# NON-PNEUMATIC TYRES

## SEMINAR REPORT

*Submitted in partial fulfilment of the requirements for the award of* ***Bachelor of Technology*** *Degree in* ***Mechanical Engineering*** *of the University of Kerala*


Submitted by

**ANTONY MANGALATH**

**DEPARTMENT OF MECHANICAL ENGINEERING**
**LOURDES MATHA COLLEGE OF SCIENCE & TECHNOLOGY**

**KUTTICHAL, THIRUVANANTHAPURAM**

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DEPARTMENT OF MECHANICAL ENGINEERING
LOURDES MATHA COLLEGE OF SCIENCE & TECHNOLOGY

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# CERTIFICATE

*This is to cerrify that the project report entitled* ***NON-PNEUMATIC TYRES*** *is a bonafide record of the work done by* ***ANTONY MANGALATH*** *towards the partial fulfilment of the award of the Bachelor of Technology Degree in Mechanical Engineering of the Universiy of Kerala.*

**Guided by**
**Mr. Sammil.S**
Assistant Professor
Mechanical Dept.
LMCST

**Prof. Franklin.P.Joshua**
Head of Department
Department of Mechanical Engineering
Lourdes Matha College of Science and Technology

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# ABSTRACT

The Non Pneumatic Tyre (NPT) design was first developed by the French tyre company Michelin. Its significant advantage over pneumatic tyres is that it does not use a bladder full of compressed air and therefore it cannot burst or become flat. The inner hub of the NPT connects to flexible polyurethane spokes which are used to support an outer rim and assume the shock absorbing role of a traditional tyre's pneumatic properties. Potential benefits of the Non Pneumatic Tyre include the obvious safety and convenience of never having flat tyres. Eventually it may be able to outperform a pneumatic tyre since it can be designed to have high lateral strength for better handling without a loss in comfort since the design of the spokes allow the vertical and lateral stiffness to tuned independently . Commercial applications will be in lower weight vehicles such as wheelchairs, scooters, heavy vehicles like earth movers, military applications and NASA applied it in lunar rover. In future NPT will replace traditional tyres which could avoid checking of tyre pressure, highway blowouts and balancing between traction and comfort.

# CONTENTS

# LIST OF FIGURES

# LIST OF TABLES

# CHAPTER-1

# 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 tyres, something that has become more prevalent in the past few years. A few tyre companies have started experimenting with designs for non-pneumatic tyres including Michelin and Bridgestone, but neither design has made it to mass production.

Creating a new non-pneumatic design for tyres has more positive implications than one might think. For one thing, there are huge safety benefits. Having an airless tyre means there is no possibility of a blowout, which, in turn, means the number of highway accidents will but cut significantly. Even for situations such as Humvees in the military, utilizing non-pneumatic tyres has a great positive impact on safety. Tyres are the weak point in military vehicles and are often targeted with explosives. If these vehicles used airless tyres, this would no longer be a concern.

There have been recent innovations with respect to airless tires; Non Pneumatic Tyres 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 tyre. Since they never go flat and can be re-treaded, airless tyres will not have to be thrown away and replaced nearly as often as pneumatic tyres. This will cut down landfill mass significantly. Because of the benefits, I believe that it is extremely important that research and production of airless tyres is continued and increased. 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. Learning about such a topic, therefore, I believe holds extreme value- especially for us freshmen engineering students. In doing research into these kinds of topics that hold significant meaning, we can see that what we will do can make a difference.

## 1.1 HISTORY OF TYRES

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, tyre, 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 tyres for cycles.

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

In 1948, Michelin revealed the first radial tyre was developed and this was a revolutionary achievement as it used steel-belted radial tyres. 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 tyre along with Dunlop's invention, which gives us the tyre we have today. We have seen heavy tyre 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.

# CHAPTER-2

# PNEUMATIC TYRES

The basic design of all pneumatic tyres 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. 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 tyre has not gone flat, a person will usually replace it at this point.

Fig 2.1 – Pneumatic tyre

A main reason for using pneumatic tyres is the deformation that occurs during rotation. As the tyre rolls, the weight of the car pushing down on it causes the tyre to flatten slightly. This in turn, causes the tyre 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. If you've ever taken a ride in an old-fashioned carriage with wooden wheels, you know what a difference a pneumatic tyre makes.

Pneumatic tyres have their advantages, but they also have their disadvantages as well. The possibility of a blowout or flat (when air is let out suddenly from the tyre) is a major concern because they have the tendency to cause severe accidents. The task of regulating tyre pressure is also a disadvantage because consumers are usually not very good at it. Although it may help with traction to have the tyres a little flat, it comes at the price of handling. When there is not enough air pressure in the tyre, the sidewalls flex causing the tyre to not quite follow the desired line of steering. It is because of these disadvantages that tyre companies have taken an interest in designing airless tyres.

Fig 2.2- Puncture and Blowout of Pneumatic Tyres

## 2.1 PNEUMATIC TYRE MANUFACTURING

The production of a new tire is a fairly complicated process that involves many steps at a manufacturing plant, but before they can be considered, it must be understood how the necessary raw materials made it to the plant in the first placewhich is given in table1. The general process of constructing a tire involves assembling the numerous components shown in Figure 2.3 and then vulcanizing these parts together to achieve the desired properties. The details of the production process of each tire manufacturer are difficult to find because of the Confidentiality of their specific process, so for the purposes of this thesis, an average tire production process will be modeled. Combining this generic process with the specific material breakdown of a P205/45R17 tire is described which will represent an average tire built anywhere across the country with the given specifications of a section width of 205 mm, aspect ratio of 45%, and a wheel rim diameter of 17 inches.

