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Delination and Analysis of Non Inflated Tyres with ANSYS

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ABSTRACT

Non-inflated tires (NIT) have wide application prospects due to their advantages of no run-flat, no need of air pressure maintenance, and low rolling resistance. In this project, the static and dynamic behaviours of NITs with different honeycomb spokes, Plate spokes and triangular spokes were investigated. Based on the static behavior of three types of NITs with the same cell wall thickness of honeycomb or the same reference load carrying capacity, it is shown that the maximum stresses in spokes and tread of a NIT are much lower than that of traditional pneumatic tires, but its load carrying capacity is higher than the latter. The design of three NIT's is designed in Catia V5 and analysis were dined in Ansys workbench 2019 R3. In comparison with the dynamic behavior of three types of NITs designed with the same load carrying capacity, it is found that the stress level in spokes and tread under dynamic loading are higher than that under static loading. The rolling resistance of NITs with the smallest cell expanding angle is lowest, which is due to the lowest mass and smallest deformation of honeycomb spokes. Taking all these factors into account, it is suggested that an optimal NIT in applications is one with a small cell expanding angle and wall thickness.

Keywords: non-pneumatic tire; honeycomb spokes; contact pressure; rolling resistance.

1. INTRODUCTION

Since non-Inflated tires (NITs) were proposed, they have received increasing attention owing to their remarkable advantages such as no run-flat, no need of air pressure maintenance, and low rolling resistance, compared with traditional pneumatic tires. A typical NIT usually consists of a hub, a few flexible spokes, a shear ring and a tread. Normally, tread is made of synthetic rubber, and shear ring is a composite structure composed of a shear band with two circumferential reinforcements (i.e., inner and outer rings). Flexible spokes are the most unique components in NITs, and they are based on polyurethane materials. Uniform and flexible spokes that are designed to connect the composite shear ring and hub of NITs are mainlydeformed by compression, tension, bending or buckling during rolling.

Fig.1.1 Non inflated tyre in military

The spokes of a NIT require a combination of stiffness and resilience under cyclic tension-compression loading, which brings a challenge to the selection of materials and structural design. Cellular materials and their constructed structures can be applied to meet these requirements, and honeycomb spokes have a great potential in NITs. Honeycombs possess high stiffness and strength in out-of-plane directions, and relatively lower mechanical resistance and higher resilience in in-plane directions. Therefore, the in-plane configuration of honeycombs is usually utilized in NITs. In addition, the cell structures of honeycombs are tenable to optimize in-plane properties, e.g. by changing the cell angle, wall thickness, and length to produce tailored stiffness and strength.

Recently, an attempt has been made to use honeycomb spokes in constructing NITs in trucks. There are also research works conducted to guide the structural design and optimization of NITs. For instance, developed finite element models of NITs with honeycomb structures as a shear band and investigated one-dimensional contact pressure of tires. It was found that the auxetic hexagonal honeycomb shear band designed with a higher negative cell angle provided a lower contact pressure along the contact patch associated with in-plane shear flexible structures. Studied the static contact pressure of NITs with hexagonal-cell honeycomb spokes as a function of vertical loads. They discovered that the contact pressure of NITs was lower than that of traditional pneumatic tires due to a high lateral spoke stiffness of NITs. Here, it is worth noting that the load carrying capacity, defined as the displacement of a hub centre under a vertical concentrated force, is one of the most important indicators of NITs. Compared two types of NITs with conventional and auxetic hexagonal honeycombs, and showed that, under the same load carrying capability, conventional hexagonal honeycombs with a highly positive cell angle had low local stresses and mass.Obviously, most of these works are focused on the static properties and loading response of NITs. However, NITs are mainly subjected to dynamic loading in service. Thus, it is necessary to further examine the dynamic performance of NITs. Other factors such as dynamic material properties and kinetics, have also to be considered in dynamic analyses. An analytical model for a compliant NIT rolling on frictionless, rigid ground. Their model was validated by numerical and experimental data the effects of thickness of a shear band and tread on the performance of NITs, placing emphasis on impact between NITs and sand with obstacle. As is well known, rolling resistance is a key parameter to evaluate the performance of a tire. The hysteretic energy loss of a viscoelastic tire material is the main contributor to rolling resistance of the tire, which constitutes 90 to 95% of the total rolling energy loss. To reduce the rolling resistance of a NIT, a shear band made of a porous and fiber-reinforced elastomer was proposed, and numerical simulations were conducted to demonstrate the reduced energy loss by using hyper elastic and viscoelastic material models. The influence of geometric and material parameters on overall performance of NITs has been also analysed. To the best of our knowledge, however, there are few works about the dynamic behaviours of NITs with honeycomb spokes, especially on their rolling resistance.A tire is the most important part of any vehicle. A tire 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 tire, tube is present inside the tire while in tubeless tire 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.

Tire, which is used in automobile, bicycle, motorcycle is pneumatically inflated structures which provide a good rolling, cushioning effect. Such tires are used for numbers of year, and they are developing. Some companies are trying to develop tires which are airless that means they are non-pneumatic. Michelin and Bridgestone are the tires 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 tires are also a type of non-pneumatic tire [4], [5].

Pneumatic or air-filled tire is tire 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 tire is more than atmospheric air pressure, so the tire remains inflated even with the weight of a vehicle resting on it. The tire air pressure provides resistance against forces that try to deform the tire, but it gives to a certain degree of cushioning effect as the tire hits bumps in the road. Tubeless tire is an advanced version of tube tire. The basic difference between tube and tubeless is that there is no presence of tube inside it [6].

In this type of tire there is a special air retaining bead arrangement. These tires are directly mounted on the rim. In this tire the air is filled with the help of a non-returning valve which provides restriction to air to do not leave it from tube. The valve is mounted on the rim. The bead is the airtight part which fits on the circumference of the wheel rim. It consists of bead cores made of a few strands of steel wire. Carcass is the main structural element that takes the load and consists of rubber bounded cords and beads [7].

Non-pneumatic tire (NPT), or Airless tires, are tired that is not Cikitusi Journal for Multidisciplinary Research Volume 5, Issue 3, March 2018 ISSN NO: 0975-6876 219 http://cikitusi.com/ 2 supported by air pressure [8]. Airless tires generally have higher rolling friction and provide much less suspension than similarly shaped and sized pneumatic tires. Other problems for airless tires include dissipating the heat buildup that occurs when they are driven. Airless tires are often filled with compressed polymers (plastic), rather than air. The pneumatic tire is made up of polymer which has high resistance to shock of road as well as having good elastic property. They are made up of tread, shear band, deformable wheel and flexible spoke. Thread is placed on the upper side of wheel which provides good tensile strength and help to wheel to stay in position. Shear band is the outer covering of the pneumatic tire which transmits shock. Flexible spokes are attached to the shear band which is generally triangular.

