Design optimization of Airless Tyre - Numerical Approach

R. Sanjeev kumar1, K.Vetrivel kumar2, Ramakrishnan T3

1Department of Mechanical Engineering, Swarnandhra College of Engineering & Technology, Seetharamapuram, Narsapur – 534280.

2Department of Mechanical Engineering, DhanalakshmiSrinivasan College of Engineering, Coimbatore, Tamil Nadu-641 105.

3Department of Mechanical Engineering, PSNA College of Engineering & Technology, Dindigul-624004.

vetrivelkumark@gmail.com

Abstract. The airless tire is a solitary unit supplanting the pneumatic tire, haggle get together. It replaces all the segments of a normal outspread tire and is included an inflexible center point, associated with a shear band by methods for adaptable, deformable polyurethane spokes and a track band, all working as a solitary unit. An airless tire is a singular unit overriding the pneumatic tire, in getting get together. The problem in the pneumatic tyre is life of the tyre is less, danger of explosion, maintenance cost is high, pressure monitoring is required. It replaces all of the fragments of an ordinary extended tire and is contained an unyielding focus point, related with a shear band by strategies for versatile, deformable polyurethane spokes and a track band, all filling in as a singular unit. In this paper, air less tire model is presented with a substitution of common elastic materials instead of engineered elastic in track and polyester instead of nylon in body. The development and material investigation of different kinds of air less tire is finished by contrasting and pneumatic tire. The design of the Airless tyres structures is done in solidworks. A concise underlying investigation has been done on spokes of airless tire and broke down by ANSYS programming. Investigation has been completed on different structures like Spokes, triangular and custom structure of circular and Hexagon with an applied load of 1000N. Correlation study has been completed among different structures with various materials and it study shows that tire with round structure with engineered materials gives less twisting contrasted with other structure.

Keywords: Tyre structures, Circular, triangle, spokes, hexagon and composite materials.

1. Introduction

The tires which are not upheld by environmental weight are called as Airless tires or Non-pneumatic tires. It is otherwise called Tweel, it is a blended expression of tire and haggle doesn’t have any regular wheel center gathering. Its development might be a strong internal center point connected onto the vehicles shaft that is surrounded by polyurethane spokes. These arrangements like an example of wedge that commitment to absorb the effects of the street. These spokes appearance similar to bikes spokes and assumes the stun retaining function of the compacted gas as in an amazingly antiquated
tire. A sheer band is then stressed over the spokes that arrangements in the environmental factors of the tire.

More flexible spokes end outcome in a greater comfy experience with better handling. The lateral tautness of the Tweel is additionally adjustable. Notwithstanding, you can't alter a Tweel when it has been fabricated. You'll need to pick an unmistakable Tweel. Michelin equipped an Audi A4 with Tweels made with 5 examples as a great deal sidelong solidness as a pneumatic tire, resulting in “very responsive handling”. Michelin reviews that “the Tweel prototype is inside 5 percentage of the rolling resistance and mass stages of contemporary pneumatic tires. That deciphers to recommend inside one level of the mileage” of the tires on your own personal vehicle. Since the Tweel is right off the bat in its turn of events, Michelin should be foreseen to improve these numbers.

These tires usually have greater rolling resistance and grant much less suspension compared with pneumatic tires for in the same way shaped and sized. Different issues for airless tires comprise of scattering the warmth development that happens when they are driven. Airless tires are every now and again loaded up with compacted polymers (plastic), on the other hand than air. Tires are the rolling section of an car which shape the base of the vehicle and makes movement (of automobile) possible. Tires additionally guard the wheel rim by means of becoming around it. Tires supply traction between the car and avenue and additionally take in shock. The historical wheels of Mahabharata period had been made up of wood. To keep away from carrying of wood, iron band used to be constant on the wood frame, presenting it strength as nicely as durability.

1.1 Airless tyre design and material properties:

A fundamental significance in its development is the combination of tire and wheel. It comprises of a metallic center point, polyurethane balances and an external ring as demonstrated in the Figure 1. The plan allows the tire to avoid underneath pressure equivalent to pneumatic tires. For a landscape with intense surface and lopsided path needs such kinds of plan with unnecessary foothold. It's adaptable spokes twists and proceeds as a pad; its property of recovering the structure is normally because of the reality of polyurethane material.