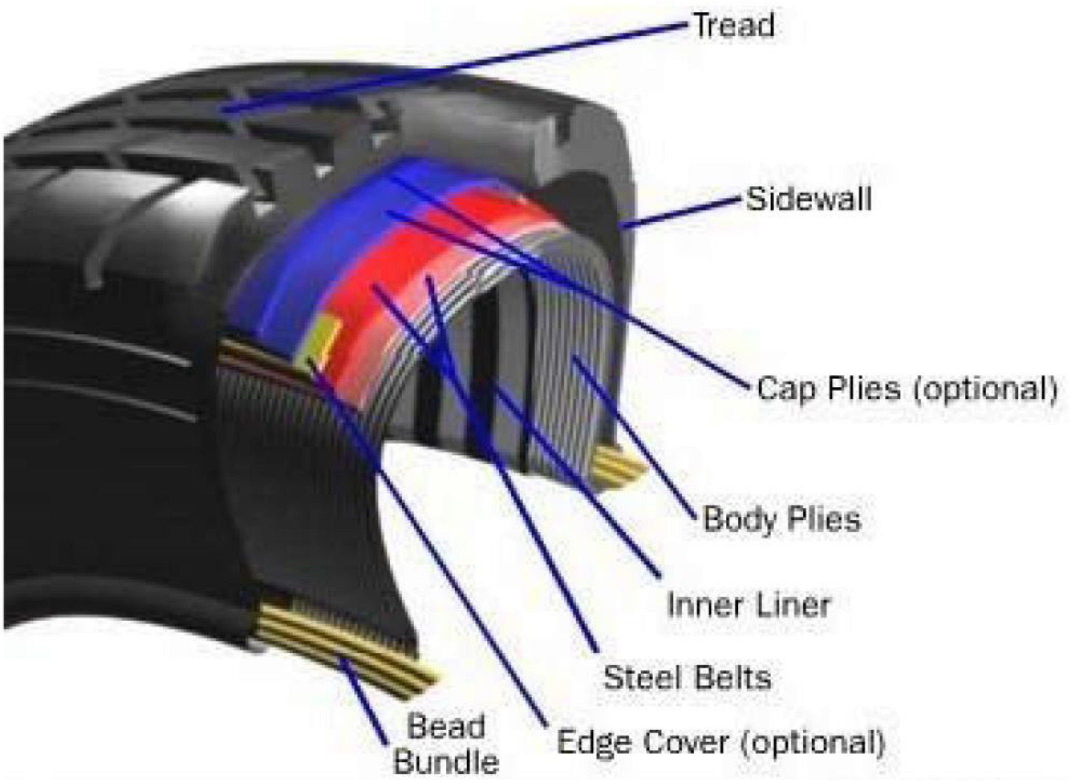


Fig 2.3- Structure of a Pneumatic tyre

| | Carcass | Tread | Total tire | Hub |
|---|---|---|---|---|
| **Raw material** | **wt %** | **wt %** | **wt %** | **wt%** |
| Synthetic rubber | 15.78 | 41.72 | 24.17 | 0 |
| Natural rubber | 24.56 | 3.53 | 18.21 | 0 |
| Carbon Black | 23.40 | 9.54 | 19.00 | 0 |
| Silica | 0.80 | 28.07 | 9.65 | 0 |
| Sulfur | 1.60 | 0.80 | 1.28 | 0 |
| ZnO | 1.83 | 0.91 | 1.58 | 0 |
| Oil | 4.02 | 10.64 | 6.12 | 0 |
| Stearic Acid | 0.87 | 1.47 | 0.96 | 0 |
| Recycled rubber | 0.60 | 0 | 0.50 | 0 |
| Coated wires | 17.2 | 0 | 11.4 | 0 |
| Textile | 7.0 | 0 | 4.7 | 0 |
| Steel | 0 | 0 | 0 | 100 |
| **Totals %** | **100.0** | **100** | **100** | **100** |
| **Weight (kg)** | **7.25** | **2.75** | **10.0** | **4.0** |

Table 2.1- Pneumatic tyre Material Composition

The process begins with the mixing of basic rubbers with process oils, carbon black, accelerators and other additives. The basic ingredients has been described above, so simply in Table 2.1.The following figure 2.4 shows the manufacturing process of Pneumatic tyres in the form of a flowchart. This mixed rubber then takes all the different forms as shown in figure 2.4 like sidewalls, tread, liner, etc. Most of these subcomponents are made by calendaring or extruding the cured rubber into the desired dimensions. Rough assumptions about the energy requirements and necessary lubricants in these two rubber processing techniques are taken. White's book titled Rubber Processing. Modeling the assembly process of all the components can be simplified to the rubber mixing process combined with the necessary lubricants and adhesives that secure the coated wires and textiles in place. Once all the components are assembled, the “green” tire is cured or vulcanized to glue everything together and to achieve the final dimensions and rubber properties. This curing process takes place under conditions of roughly 350 degrees Fahrenheit with pressures around 350 psi for around 15 minutes. After the curing process is complete, the finished tires are inspected and are sent out for distribution.