The wheels are attached to the vehicle. While the vehicle is in running various shock effects by the vehicle. As the shock gets trapped the flexible spokes bend and the shock getsabsorbed. As the shock leaves the spoke gets in their original shape [9], [10].

The comfort and safety of driving a vehicle mainly depend on the good working states and the symbiosis between the components of the vehicle suspension system. A suspension system of any vehicle is composed of a shock absorber, a spring and most importantly a tire. The main objective of this trio is to isolate the occupants of the vehicle from any external disturbances caused by interaction with a roughened ground while permitting the driver to keep an efficient and safe control on his vehicle.

If any one of these components is badly designed, manufactured, mounted or used, severe consequences could disturb the ride comfort of people inside the vehicle and even jeopardize their safety. As vehicles have become more robust, reliable and sophisticated, drivers became less aware of the importance of their tires. Tires have significantly improved in terms of safety, performance and wear, but they still need more attention than most of the car components.

There are many factors that can result in a tire failure (puncture or blowout) or increase its probability. Such an unpleasant event can happen at any time when a tire loses suddenly or gradually its internal air pressure. This pressure drop prevents the tire from accomplishing its principal task; that is to support the weight of the vehicle and thus, make the driver fail to maintain a straight and safe trajectory which leads very frequently to a harmful car accident.

A lot of car accidents due to tire failure are being recorded annually. These accidents involve either injuries or fatalities and thus should be taken seriously. The National Highway Traffic Safety Administration (NHTSA) estimates that tire failures play a role in causing about 1100 traffic accidents each Month in INDIA, and almost 200 people die in those crashes. Similarly, road casualty data in the UK reveal that defective tires were responsible for more than 1,210 road casualties in Great Britain during 2010. In the period between 2006 and 2010, the total number of tire-related deaths on UK roads exceeded 160. Moreover, in the UK during 2012/13, around 7.7% of cars, 3.8% of large passenger vehicles, and 7.2% of goods vehicles failed the ministry of transport test because of faulty tires.

A tire is a product of complex engineered composites. It consists mainly of a reinforced rubber toroid mounted on a metallic rim. The air trapped inside creates an inflation pressure that is responsible for carrying the load, transmitting forces, absorbing shock, providing grip and resisting wear. In a tire, there are multitudes of components and rubber formulations. For reinforcement, tires also have several types of fabric and several kinds and sizes of steel. Some of the steel are twisted or braided into strong cables. On the external shell, the tread provides the required friction with the road surface and gives better traction. The purpose of the patterns on the tread is to facilitate the evacuation of water and optimize the wear rate. Compared to a rigid wheel, the conventional air-filled tire has numerous advantages: good radial elasticity, better grip with the road, and a low mass.

On the other hand, the air tire has also many weak points: mainly its vulnerability to unsteadiness of air pressure. The variation of air pressure affects the performance of the tire and considerably modifies the ride comfort of passengers. Among all possible threats, the risk of a blowout on the road is certainly the most dangerous one. In addition to its complex structure, even the computational modeling, and analysis of a pneumatic tire is a difficult and challenging task too.

The main complication is due to the presence of constraints such as nonlinear material, nonlinear geometric conditions, and nonlinear contact boundary conditions. Since the beginning of the twentieth century, several attempts have been made to develop flat-proof non-pneumatic tires (NPT) based on flexible elastomer layers or deformable spokes that could provide the same mechanical properties of the air trapped inside the tire. In the early 1970s, the NASA's Lunar Roving Vehicle was the first serious project where airless tires were used. To provide the required traction on the dusty moon surface, the 9x32-inch tires consisted of V-shaped titanium treads wrapped around steel-mesh toroids and attached to aluminum wheels. With the new technology of airless tires, there is no need for periodic maintenance to refill the tires with air and maintain an appropriate internal pressure. Such principle eliminates the worry of punctures and enhances considerably the safety of the vehicle. Since the recent emergence of newly invented non-pneumatic tires (NPTs), the most common concept was the use of an elastomer layer with reinforced rings and a distinctive structure of spokes, anchored to the inner side of the tire and uniformly distributed around the rim. The set of spokes support the weight of the vehicle and deform to provide the cushioning effect exactly like air pressure tire.

Research on NPTs has been actively conducted to improve structural performance, e.g., contact pressure, design and structure of flexiblespokes and rolling resistance. To cope with the growing demand for safer tires, the concept of flat-proof airless tires was brought back home to the tires market by several companies.

Due to their non-hazardous behavior and to their good stability, innovative designs such as those propose had already gained the attention of researchers for particular use in military and space mission's applications. In both solutions, the air of pneumatic tires (PT) was replaced by series of flexible polygon spokes that undergo millions of tensions–compression cycles while the tire is rolling.

In particular, the model developed by Michelin called the "Tweel" and classified by Time magazine as "one of the 2005's most amazing inventions" was claimed by the Michelin to possess three-timeslonger tread life and five-times-higher lateral stiffness, compared to conventional PT, with only a slight increase in rolling resistance. For this model, and all other spokes-based models, the main concern remain an optimum geometry design and a good material selection which ensure an efficient resistance to the highly disturbing tensioncompression cyclic fatigue load, especially in the critical spots with sharp geometrical entities usually more vulnerable to high-stress concentration levels.

Recently, flexible honeycomb solution with different shapes, made of polyurethane (PU) has been proposed as a new alternative for NPT spokes, to be used in applications that require high deformation. It was found that having both resilience and stiffness while relying exclusively on material properties is impossible. Types and geometries of the cells are the key factors in determining the in-plane flexibility of hexagonal honeycombs under uniaxial loading.

2. LITERATURE REVIEW

Mohammad Fazelpour et al, [1] stayed considered about the evolution of meso-structures in the development of the shear band of non-pneumatic tyre and he concluded as follows below. To increase fuel efficiency in NASA manned exploration system. They replaced elastomeric material with shear of shear band with materials which can tolerate harsh temperatures and shear loads or to replace the materials with linear elastic low-hysteretic loss materials. Topologies were created such as honeycombs; new shapes like s-type meso-structures and the structural analysis were carried out of shear band of non-pneumatic tyre with meso-structure was investigated through shear flexure, shear strain, and contact pressure. At the end of research, they set up guidelines on custom-designing meso-structures for challenging applications such as non-pneumatic tyre and passive morphing airfoils which will be addressed in future research.

A.M. Abdul-Yazid et al, [2] examined three dissimilar structures of the Tweel, resistant technologies, and NIT by seeking yielding spoke structures. He conducted the quasi-static, 2D analysis on contact pressure, vertical tire stiffness and stress which are affected by spoke structures and shear band by creating two NITs, a tire with a composite ring and another without composite ring. The results showed that shape and size of spokes has effect on tire behavior and the shear layer reduces the impact of the deformed spokes shape in contact pressure distribution.