The airless tires guarantees overall performance tiers past these feasible with traditional pneumatic technology because of the reality of its shear band configuration, brought suspension and diminished moving obstruction. It offers pneumatic like burden conveying limit, ride comfort and as it has no pressurized air cavity it can't be penetrated. Airless tires are tantamount to pneumatic tires in that they convey tremendous burdens at gigantic distortions anyway are pretty particular in that they hoist these heaps notwithstanding the addition of expansion pressure. While all pneumatic tires of a given size, expanded to an extraordinary weight, will have practically equivalent vertical solidness and ground contact pressure, an airless tire has it's stiffness and contact stress governed via a host of geometric and material parameters.
2. Literature Review:

Anuj Suhag and Rahul Duyal, Polyurethanes are produced via combination of two or greater liquid streams. The poly movement includes speeding agent, interfacial tension, blowing sellers and so on. The combination may additionally be known as a 'resin'. Amir Gasmi et al, the predominant trouble of design the non-pneumatic tire is that with deformation of the tire in dynamic condition. Balamurugan et al, non- pneumatic and pneumatic tires are carry a massive load with deformation however the distinction is that air much less tire are with absence of contact pressure. Bert Bras and Austin Cobert et al, to design a non-pneumatic tire is the problem of distortion via making use of 3d exhibiting programming. The tire needs to be sufficiently strong to preserve the auto and stand up to a lot of load, and additionally have the ability to distort quite when it interacts with the street. Chu et al, Model the tires via the use of SOLID WORKS, import to ANSYS software. Street and track have been held contact limit and the street used to be held fixed. Vertical stacking on the wheel by means of the utilization of a consistently administered load on to the focal point of edge which acts t edge tire contact locale. Several automobile components like the chassis are normally modeled the usage of the FE/FFR method on the grounds that a little disfigurement supposition can be made. The FE/FFR parts used to be utilized to get some answers concerning the nonlinear elements of a car navigating over an obstruction with the goal of investigating the case disfigurement. The FFR third-dimensional pillar thing was once used to life sized model the body of a hill carriage exposed to outside excitation by means of a half-sine include based absolutely street knock. Cobert in contrast the consequences of the inflexible and bendy chassis models of a precise activity car present process quite number tests. Palinkas and Page researched the effect of the use of many non-modular model-request decrease procedures on the adaptable suspension of a specific dashing vehicle model with one of a kind accentuation on ride attributes.

Periasamy and Vijayan displayed the tire the utilization of the bi direct ANCF shell factor and tried slowing down and cornering circumstances with the tire model. RutikaGotad modeled the tire as a ring-type shape the utilization of planar bended ANCF bar factors and interestingly its vibration modes with scientific and exploratory outcomes. Most tires for vehicles of this conventional nature are expensive and exposed to outrageous wear. By and by these tires are pneumatically swelled which gives to the estimation of assembling as pleasantly as making them trouble to harm. Numerous endeavors stretching out over numerous years have been made to get a financially legitimate tire of this nature. Until this point, despite enormous sources available to tire makers, no fine tire has been delivered. Tires as of now made and utilized when worn past fix are a genuine garbage removal risk. As per this creation there is provided a non-inflatable vehicle tire containing an elastic remains formed to fit and be made sure about to a wheel edge with an assortment of similarly divided entries stretching out transitionally through the cadaver to allow tough supporting ribs between the sections and having a street drawing in track shaped to the body over an of adaptable fortifying.
Further components of this creation accommodate the tire to be made by utilizing forming a gathering of a crude elastic corpse and a fortifying layer and elastic track onto a wheel edge and applying a band of strengthening underneath a group of elastic track material to entire a strong tire, and restoring the elastic underneath warmness and strain to bond the remains and strengthening to the track.

3. Methodology:

The following block diagram shown in Figure 2 which is explained the methodology adopted for the research work.

![Figure 2. Methodology](image)

The material properties of Polyethylene is given in the below table 1.

| Properties            | Polyethylene |
|-----------------------|--------------|
| Young’s modulus (GPa) | 2.7          |
| Poisson’s ratio       | 0.4          |
| Density (kg/m³)       | 1400         |

The process of finite element method is represented in the Figure 2.
4. Modelling

The model was developed exploitation Solid modeling computer code by using SOLID WORKS 2015. Solidworks was the industry’s defacto commonplace 3D mechanical style suit. it had been the world's driving CAM/CAE programming, offers a wide differ of coordinated answers for conceal all parts of item plan and assembling. Strong works gives the needs of minimal medium measured ventures moreover as goliath mechanical organizations inside and out enterprises, customer products, creations and gathering. Electrical and actual science products, car, aviation, development and plant plan, it had been easy to use strong and surface demonstrating might be done without any problem. The ployurethan flexible structure and also the rubber tire. This style was full sketched partly space and it assembled in assemble area. The projected totally different models are conferred within the Figure 3.
5. Numerical Investigation:

Now the analysis is taken by ANSYS WORKBENCH 17.0 and we do different kind of analysis with different kind of models, one of analysis we do in the ANSYS WORKBENCH are similar to standard analysis, something like that total deformation of tyre, Equivalent stress and equivalent strain. Here four kind of models with natural rubber (polyethylene) material are assigned in each and step by step procedure for getting analysis results is given in below figures. The meshed views of different design of tyre are presented in the Figure 4.