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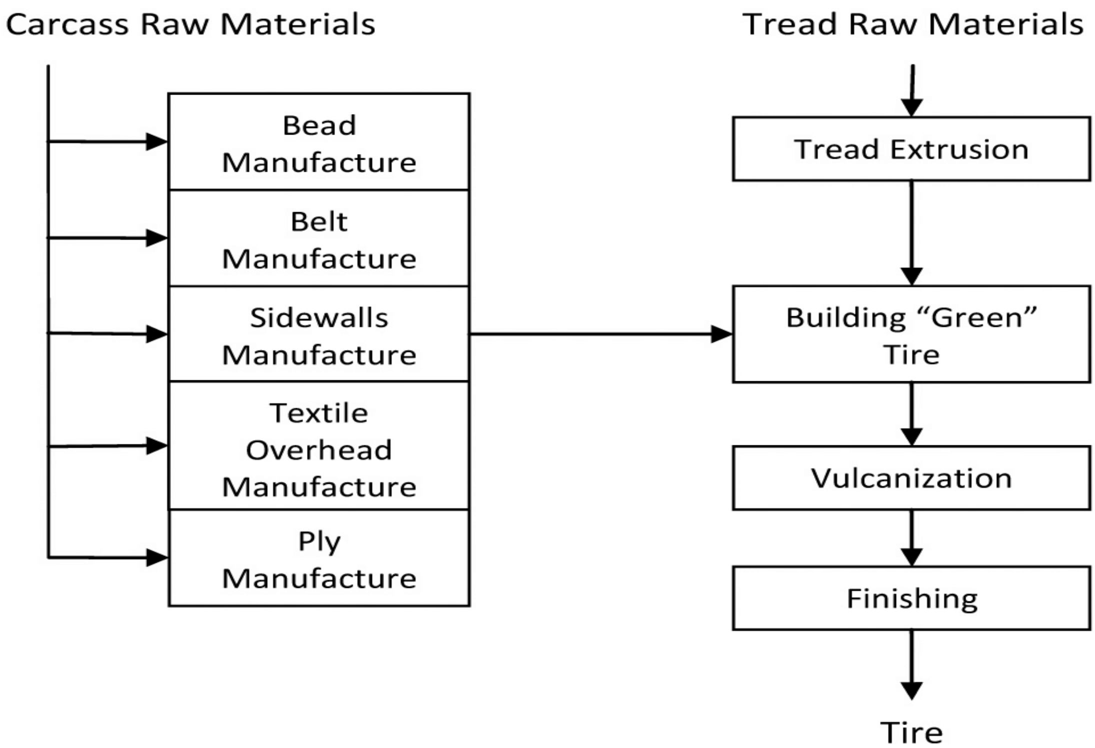



Fig 2.4- Manufacturing stages of Pneumatic Tyre

## CHAPTER-3

# NON-PNEUMATIC TYRES (NPT)

Airless tyres or Non-pneumatic tyres (NPT), are the tyres that are not supported by air pressure. These tyres are also called as 'Tweel' which is a merger of the words tyre 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 tyre. A sheer band is then stretched across the spokes, which forms the outer edge of the tyre. It is the tension of the band and the strength of the spokes that replaces the air pressure used on traditional tyres. 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.

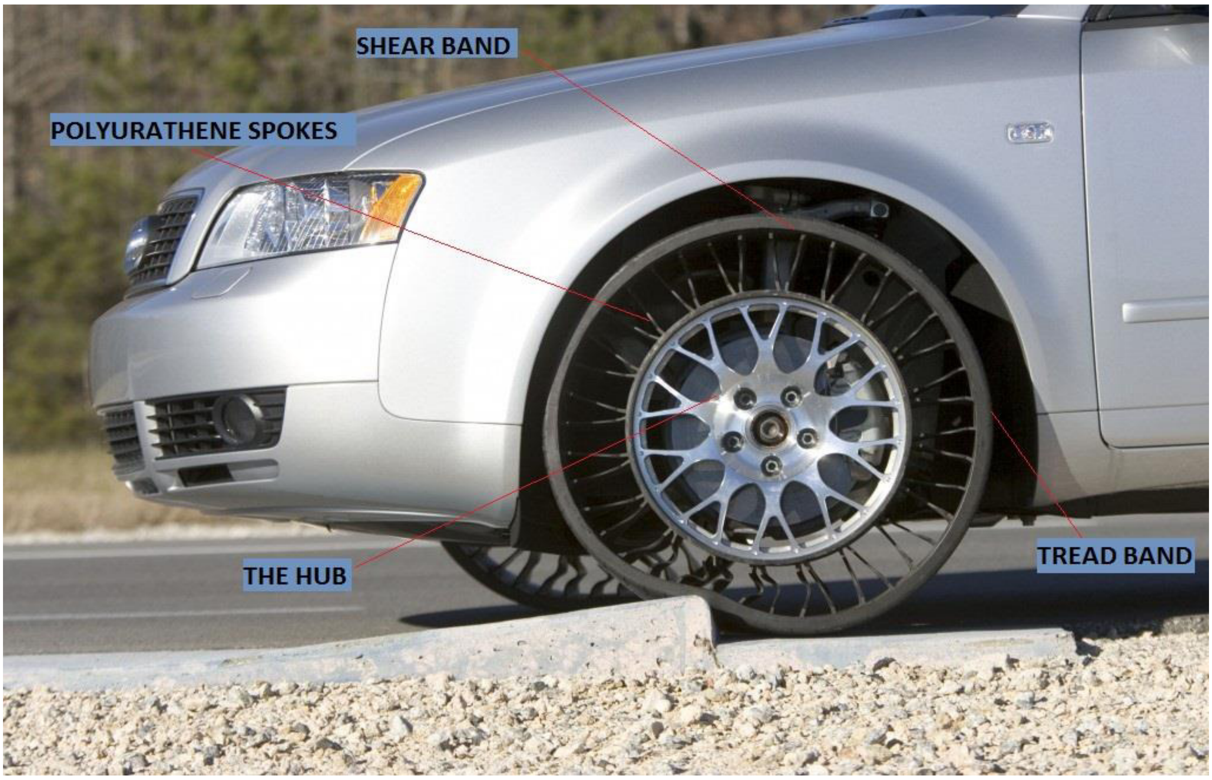



Fig 3.1- Non-Pneumatic Tyre Parts.