Bert Bras et al, [3] discussed about the ecological effect of the Tweel tyre amid its lifecycle from assembling, through use and transfer. Since the Tweel tyre is as of now still in the examination stage and is most certainly not made and utilized on a vast scale, there are instabilities as for end-of-life situations and rolling resistance evaluates that will influence the LCA.

The pneumatic tire may have several disadvantages: catastrophic damage by flat while driving, requirement of maintenance of air pressure, and complicated manufacturing processes [1].

The non-uniform contact pressure distribution is also one of the disadvantages of pneumatic tire. The high contact stress peaks at the contact edges in the lateral direction due to the interaction of air pressure on the road surface causes a high contact pressure difference between the shoulder and the crown [2-5].

Traction, tire/pavement interaction noise, ride over road irregularities, passengers' comfort, vehicle handling and wear are worst affected by high contact pressure difference between the shoulder and the crown [1].Therefore, contact pressure distribution is an important issue on the tire design. Recently several tire engineers have attempted to develop non-pneumatic tires (NIT) by building polygon typed lattice spokes to replace air of the pneumatic tire [6-9]. Non pneumatic tire has several advantages: low rolling energy loss with a use of low viscoelastic energy loss materials, low mass, and low contact pressure [9]. Considering the NIT structure, the spokes undergo the tension-compression cyclic loading while the tire rolls [10, 11]. Therefore, minimizing the local stress in the spokes is important for fatigue resistant design.In this paper, we suggest lattice spokes of non-pneumatic tire which has honeycomb geometries. The honeycomb with two-dimensional cross section has a high out-of-plane stiffness [12, 13].

The in-plane properties of honeycomb with two-dimensional cross section are two to three orders of magnitude weaker than those of the out-of-plane loading [12]. Therefore, spokes of NITs which made of honeycomb with two-dimensional cross section have high lateral stiffness. In this paper, we suggest tree-dimensional hexagonal cellular spokes of NITs which has an out-of-plane stiffness under targeted load and a lower mass.

In this study, the NITs with two-dimensional hexagonal cellular spokes and tree-dimensional hexagonal cellular spokes are designed to have a load carrying capacity and their contact pressures are analysed as a function of vertical loading. Due to the computational complexity of the hyper elastic material and large deformation induced geometric nonlinearity, a commercial FE code, ABAQUS, is used for numerical computation of contact pressure of NITs. This study investigates a contact pressure of NIT through comparison of FEA result between pneumatic and non-pneumatic tires with two-dimensional lattice spokes and tree-dimensional lattice spokes.

K. TARAKARAM, 1. From the design analysis, it was concluded that the Honeycomb spokes tyre structure was found out to be solid and bears more load comparative to the other structures.

2. Here honeycomb spokes design constitutes low stress values, strains and deformations than other designs because the honeycomb structure offers more space for the same material and closed cellular structural(hexagonal) which can sustain greater amount of force thereby exhibiting more compressive and shear strength.

3. Honeycomb spokes structure shows lower localized stresses and deformation values which is good for a fatigue resistant spoke design and thus the proposed work can bear a greater amount force and at the same time exhibits a comparatively small total deformation.

4.The NPT based on hexagonal honeycomb spokes can be used to replace a conventional pneumatic tyre since they provide uniform traction and wear as that of conventional tyreand it offers good strength, fatigue life (endurance limit), reliability and reduces the overall weight and cost than the conventional pneumatic tyre.

Kwangwon Kim, Seunghye Kim, In this study, we suggested NPTs with 2D and 3D hexagonal honeycomb spokes when NPTs are designed to have the same load carrying capability. And contact pressure and local stress in the spoke cell wall were investigated using the FE analysis. The results were compared with those of each NPTs. Major Findings on the study are as follows:

- The NPTs have nonlinear vertical force-deflection curves which show that the vertical stiffness decreases with load.
- A higher local stress on spoke was obtained with NPTs with 3D honeycomb structures than NPTs with 2D honeycomb structures due to the small cross section area in the lateral direction.
- The NPTs with 2D honeycomb spokes have lower contact pressures than NPTs with 3D honeycomb spokes.
- The NPT with Type D spoke has the biggest contact pressure difference in the lateral direction. However, contact pressure differences of the others are similar.

The NPTs with 3D hexagonal honeycomb spoke have lower mass than NPTs with 2D spoke, when has same load carrying capability. However, a higher contact pressure and locals stress on spoke was obtained with the 3D spoke than with 2D spoke.

A higher contact pressure and local stress concentration should be improved and the other effects such as lateral force and torque should be considered for further design of NPTs.

Nibin Jacob Mathew, From the design analysis it was concluded that the Diamond tyre structure was found out to be solid and bears more load comparative to the other structures. The material changes brought about in the carcass and in the tread has also contributed to the reduction the total deformation. Thus, the proposed work can bear a greater amount force and at the same time exhibits a comparatively small total deformation. These types of tyres can be mainly employed for heavy load vehicles where the load factor is a main concern.

Xiaochao Jin a, Cheng Hou a, the static and dynamic behaviours of non-pneumatic tires (NPTs) with honeycomb spokes were investigated by numerical simulations. The focus is mainly on the stress distribution and rolling resistance of NPTs. Three NPTs with different geometric parameters but same cell wall thickness or load carrying capacity were considered. The conclusions can be summarized as follows:

(1) For three NPTs designed with the same cell wall thickness of honeycomb spokes, the maximum stress in spokes of NPT−C1 with a higher cell expanding angle is the highest, but the load carrying capacity of NPT−A1 with a lower cell expanding angle is the highest.

(2) For three NPTs designed with the same reference load carrying capacity, the mass of spokes of NPT−A2 with a lower cell expanding angle is the lowest, while the load carrying capacity is the highest. The maximum stresses in spokes and tread under dynamic loading are much higher than that under static loading.

(3) The rolling resistance of NPT−A2 with a lower cell expanding angle is the lowest under the same vertical concentrated force, due to the lowest mass and smallest deformation of honeycomb spokes. In addition, the friction coefficient and angular velocity have a negligible effect on the rolling resistance of NPTs.

(4) Taking all the relevant factors into account, the design of NPT−A1(A2) with a cell wall thickness of 2 mm and a cell expanding angle of 15.76° is optimal.

3. METHODOLOGY

Non inflated tires or flat-free tires are tires that are not supported by air pressure. They are used on some small vehicles such as riding lawn mowers and motorized golf carts. They are also used on heavy equipment such as backhoes, which are required to operate on sites such as building demolition, where risk of tire punctures is high. Tires composed of closed-cell polyurethane foam are also made for bicycles and wheelchairs. They are also commonly found on wheelbarrows which may be used for yard work or construction.

