an automobile that cannot be improved, but research into airless tires shows otherwise. This new technology will increase the safety of automobile as well as have a positive impact environmentally. Since these tires are also able to retreated, there is the possibility of a smaller cost per tire- which is always embraced by the consumer. This innovative project is also backed and guided by engineering codes of ethics which will ensure that the development is conducted in a way that it responsible and fair.

It is also important to think about the implications of a technology such as this. This is reinventing the wheel in a way. This type of innovation will become increasingly valuable in the future because of the advantages that this tire has and the wide range of applications in which it can be used. A structural application of the flexible in-plane properties of hexagonal honeycombs was suggested – the honeycomb spokes of an NPT to replace the air of a pneumatic tire. Cellular spoke geometries for an NPT were investigated with regular and axenic honeycomb spokes using the compliant cellular design concept.

The results from von-misses stress (equivalent stress) to maximum shear stresses in static analysis and total deformation in dynamic analysis are compared below. The static analysis are done by taking 3 different force conditions on the tire, they are 750N,1500N,3200N.The dynamic analysis is done by taking 4 different frequencies, are 554.68Hz,1007Hz,1007.3Hz,1018.8Hz,

In static analysis found that the total deformation goes on increasing with the increasing of the loading condition which is not more than 10mm according to the standard condition of any tire, and the obtained value is 7.7128mm.The von misses stress plays a key role in the analysis part which shows gradual increment in the stress values during the loading conditions up to 138.78Mpa.

The minimum principle stresses does not have any impact on the tire on any kind of loading condition and hence it is in safe era which have the maximum value up to 2.2746Mpa. The maximum shear stress gives a good impact on the tire with highest stress value of all the 3 loading conditions that is 144.34Mpa.

The minimum shear stress is also in the part of the analysis which gives 72.295Mpa which is the highest in case of 3200N loading conditions. The dynamic analysis ranging from 554.68Hz to 1007.3Hz the deformation values goes on increasing, they are 5.461max to 9.7562max. From 1007.3Hz to 1126.6Hz the deformation values goes on decreasing, they are 9.074max to 5.8024max. From this when frequency increases the deformation values decreases.

11. CONCLUSIONS

In this project we modelled and did analysis for the Non Pneumatic tire of automobile .The 3D model of honeycomb structure was done in SOLIDWORKS CAD software and analysis of the same was done in ANSYS 18.2 CAE software.

The static structural and dynamic (modal) analysis of NPT with honeycomb structure was done with four different materials i.e. (aluminum alloy for hub, Polyurethane for spoke, steel for outer ring, synthetic rubber for tread). Analysis was done with these materials and the values are presented in the table

Type of analysis	Force 750N	Force 1500N	Force 3200N
Total deformation	2.4102	4.8205	7.7128
Von-mises equivalent stress	43.367	86.735	138.78
Maximu principal stress	45.105	90.21	144.34
Minimum principal stress	0.7108	1.4216	2.2746
Maximum shear stress	45.105	45.184	72.295

Modal analysis in dynamics the frequency must be of 554.68Hz for this design

So we conclude as per our analysis using these materials and load conditions design is safe.

12. PIEZOELECTRIC POWER GENERATION

Piezoelectric effect is the ability of certain materials to generate a electric charge in response to applied mechanical stress. The word piezoelectric is derived from the Greek piezein, which means to squeeze or press, and piezo, which is Greek for "push".

The phenomenon was first discovered in 1880 when Pierre and jacques curie demonstrated.

These materials are used in many applications like in Automotive, computers, consumer, medical, military.

Normally, the charges in a piezoelectric crystal are exactly balance, even if they are not symmetrically arranged.

The effects of the charges exactly cancel out, leaving no net charge on the crystal faces (more specifically, the electric dipole moments-vector lines separating opposite charges-exactly cancel one another).

If you squeeze the crystal, you force the charges out of balance.

Now the effects of the charges(dipole moments) no longer cancel one another out and net positive and negative charges appear on opposite crystal faces by squeezing the crystal you have produced a voltage across its opposite faces-and that's PIEZOELECTRICITY.

12.1. PLACEMENT OF PZT MATERIAL ON HONEY COMB TYRE

After static and dynamic analysis, the results of the maximum stress values occured between shear band and thread of the tyre. Later, the pzt plates are placed at the maximum stress values of the tyre and static voltage is obtained based on different loading conditions. The values of static voltage are calculated and obtained as below.

12.2 STATIC VOLTAGE CALCULATION FOR PZT PLATE

$$V=\frac{g_{33}F_3H}{lW}$$

V=static voltage

$g_{33} = piezoelectric\ voltage\ constsnt(10^{-3}Vm/N)$

F_3 = force in newtons (N)

H= Thickness (mm)

W=width (mm)

L=length (mm)

12.2.1: For 750 N Force

$$V=\frac{g_{33}F_3H}{lW}$$

g_{33}=26.5($\frac{10^{-3}Vm}{N}$) for pzt 840 material

H=2mm

W=14mm

L=35mm

$$V=\frac{(26.5\times10^{-3})\times750\times2}{35\times14} = 81.1224mv$$

12.2.2: For 1500 N Force

$$V=\frac{g_{33}F_3H}{lW}$$

g_{33}=26.5($\frac{10^{-3}Vm}{N}$) for pzt 840 material

H=2mm

W=14mm

L=35mm

$$V=\frac{(26.5\times10^{-3})\times1500\times2}{35\times14} = 162.2449mv$$

12.2.3: For 3200 N Force

$$V=\frac{g_{33}F_3H}{lW}$$

g_{33}=26.5($\frac{10^{-3}Vm}{N}$) for pzt 840 material

H=2mm

W=14mm

L=35mm

$$V=\frac{(26.5\times10^{-3})\times3200\times2}{35\times14} = 346.1224mv$$

13. CONCLUSIONS

12.1 By using PZT-840 material in honeycomb tyre at various loading conditions the obtained theoretical results of static voltages are:

Material	Force (N)	$g_{33}10-^3$v m/N	Length (mm)	Width and thickness (mm)	Static voltage (mv)
PZT 840	750	26.5	14	35&2	81.1224
PZT 840	1500	26.5	14	35&2	162.244
PZT 840	3200	26.5	14	35&2	346.1224

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