## 3.1 MAIN PARTS OF NON PNEUMATIC TYRES

The 4 main parts of the non-pneumatic tyres includes:

- HUB
- POLYURETHANE SPOKES
- SHEAR BAND
- TREAD BAND

## 3.2 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 tyres. It is the component in the Non Pneumatic tyre which has the longest life than any other component. The hub is an integrated part of the tyre and cannot be removed or replaced. Separating a Non Pneumatic tyre from its hub is not as simple as the process for a tyre because the polyurethane spokes of a tire are molded directly to the steel hub with a bond that is not easily broken. The hub is made by ordinary casting process just like the making of ordinary hubs.

Fig 3.2- Steel hub

## 3.3 POLYURETHANE SPOKES

The discovery of polyurethane [PU] dates back to the year 1937 by Otto Bayer and his coworkers at the laboratories of I.G. Farben in Leverkusen, Germany. The initial works focused on PU products obtained from aliphatic diisocyanate and diamine forming polyurea, till the interesting properties of PU obtained from an aliphatic diisocyanate 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 diisocyanate (PMDI) became available. These PMDI based PU foams showed good thermal resistance and flame retardance.

This polyurethane is used as the spokes in the Non Pneumatic tyres. It serves the function of air in this tyre. It has a capacity to take heavy loads and can deform its shape temporarily and can regain it. These are made in wedge shaped designs or in honeycomb designs. The wedge shaped design is introduced by Michelin and the honeycomb structure by Resilient Technologies, LLC.

Fig 3.3- Honeycomb structure and wedge structure

### 3.3.1 MANUFACTURING OF POLYURETHANE

The manufacturing process involves the reaction of a pre polymer with a curative. The pre polymer consist of two parts, Polyols and Diisocyanate. The Polyols are mainly Polyesters or Polyethers and the Diisocyanate are Toluene Diisocyanate or Methylene Diphenyl Diisocyanate. The reaction of the Polyols and Diisocyanateis 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. A block diagram showing the formation of polyurethane is shown below.

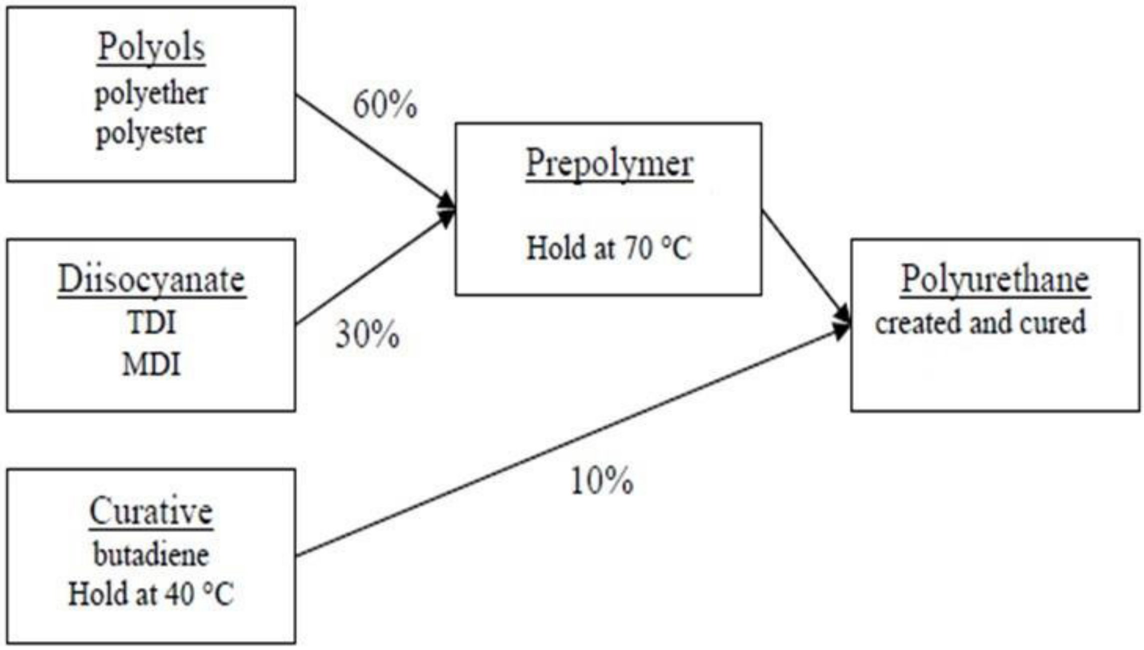



Fig 3.4 – Block diagram of polyurethane formation

## 3.4 SHEAR BAND

It is a flexible band which is between the polyurethane spokes and the tread band. The shear band mainly consists of steel wire wound in circular shapes. It gives reinforcement to the tread band from shearing off while running. Its manufacturing is done with the tread band so that it firmly sticks together with the tread and provide great cornering stiffness to the vehicle. The making of the shear band involves winding steel chord on top of a drum until desired base thickness of 15mm is obtained. The material used as the shear band is ANSI:4340 (American National Standard Instruction codes) which is a high strength steel.