3.1 Advantages & Disadvantages

The main advantage of airless tires is that they do not go flat. Other advantages are that airless tires need to be replaced less frequently, resulting in savings. Heavy equipment outfitted with airless tires will be able to carry more weight and engage in more rugged activities. Airless tires generally have higher rolling resistance and provide somewhat less suspension than similarly shaped and sized pneumatic tires. Other problems for airless heavy equipment tires include dissipating the heat buildup that occurs when they are driven. Airless tires are often filled with compressed polymers (plastic) rather than air or can be a solid molded product.

Non inflated tires are attractive to cyclists, as bicycle tires are much more vulnerable to punctures than motor vehicle tires. The drawbacks to airless tires depend on the use. Heavy equipment operators who use machinery with solid tires may complain of fatigue. Bicycle riders who use airless tires may complain that the tire is harder than a comparable pneumatic tire, however, only anecdotal evidence suggests that airless tires may cause broken spokes on a bicycle wheel. Any airless tire will be heavier than the rubber tire it is meant to replace.As of 2021, airless tires are not popular with hardcore off-roaders as those vehicles often need to travel long distances at highway speeds. They are unstable, cause severe vibrations (passenger discomfort) and therefore potential for drivers to lose vehicle control at speeds above 80 km/h.

Installation of airless tires depends on the use. Heavy equipment will need special equipment to mount, but an airless bicycle tire can be mounted with little or no effort. Solid airless lawnmower tires come pre-installed on the wheel, allowing quick installation.

3.2 Examples

Many bicycle-sharing systems use these tires to reduce maintenance.In 2005, Michelin started developing an integrated tire and wheel combination, the "Tweel" (derived from "tire" and "wheel," which, as the name "Tweel" suggests, are combined into one new, fused part), which operates entirely without air. Michelin claims its "Tweel" has load carrying, shock absorbing, and handling characteristics that compare favorably to conventional pneumatic tires. However, the tire has a lot of vibration when driving over 80 km/h (50 mph).

Fig. 3.1 Non inflated tires

Therefore, the tire is only available for golf carts, ATV's and skid steer vehicles. In 2019 however Michelin and GM announced their goal of making a new airless tire for passenger vehicles available in 2024. The automotive engineering group of the mechanical engineering department at Clemson University is developing a low energy loss airless tire with Michelin through the NIST ATP project.Resilient Technologies and the University of Wisconsin–Madison's Polymer Engineering Center are creating a "non-pneumatic tire", which is basically a round polymeric honeycomb wrapped with a thick, black tread. The initial version of the tire is for the Humvee and is expected to be available in 2012. It is also the first group to make a commercially available mass-produced airless tire after its acquisition by Polaris, albeit only as coupled with their vehicle.

3.3 Benefits of Airless Tires For Cars

3.3.1 No Flat Tires – Ever

With airless tires, you never have to worry about your tires leaking because--you knew this was coming--non-pneumatic tires have no air to leak. For most drivers, this feature will sound nothing short of revolutionary. When you run over a sharp object in the road, you won't have to worry about a flat tire because tires without air can't go flat. An end to the days of changing a tire on the highway shoulder would be welcome to drivers everywhere.

3.3.2 You Won't Need a Spare Tire

Since you won't be changing or repairing a flat, you don't need to carry a spare. Just like cars using run-flat tires, this feature could free up trunk space. No spare also means less weight and less weight means better fuel economy.

3.3.3 Vehicle-Heavy Industries Can Save Money

Airless tires also may offer other specific advantages for trucks in industrial application. In the farming, mining, and construction industries, tire failure can cause a loss of productivity and efficiency. Tires that never leak or puncture would be a welcome advancement.

3.3.4 Reduced Co2 Emissions

About 90% of energy loss from tire rolling resistance comes from repeated changes in the shape of the tires as they roll. By simplifying the structure of the tire, Bridgestone was able to minimize the energy loss in these "air free concept tires." As a result, these tires have the same level of low rolling resistance as Bridgestone pneumatic fuel efficient Ecopia tires, contributing to reductions in CO_2 emissions.

3.3.5 ECO-CONSCIOUS

The airless concept tire is one of the initiatives aimed toward Bridgestone's long-term vision of the use of sustainable materials. The materials used in the tire are recyclable, contributing to the efficient use of resources. No part of a non-pneumatic tire ever needs to go in the garbage, which goes together with Bridgestone's effort to create a "cradle-to-cradle" system in which all tires are first recycled and then factory-refashioned into new tires. Airless tires will be among the first for which this process is a reality.

3.6 The Future

Bridgestone is advancing development of the air-free concept tire are a more environmentally friendly product than existing tires and aims to bring about commercial use in a wide range of vehicles as soon as possible.Bridgestone believes that through effective resource usage and efficient operations alongside CO_2 emissions from improved fuel efficiency, as part of its aim to achieve a balance between its business and the environment, it can continue to offer attractive products to its consumers far into the future. Bridgestone will continue to implement multiple technological innovations to help bring about a more sustainable society.

4. INTRODUCTION TO CAD

The modern manufacturing environment can be characterized by the paradigm of deliveringproducts of increasing variety, smaller batches and higher quality in the context of increasingglobal competition. Industries cannot survive worldwide competition unless they introduce newproductswithbetterquality,atlowercostsandwith shorterlead-time.Thereisintenseinternational competition and decreased availability of skilled labor. With dramatic changes incomputingpowerandwideravailabilityofsoftwaret oolsfordesignandproduction,engineersarenowusing ComputerAidedDesign(CAD),ComputerAidedMan ufacturing(CAM)andComputerAided Engineering (CAE) systems to automate their design and production processes. Thesetechnologies are now used every day for sorts of different engineering tasks. Below is a briefdescriptionofhowCAD,CAM,andCAEtechnolo giesarebeing useddduring theproductrealizationprocess.

4.1.1 ProductRealizationProcess

Theproductrealizationprocesscanberoughlydivide dintotwophases:designandmanufacturing.The design process starts with the identification of new customer needs and design variables to beimproved,whichare identifiedby the marketing personnelaftergetting feedbackfromthecustomers.Oncetherelevantdesigninformationisgathered,designspecificationsareformulated.Afeasibilitystudyisconductedwithrelevantdesigninformationanddetaileddesignandanalysesareperformed.Thedetaileddesignincludesdesignconceptualization,prospectiveproductdrawings,sketchesandgeometricmodeling.Analysis includesstressanalysis,interferencechecking, kinematics analysis, mass property calculations and tolerance analysis, and designoptimization. The quality of the results obtained from these activities is directly related to thequalityoftheanalysis and thetools used forconductingtheanalysis.

Themanufacturingprocessstartswiththeshop-flooractivitiesbeginningfromproductionplanning, which uses the design process drawings and ends with the actual product. Processplanningincludesactivitieslikeproductionplanning,materialprocurement,andmachineselection. There are varied tasks like procurement of new tools, NC programming and qualitychecksatvariousstages duringtheproductionprocess.Processplanningincludesplanningforall the processes used in manufacturing the product. Parts that pass the quality control inspectionsareassembled functionallytested,packaged, labeled, andshipped to customers.A diagram representing the Product Realization Process (Mastering CAD/CAM, by Ibrahim Zeid,McGraw Hill, 2005)is shown below.