\textbf{Figure 3} Different proposed models
6. Boundary Conditions

Air-less tire incorporates layers of the inward band, external band to make a composite structure. Steel rings are likewise utilized as strengthening factors in Air-less tire. Tires ordinarily face the significant thing inconveniences of disappointment approach to warm development and driving solace. In order to improve style of Air-less tire, it is fundamental to be equipped to are anticipating the mechanical direct of the tire underneath actualized load. Conjointly anxiety energy dissemination progressed should be dissected. The approval of metallic component forecast contrary to air tire results got attempted.

The sharing of strain energy and deflection below loading was conjointly distributed discrimination metallic element analysis. The uniformly distributed edge load at the tire-rim contact
region while vertical loading on the wheel. The all tire half square measure pound by discrimination the solid tetrahedral elements. The properties square measure E=27 Gpa, density=1400 kg/m3. Same material properties and also the wheel load of 1000 N is applied for each bands. The same boundary conditions are applied to all different models and it is in Figure 5.

7. Load deflection & analysis:

Road and tread were order contact specification not affixed. The avoidance is inside the stacking course of the wheel community and the removal inside the parallel bearing. The results of numerical analysis are in table 2 and comparison charts are illustrated in Figure 6 to Figure 8.

| S.no | Design   | Maximum Total | Equivalent | Equivalent |
|------|----------|---------------|------------|------------|
| 1    | Spokes   | 0.010543      | 10.028     | 5.2024e-5  |
| 2    | Triangular| 0.019843      | 24.158     | 0.00014651 |
| 3    | Circular | 0.0067021     | 11.343     | 9.794e-5   |
| 4    | Hexagon  | 0.0082758     | 10.085     | 3.9268e-5  |

![Max. Total Deformation (mm)](image)

**Figure 6** Comparisson chart of Max. Total Deformation
Conclusion

Tires could appear to be a trifling piece of a vehicle that can't be improved; in any case, examination into airless tires shows in any case. This new innovation will expand the security of vehicles similarly as have a positive effect naturally. Since these tires additionally are fit to be retreaded, there's the possibility of a more modest worth for each tire that is typically grasped by the buyer. This inventive undertaking is moreover supported and guided by designing codes of morals which can ensure that the occasion is led during a methodology that is responsible and reasonable. By our analysis, over four design models of the unaired tyre, named Spokes, Triangular, Circular, and polygon styles. The circular will be given minimum deflection, wherever applying the load. Therefore we advise the tyre with a Circular structure will be best from our analysis.

References:

[1] Anuj Suhag, Rahul Dayal. Static Analysis on Custom Polyurethane Spokes of Airless Tire. Volume 3, International Journal of Scientific and Research Publications, Issue 11, November 2013.
[2] Amir Gasmi, Paul F. Joseph. - Development of a two-dimensional model of a compliant non-pneumatic tire. International Journal of Solids and Structures, March 2012
[3] Balamurugan, S, Manibaalan, C, Keshore, Dr. Joshi. C. Haran. Static analysis of airless Tyres. Volume 3, International Journal of Scientific and Research Publications, Issue 8, August 2013.
[4] Bert Bras and Austin Cobert-Life-Cycle Environmental Impact of Michelin Tweel Tire for Passenger Vehicles. SAE International. Published, Issue 4, December 2011.
[5] Chih-Hsing Chu, Mu-Chi Song, Vincent C.S. Luo, ‘Computer aided parametric design for 3d tire mold production’ Journal of ELSEIER, February 2005.
[6] Cobert, A., Environmental Comparison of Michelin Tweel and Pneumatic Tire Using Life Cycle Analysis, in Mechanical Engineering. 2009, Georgia Institute of Technology: Atlanta. p. 193.
[7] Palinkas RL, Page GJ. Non-pneumatic tire with supporting and cushioning members.
[8] Periasamy, K, S.Vijayan-Design and development of air-less car tire. J.J College of Engineering & Technology, Trichy – 09. Tamil Nadu, India. International Journal of Advances in Engineering & Technology, September 2014.
[9] Rutika Gotad, Sukanya Yadav, Aarti Dung. - Tweel Tyre Technology, International Journal of Advance Foundation and Research in Science & Engineering, 2015.
[10] Zeev Bareket Paul Fancher. Representation of truck tire properties in braking and handling studies: The influence of pavement and tire conditions on frictional characteristics, December 1989.
[11] Nibin Jacob Mathew, Dillip Kumar Sahoo, E.Mithun Chakravarth, Design and static analysis of airless tyre to reduce deformation, IOP Conf. Series: Materials Science and Engineering 197 (2017) 012042.