Fig 3.5- Shear Band

## 3.5 TREAD BAND

It is the part of the non-pneumatic tyre which comes in contact with the road. It contains rubber grip or tread for traction and grip on the road surface or any other terrains. The design of the tread depends upon the terrain in which the vehicle meant to move. The manufacturing process of the tread band is similar to that of the tread making in pneumatic tyres which is the extrusion process. The extruded tread is rolled on the shear band of desired thickness so that it forms the part which comes in contact with ground. The whole assembly is vulcanised so as to give the rubber tread more durability and strength. Vulcanisation is done by treating the rubber tread with sulphur so that it forms links within the material and becomes difficult to break.

Fig 3.6- Tread band

## 3.6 FABRICATION OF AIRLESS TYRES

Non-Pneumatic tyres 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 tyre tread manufacturing process. The tread on a Non-Pneumatic tyre is exactly the same as a pneumatic tyre and is extruded in the same way. It is then mated to layers of belts in the same manner as conventional tyres. 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 tyres will be mimicked when the non-pneumatic tyre 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 tyre 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 (shear band, spokes, and hub) 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. To save some energy this curing process could take place at room temperature, but it would take much longer to complete and during this time it would be susceptible to being bumped and permanently damaged. The properties of the materials used for making non-pneumatic tyres are given in table 3.1. The 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 Tweel manufacturing, 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.

| Part | Hub | Spokes | Outer Ring | Thread |
|---|---|---|---|---|
| Material | AL 7075-T6 | Polyurethane | AISI 4340 | Rubber |
| Density P,kg/m3 | 2800 | 1200 | 7800 | 1043 |
| Youngs Modulus E (MPa) | 72000 | 32 | 210000 | 11.9 |
| Poisons Ratio,υ | 0.33 | 0.49 | 0.29 | 0.49 |
| Yield Strength (MPa) | 500 | 140 | 470 | 16 |

Table 3.1-Material properties of non-pneumatic tyres.

| | Carcass | Tread | Spokes | Hub | Total |
|---|---|---|---|---|---|
| **Raw material** | **wt %** | **wt %** | **wt %** | **wt%** | **kg** |
| Synthetic rubber | 0 | 41 | 0 | 0 | 1.15 |
| Natural rubber | 0 | 4 | 0 | 0 | 0.10 |
| Carbon Black | 0 | 10 | 0 | 0 | 0.26 |
| Silica | 0 | 28 | 0 | 0 | 0.77 |
| Sulphur | 0 | 1 | 0 | 0 | 0.02 |
| ZnO | 0 | 1 | 0 | 0 | 0.03 |
| Oil | 0 | 11 | 0 | 0 | 0.29 |
| Stearic Acid | 0 | 1 | 0 | 0 | 0.04 |
| Recycled rubber | 0 | 0 | 0 | 0 | 0 |
| Coated wires | 10 | 0 | 0 | 0 | 0.62 |
| Textile | 0 | 0 | 0 | 0 | 0 |
| Polyurethane | 90 | 0 | 100 | 0 | 8.44 |
| Steel | 0 | 0 | 0 | 100 | 4.00 |
| **Totals %** | **100.0** | **100** | **100** | **100** | |
| **Weight (kg)** | **6.35** | **2.75** | **2.65** | **4** | **15.75** |

Table 3.2- NPT material composition in wt%

# CHAPTER 4

# DESIGN ANALYSIS OF HONEYCOMB SPOKES

## 4.1 SUGGESTED HONEYCOMB DESIGNS

Effective in-plane modulus of hexagonal honeycombs were developed by earlier honeycomb engineers using the beam theory and these developments are collectively called cellular materials theory. The suggested honeycomb designs of the non-pneumatic tyres are as follows.