4.1.2 BriefHistoryofCad/CamDevelopment

The roots of current CAD/CAM technologies go back to the beginning of civilization whenengineersinancientEgyptrecognizedgraphicscommunication.Orthographicprojectionpracticedtoday was invented around the 1800s. The real development of CAD/CAM systems started in the1950s.CAD/CAMwentthroughfourmajorphasesofdevelopmentinthelastcentury.The1950swas known as the era of interactive computer graphics. MIT's Servo Mechanisms Laboratorydemonstratedtheconceptofnumericalcontrol(NC)onathree-axismillingmachine.Developmentinthisera wassloweddownbytheshortcomingsof computersatthetime.Duringthelate1950s thedevelopmentofAutomaticallyProgrammedTools(APT)began,andGeneralMotorsexploredthepotential ofinteractivegraphics.The1960swasthemostcriticalresearchperiodforinteractivecomputergraphics.IvanSutherland developed a sketchpad system, which demonstrated the possibility of creating drawings andaltercationsofobjectsinteractivelyonacathoderaytube(CRT).ThetermCADstartedtoappearwiththeword'design' extendingbeyondbasicdraftingconcepts.GeneralMotorsannouncedtheirDAC-1systemandBellTechnologiesintroducedtheGRAPHIC1remote displaysystem.

During the 1970s, the research efforts of the previous decade in computer graphics had begun tobe fruitful, and the potential of interactive computer graphics in improving productivity was realizedbyindustry,governmentandacademia.The1970sis characterizedasthegoldeneraforcomputerdraftingandthe beginningofadhocinstrumentaldesignapplications.The NationalComputerGraphics Association (NCGA) was formed, and Initial Graphics Exchange Specification (IGES)wasinitiated.In the 1980s, new theories and algorithms evolved, and integration of various elements of designand manufacturing was developed. The major research and development focus was to expandCAD/CAM systems beyond three-dimensional geometric designs and provide more engineeringapplications.

Thepresent-dayCAD/CAMdevelopmentfocuseson efficientandfastintegrationandautomationof various elements of design and manufacturing along with the development of new algorithms.TherearemanycommercialCAD/CAMpackagesavailablefordirectusagethatareuser-friendlyandveryproficient.

4.2 INTRODUCTION OF SOLIDWORKS

SolidWorks is a solid modeling computer-aided design (CAD) and computer-aidedengineering(CAE) computer program that runs on Microsoft Windows. SolidWorks is published by Dassault systems.More than 3,246,750 product designers and engineers worldwide, representing 240,010 organizations, use SOLIDWORKSto b r i n g their designs to life–from the coolest gadgets to innovations that deliver a bettertomorrow. Dassault systems SOLIDWORKS Corp. offers complete 3D software tools that let you create, simulate, publish, and manage your data. SOLIDWORKS products are easy to learn and use and work together to help you design products better, faster, and more cost-effectively. SOLIDWORKS'focus on ease-of-use allowsmore engineers, designers and other technology professionals than ever before to take advantage of 3D inbringing their designs tolife.

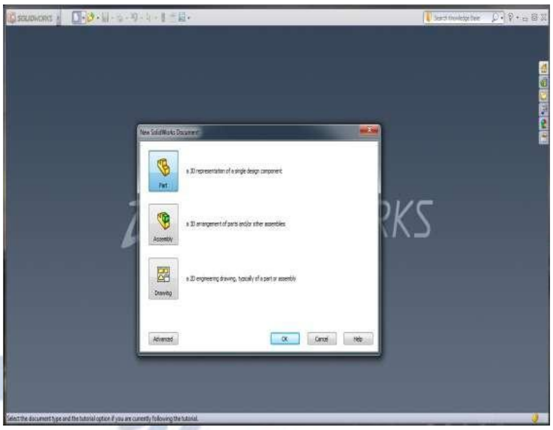
- It is headquartered at Waltham, Massachusetts, USA.
- The latest version of Solidworkswas released on 19thSeptember2016 Solidworks2017.
- SolidWorks partners with third party developers toadd functionality in niche market applications likefinite element analysis, circuit layout, tolerance checking, etc. SolidWorks has also licensed its 3D modelingcapabilities toother CAD software vendors, notablyANVIL.

SolidWorks Corporation was founded in December 1993 by Massachusetts Institute ofTechnology graduate Jon Hirschtick.Hirschtickused $1 million he had made while a member of the MIT Blackjack Team to set up the company. Initially based in Waltham,Massachusetts,United States, Hirschtickrecruited a team of engineers with the goal of building 3D CAD software that was easy-to-use, affordable, and available on the Windows desktop. Operating later fromConcord, Massachusetts, SolidWorks released its first product SolidWorks 95, in November 1995. In 1997 Dassault, best known forits CATIA CAD software, acquired SolidWorks for $310 million in stock.[5]Jon Hirschtickstayed on board for the next 14 years in various roles. Under his leadership, SolidWorks grew to a $100 million revenuecompany. SolidWorks currently markets several versions of the SolidWorks CADsoftware in addition to eDrawings, a collaboration tool, and DraftSight, a 2D CAD product. SolidWorks was headed by John McEleney from 2001 to July 2007 and JeffRay from2007 to January 2011. The current CEO is Gian Paolo Bassi from Jan 2015. Gian Paolo Bassi replaces Bertrand Sicot, who ispromoted VicePresidentSales ofDassault Systèmes' Value Solutions saleschannel.

4.2. The SolidworksModel

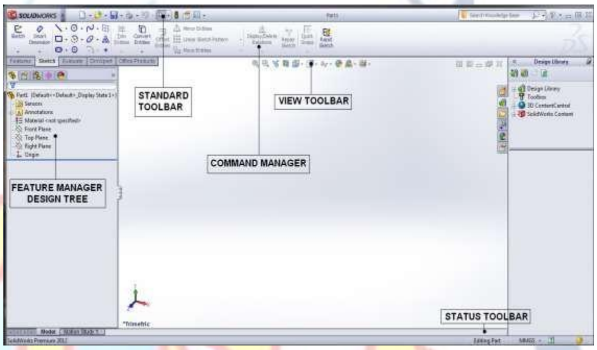
The SolidWorks model is made up of:

- Parts -2D design (Sketch), 3D design (Features) , Part design consider in the part designsection.
- Assemblies - Assembling of two or more than two parts considered in thissection.
- Drawings - Designing with standards is considerin the drawingsection.



4.3Solidworks UserInterface

The interface isnative Windowsinterface, andsuch behavesin the same manner as other Windowsapplications.



4.5 Design of Non-Inflated Tires

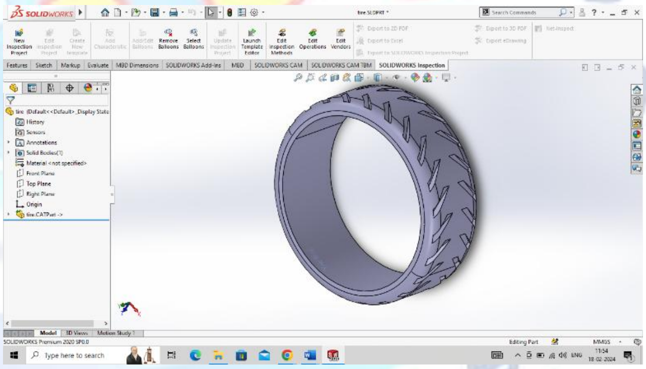


Fig.4.1 tyre

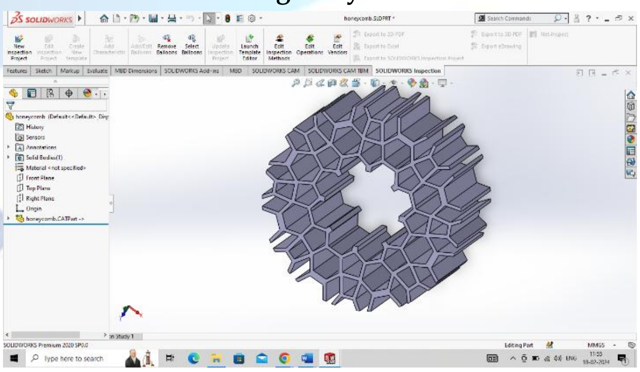


Fig.4.2 honeycomb

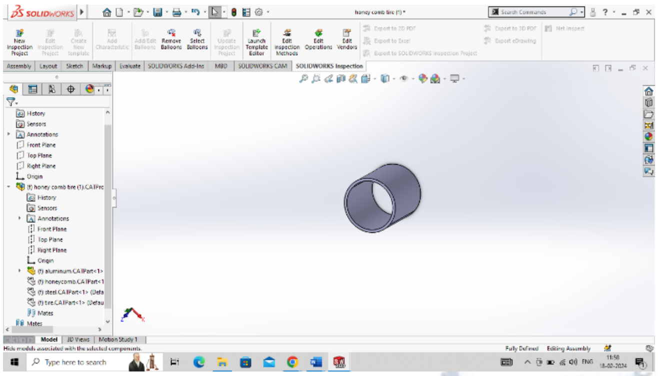


Fig.4.3 Small hollow shaft

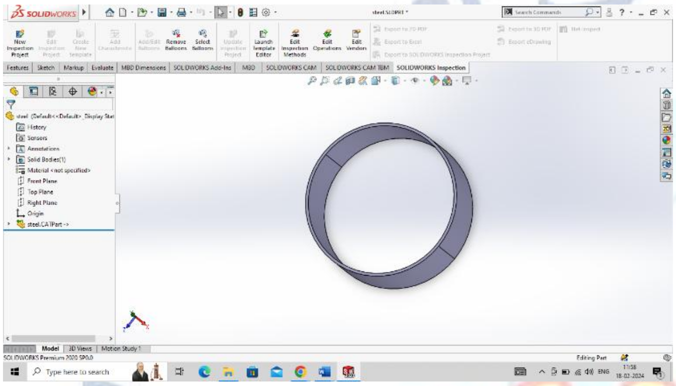


Fig.4.4 Hollow shaft 2

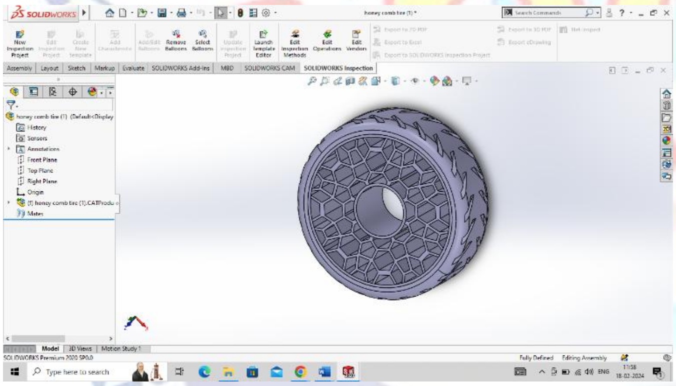


Fig.4.5 non inflated tyres

5. INTRODUCTION TO FEA

Finite Element Analysis (FEA) was first developed in 1943 by R. Courant, who utilized the Ritz method of numerical analysis and minimization of variation calculus to obtain approximate solutions to vibration systems. Shortly thereafter, a paper published in 1956 by M. J. Turner, R. W. Clough, H. C. Martin, and L. J. Topp established a broader definition of numerical analysis. The paper centered on the "stiffness and deflection of complex structures". By the early 70's, FEA was limited to expensive mainframe computers generally owned by the aeronautics, automotive, defense, and nuclear industries. Since the rapid decline in the cost of computers and the phenomenal increase in computing power, FEA has been developed to an incredible precision. Present day supercomputers are now able to produce accurate results for all kinds of parameters.FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. A company can verify a proposed design will be able to perform to the client's specifications prior to manufacturing or construction. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition.In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition.

There are generally two types of analysis that are used in industry: 2-D modeling, and 3-D modeling. While 2-D modeling conserves simplicity and allows the analysis to be run on a relatively normal computer, it tends to yield less accurate results. 3-D modeling, however, produces more accurate results while sacrificing the ability to run on all but the fastest computers effectively. Within each of these modeling schemes, the programmer can insert numerous algorithms (functions) which may make the system behave linearly or non-linearly. Linear systems are far less complex and generally do not consider plastic deformation. Non-linear systems do account for plastic deformation, and many also can test a material all the way to fracture.

FEA uses a complex system of points called nodes which make a grid called a mesh. This mesh is programmed to contain the material and structural properties which define how the structure will react to certain loading conditions. Nodes are assigned at a certain density throughout the material depending on the anticipated stress levels of a particular area. Regions which will receive large amounts of stress usually have a higher node density than those which experience little or no stress. Points of interest may consist of: fracture point of previously tested material, fillets, corners, complex detail, and high stress areas. The mesh acts like a spider web in that from each node, there extends a mesh element to each of the adjacent nodes. This web of vectors is what carries the material properties to the object, creating many elements.

A wide range of objective functions (variables within the system) are available for minimization or maximization:

- Mass, volume, temperature
- Strain energy, stress strain.
- Force, displacement, velocity, acceleration.
- Synthetic (User defined)

There are multiple loading conditions which may be applied to a system. Some examples are shown:

- Point, pressure, thermal, gravity, and centrifugal static loads.
- Thermal loads from solution of heat transfer analysis
- Enforced displacements.
- Heat flux and convection.
- Point, pressure and gravity dynamic loads.