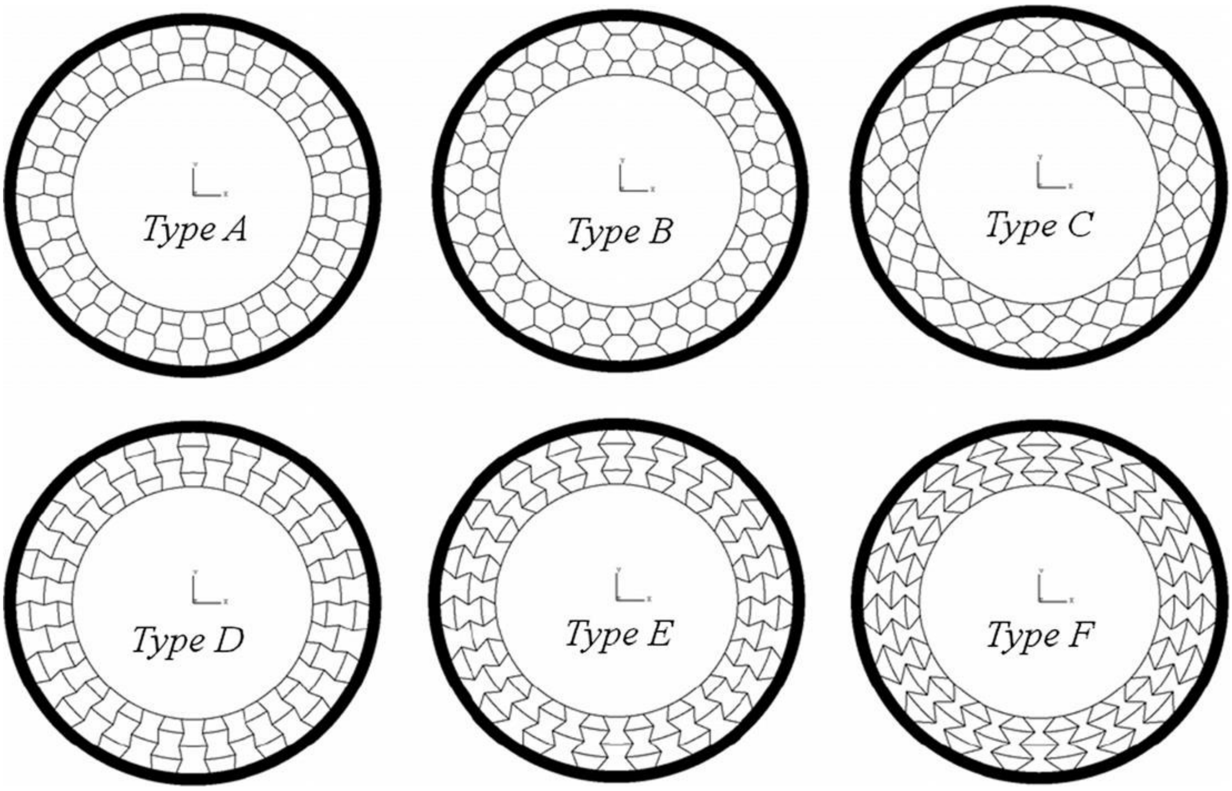
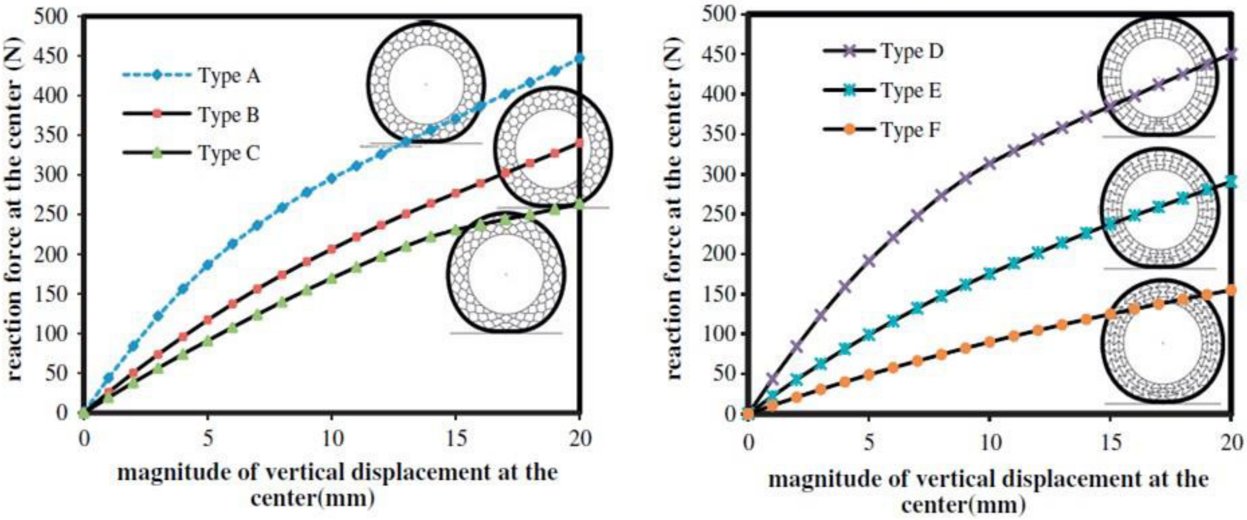



Fig 4.1-Suggested Honeycomb Designs

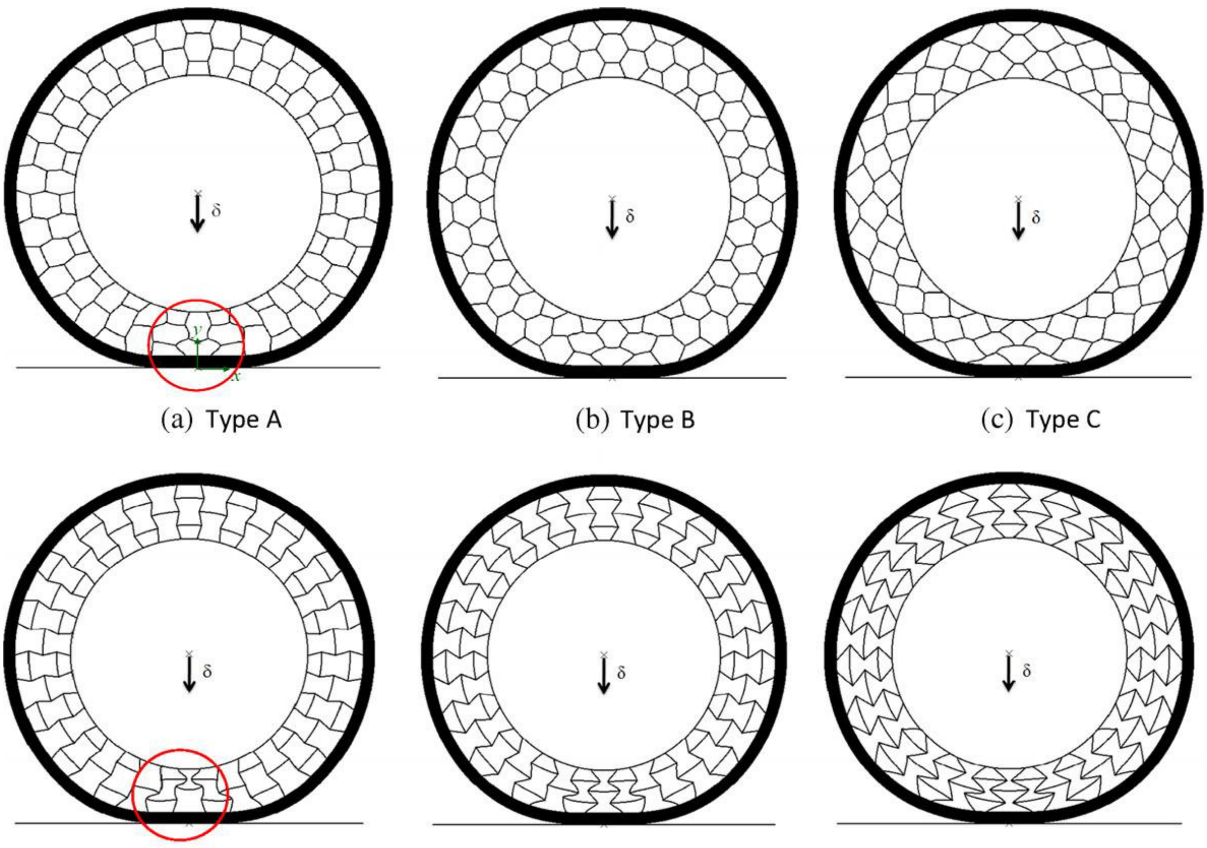
Six types of honeycomb spokes are considered for NPTs as shown in Fig. 4.1. Both regular honeycombs and auxetic honeycombs having a negative effective Poisson's ratio are used for the cellular spoke design. The type A,B,C are the regular honeycomb structures and type D,E,F are the auxetic honeycomb structures. These six cellular spoke designs are loaded for a magnitude of vertical displacement of 20mm for each type of tyre and the force displacement graphs are analysed.