Each FEA program may come with an element library, or one is constructed over time. Some sample elements are:

- Rod elements
- Beam elements.
- Plate/Shell/Composite elements.
- Shear panel.
- Solid elements
- Spring elements.
- Mass elements
- Rigid elements
- Viscous damping elements

Many FEA programs also are equipped with the capability to use multiple materials within the structure such as:

- Isotropic, identical throughout
- Orthotropic, identical at 90 degrees
- General anisotropic, different throughout

5.2 TYPES OF ENGINEERING ANALYSIS

Structural analysis consists of linear and non-linear models. Linear models use simple parameters and assume that the material is not plastically deformed. Non-linear models consist of stressing the material past its elastic capabilities. The stresses in the material then vary with the amount of deformation as in.

Vibrational analysis is used to test a material against random vibrations, shock, and impact. Each of these incidences may act on the natural vibrational frequency of the material which, in turn, may cause resonance and subsequent failure.

Heat Transfer analysis models the conductivity or thermal fluid dynamics of the material or structure. This may consist of a steady-state or transient transfer. Steady-state transfer refers to constant thermo properties in the material that yield linear heat diffusion.

5.3 RESULTS OF NON-INFLATED TYRES

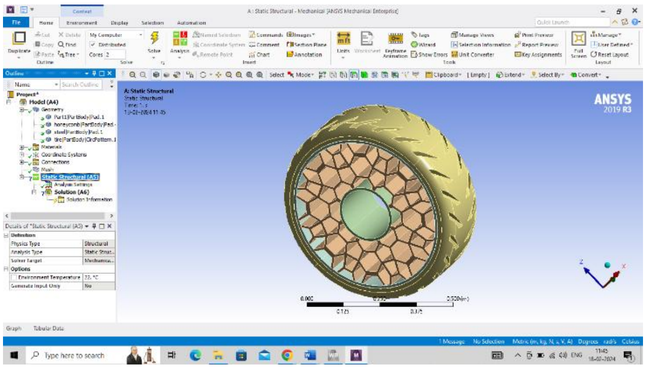


Fig.5.1 Imported file from SolidWorks

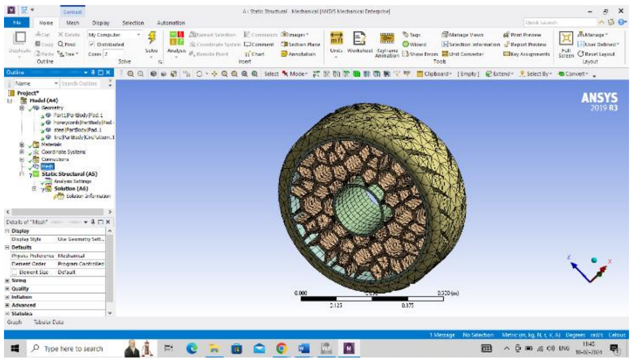


Fig.5.2 Meshed file

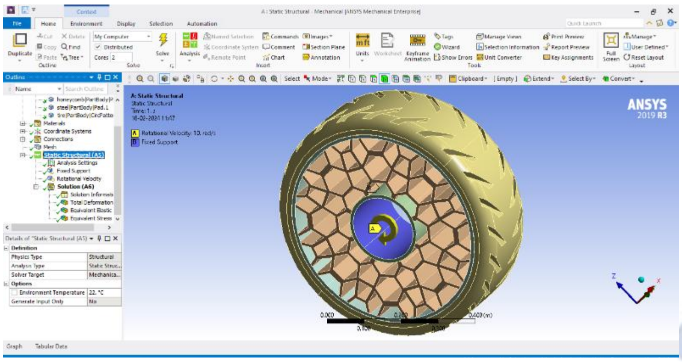


Fig.5.3 Boundary conditions

5.5.1 Materials

5.5.1.1 Structural steel

Structural Steel

Fatigue Data at zero mean stress comes from 1998 ASME BPV Code, Section 8, Div 2, Table 5-110.1

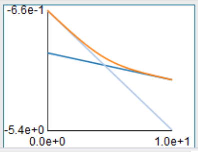
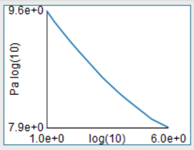
Density	7850 kg/m³
Structural	
Isotropic Elasticity	
Derive from	Young's Modulus and Poisson's Ratio
Young's Modulus	2e+11 Pa
Poisson's Ratio	0.3
Bulk Modulus	1.6667e+11 Pa
Shear Modulus	7.6923e+10 Pa
Isotropic Secant Coefficient of Thermal Expansion	1.2e-05 1/°C
Compressive Ultimate Strength	0 Pa
Compressive Yield Strength	2.5e+08 Pa
Strain-Life Parameters	
S-N Curve	
Tensile Ultimate Strength	4.6e+08 Pa
Tensile Yield Strength	2.5e+08 Pa
Thermal	
Isotropic Thermal Conductivity	60.5 W/m·°C
Specific Heat Constant Pressure	434 J/kg·°C
Electric	
Isotropic Resistivity	1.7e-07 ohm-m
Magnetic	
Isotropic Relative Permeability	10000

Table 5.1 properties of structural steel

5.5.1.3 Polyurethane

polyurethane

Density	1.25e-06 kg/mm³
Structural	
Isotropic Elasticity	
Derive from	Young's Modulus and Poisson's Ratio
Young's Modulus	6 MPa
Poisson's Ratio	0.4
Bulk Modulus	10 MPa
Shear Modulus	2.1429 MPa
Isotropic Secant Coefficient of Thermal Expansion	100 1/°C
Compressive Ultimate Strength	210 MPa
Compressive Yield Strength	131 MPa
Tensile Ultimate Strength	420 MPa
Tensile Yield Strength	300 MPa

Table 5.2 polyurethene mechanical properties

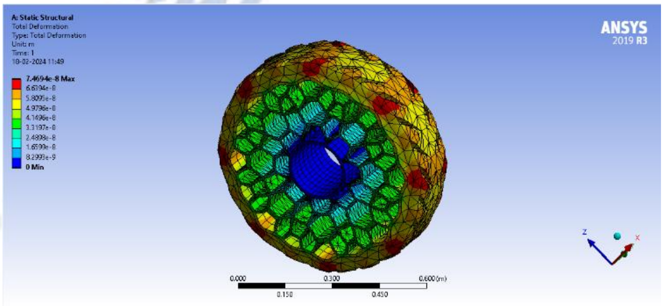


Fig.5.5 Total deformation

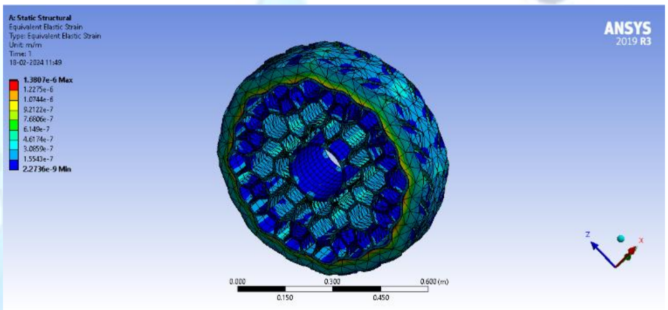


Fig.5.4 Equivalent elastic strain

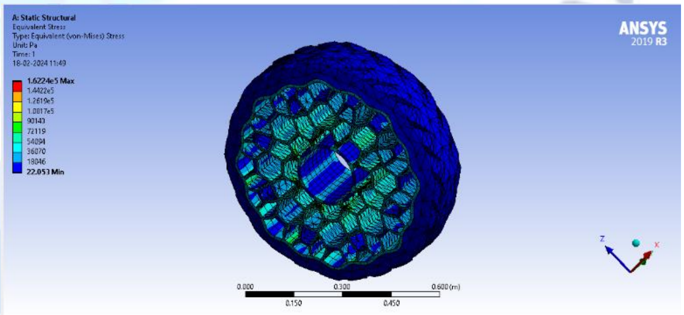
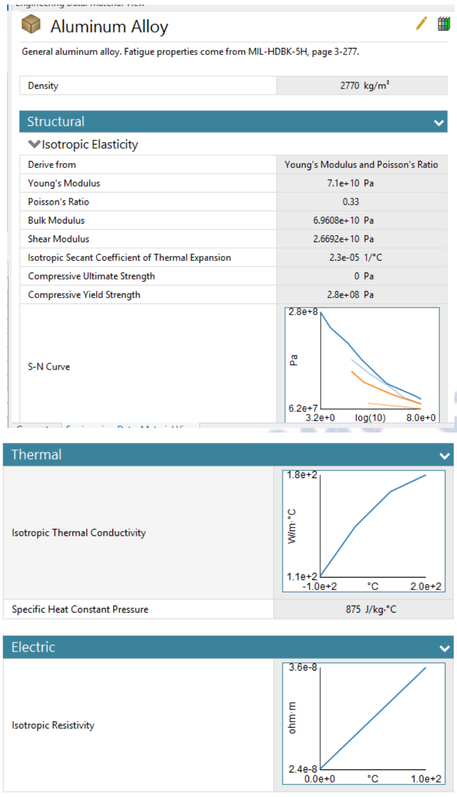


Fig.5.5 Equivalent stress

5.5.1.2 Aluminum alloy



Aluminum Alloy

General aluminum alloy. Fatigue properties come from MIL-HDBK-5H, page 3-277.

Density	2770 kg/m³
Structural	
Isotropic Elasticity	
Derive from	Young's Modulus and Poisson's Ratio
Young's Modulus	7.1e+10 Pa
Poisson's Ratio	0.33
Bulk Modulus	6.9608e+10 Pa
Shear Modulus	2.6692e+10 Pa
Isotropic Secant Coefficient of Thermal Expansion	2.3e-05 1/°C
Compressive Ultimate Strength	0 Pa
Compressive Yield Strength	2.8e+08 Pa
S-N Curve	
Thermal	
Isotropic Thermal Conductivity	
Specific Heat Constant Pressure	875 J/kg·°C
Electric	
Isotropic Resistivity	

Table 5.3 aluminum alloy properties

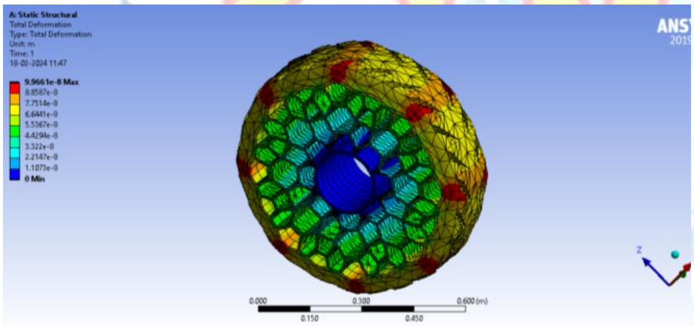


Fig.5.6 Total deformation

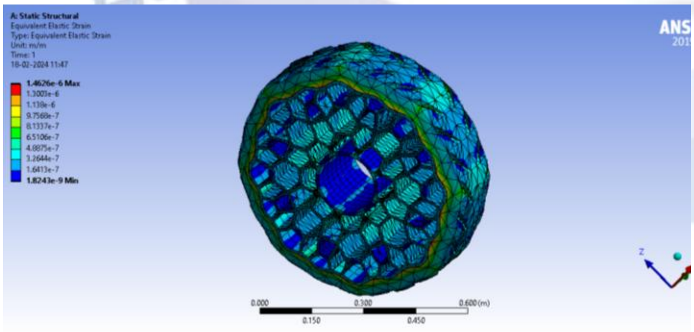


Fig.5.7 Elastic strain

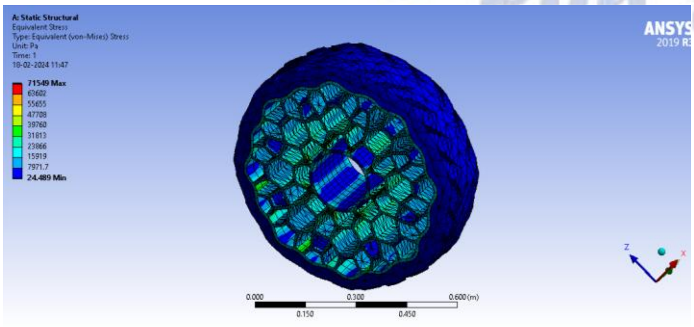


Fig.5.8 Elastic stress

Honeycomb Load: 10 rad/s

Models	Total deformation (m)		Equivalent Stress		Equivalent strain (Pa)	
	Min.	Max.	Min.	Max.	Min.	Max.
Structural Steel	0	2.2109e-004	7.1949e-010	1.029e-006	2.993e-005	7.0361e-002
Aluminum alloy	0	9.9661e-008	1.8243e-009	1.462 6e-006	24.489	71549

Table 5.7 results non inflated tires

6. CONCLUSION

Modeling and analysis of the Non-Pneumatic Tire is done in SolidWorks and imported to Ansys (19.3) for processing work. The amount of load 3000N applied along the circumference of the tire, made up of hub ring with material Aluminum, spokes with material polyurethane, shear band with material synthetic rubber.

- Honeycomb structure designed in SolidWorks.
- Based on comparison of stress, strain, shear stress and total deformation when load of 10rad/sec applied on the structure, the highest values occurred in honeycomb structure at aluminum.
- Honeycomb spoke structure is the most suitable design of spoke structure because of high stress, strain, shear stress and total deformation values.
- By manufacturing with aluminum honeycomb spoke structure, it is a good strength, fatigue life, reliability, reduces the overall weight and cost compared to the other material.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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