## 4.2 FORCE DISPLACEMENT CURVES AND DEFORMED SHAPES OF DESIGNS




(a) Regular honeycomb spokes (b )Auxetic honeycomb spokes

Fig 4.2- Force-displacement curves with cell wall thickness is 5mm and tyre width of 100mm




(a) Type A (b) Type B (c) Type C

(d) Type D (e) Type E (f) Type F

Fig 4.3- Deformed shapes of NPTs under a vertical displacement, 10mm at the center.

The local stresses in the honeycomb spokes are investigated when the NPTs are designed to have the same load carrying capability. Due to the nonlinear load carrying behavior as a function of vertical displacement, loading at a certain vertical displacement can be used as a reference value. The effective force–deflection curve shows the nonlinear behavior associated with combined nonlinear effects of materials and geometries; primarily (i) hyper elastic material behavior, and (ii) large deflection and buckling of cell walls of honeycomb spokes, respectively.

Force–deflection curves of NPTs with the honeycomb spokes having negative cell angles and their deformation are investigated. Fig 4.2shows the force–deflection curve of an NPT with the Type D honeycomb spokes whose cell wall thickness, is 4.85 mm associated with the reference load carrying capability design. A similar macroscopic force–deflection behavior as an NPT with the Type A spokes is noticed due to the similar effective modulus between the Type A and the Type D spokes in the radial and the circumferential directions. The maximum local stress levels of the Type D spokes are also almost the same as those of the Type A spokes. Large cell deformation of the Type D honeycomb spokes is also observed just as it was in the Type A spokes, which might be caused by the low cell wall thickness design leading to easy deformation of cell walls, including buckling.

A lower geometric nonlinear effect is observed with the Type E spokes having a cell wall thickness, t of 6.74 mm as shown in. The corresponding maximum von Mises stresses are 2.3 MPa and 4.7 MPa at the global central displacements of 10 and 20 mm, respectively, which are lower than those with the Type D spokes. The auxetic honeycomb spokes require more mass to meet the reference load carrying capacity; for example, the Type D and the Type E spokes have about 15% and 80% increased. Total mass of NPTs with the honeycomb spokes for a lateral width of 100 mm is shown in fig 4.4.

The Type F spokes have a higher t, resulting in an increase in mass to meet the reference load carrying capacity; a 23.5% mass increase compared to the Type A spokes. The global force– deflection curve of an NPT with the Type F spokes having a t of 10.2mm. A geometric nonlinear effect is rarely observed compared to the former honeycomb spokes. This leads the spokes to have the lower local stress values, which is good for fatigue resistant honeycomb spokes.

The honeycomb spokes with a high cell angle magnitude show low local stresses, which is good for the fatigue resistant spoke design. The honeycomb spokes of Types C and F are good for fatigue resistance. In terms of lower mass design, the Type C spokes are thought to be good among the honeycomb spokes investigated.

Fig.4.4 shows the total mass of NPTs with the honeycomb spokes when the lateral width is set to be 100 mm.

## 4.3 RESULT

As can be confirmed, an NPT with the Type F spokes has the highest mass, which is not good for light weight design. The mass of an NPT with the Type C spokes is 18% higher than that of Type A. In order to design a tire for both low mass and high fatigue resistant honeycomb spokes, a higher modulus elastomer as a base material with the Type C spokes is preferable when designed to possess the same load carrying capacity.

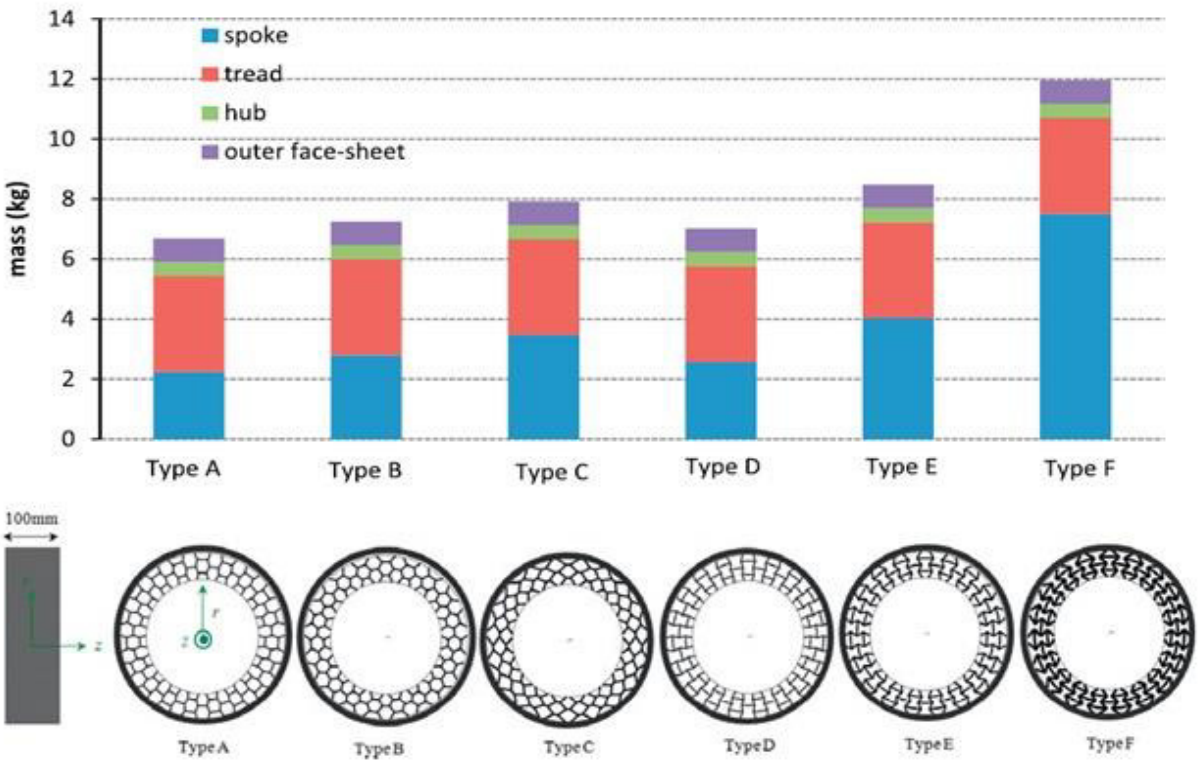



Fig 4.4- Total mass of NPT sith honeycomb spokes with lateral width of 100mm

# CHAPTER 5

# VEHICLES USING NON-PNEUMATIC TYRES

There are a number of vehicles using non-pneumatic tyres. Some of them are listed below:

- Earth movers
- Wheelchairs
- NASA Lunar rover
- Military vehicles

## 5.1 EARTH MOVERS

The non-pneumatic tyres give high stability to the earth movers to climb in all terrains. It provides a much smoother ride than a pneumatic tyre due to its excellent shock absorption. Even if the vehicle is heavy it will no damage the running surface. The NPT are very resistant to cuts than the traditional tyres, so it last longer.


Fig 5.1 Earth mover using NPT

## 5.2 WHEELCHAIRS

Non-pneumatic tyres are used in motor powered wheelchairs which can climb stairs. It was first introduced by a company called Michelin so that the suspension system in the wheelchairs can be eliminated.


Fig 5.2-Wheelchairs using NPT

## 5.3 NASA LUNAR ROVER

It is a six legged robot designed by NASA for moon exploration. It has 6 legs, all of them contain NPT. It is able to roll or walk over large range of terrains.

Fig 5.3- NASA lunar rover using NPT

## 5.4 MILITARY VEHICLES

American military vehicles such as Hummer, trucks, etc. are using the non- pneumatic tyres. The main advantage of the military vehicles using this tyre is that it requires very little or no maintenance. It will still remain mobile even with some spokes damaged or missing. It passed the ballistic test ie. it will remain mobile eve if it is hit by a bullet.

Fig 5.4- Military vehicles using NPT

# CHAPTER 6
# ADVANTAGES AND LIMITATIONS

## 6.1 ADVANTAGES

It provides a comfortable ride and increases vehicle handling. Its flexibility provides an increase in surface area of contact thereby increases the grip with the ground. It can take gun fires and spikes without becoming immobile. It reduces down time as compared to pneumatic tyres as it require very little or no maintenance. It increases the load carrying capacity of the vehicle. It reduces the environmental impacts as the chemicals used in the manufacturing of non-pneumatic tyres are very less compared to traditional pneumatic tyres.

## 6.2 LIMITATIONS

The non-pneumatic tyres are expensive as compared to pneumatic tyres. The replacement of any component in the non-pneumatic tyre is impossible ie. every time the tyre is worn-out we have to replace the whole assembly. It can withstand police spikes which may make it difficult for law enforcement. Lack of adjustability is one disadvantage of non-pneumatic tyresie if once manufactured cannot be altered or adjusted. It cannot be implemented in fast moving vehicles above 50mph as the spoke vibrates considerably and is unpleasantly loud.

# CHAPTER 7

# CONCLUSION

Tyres may seem to be a trivial part of an automobile that cannot be improved, but research into airless tyres shows otherwise. This new technology will increase the safety of cars as well as have a positive impact environmentally. Since these tyres are also able to be retreated, there is the possibility of a smaller cost per tyre- 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 tyre 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 auxetic honeycomb spokes using the compliant cellular design concept.

# REFERENCES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