International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 05 | May - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

MODELLING AND 3D PRINTING OF TRACTOR TYRE

P. Varalakshmi[1], Chavan Ravi Nayak[2], Banavath Srinu[3], Vishesh agarwal[4], kashamoni Abhishek[5]

[1] Assistant Professor, Dept. Of Mechanical Engineering, Gurunanak Institute Of Technology, Khanapur, India.
[2,3,4,5] UG Scholars, Dept. Of Mechanical Engineering, Gurunanak Institute Of Technology, Khanapur, India.

---***---

Abstract -3D printing could revolutionize tractor tires. It allows for customization, optimized designs, and advanced materials. The paper explores design software, material selection, and new printing techniques like multi-material for improved tires. Challenges include production scale, machinery compatibility, and post-processing optimization. Overall, 3D printing holds promise for better tractor tires and a more sustainable agricultural sector.

- ***Key Words*:** Revolutionize, Customization, Postprocessing.

1. INTRODUCTION

1.1 Introduction to Modelling and Analysis of Tractor Tyre:

A driving wheel is a part of a tractor, which transmits forces from a tyre to the ground. Therefore, it affects the tractor movement and the pulling of an implement. The paper is aimed at a tractive performance evaluation of special driving wheels based on drawbar pull at 100%-slip. These wheels consist of steel spikes to be applied in the base or working position. The design is characterized by the spikes placed in a tyre-tread pattern. The rubber lugs of the tyre are higher than spikes, therefore, they are not in contact with the ground in the base position. The spikes in the working position exceed the tyre diameter to be in contact with the ground.Tests were performed on a grass plot at a relatively low soil moisture. The spike tyres were compared with the standard tyres using a sub-compact tractor. An increase in drawbar pull reached a statistically significant value of 15.9% in the 2nd gear and 16.7%in the 1stgear.The driving wheel is the only part of a vehicle which interacts with the ground.Force interactions affect the tractive efficiency and effectivity of machine operation. Besides fuel consumption, exhaust gases are produced in higher measure in case of a low tractive efficiency of agricultural machinery. The properties of standard tyres can be improved in various ways. There are, for example, snow chains which improve the tractive properties of tyres on snow. In certain countries, it is allowed using studded tyres. As mentioned above, the improvement of tyre traction properties is often based on the combination of rubber tyre-tread pattern with steel components. Drawbar pull, travel reduction (slip) and rolling resistance are the main criteria to describe the traction behaviour of tractors. Besides engine performance, drawbar pull is influenced by the traction conditions, such as soil and tyre parameters (Schreiber and Kutzbach, 2008). Tyre diameter and width are the basic parameters significantly affecting the driving wheels performance. Variable inflation pressure is also used to modify the tyre contact patch to better transmit the forces from a tyre to the ground. Finally,the selection of a modern tyre-tread pattern type and tyre construction is very important to achieve the effective tractor operation (Freitag, 1965). There are two essential ways how to reduce the slip of tractors. The first one lies in increasing the tractor weight by adding ballast. The other possibility is to enlarge the contact area between the tyres and surface (Šmerda and Čupera, 2010). Tractors often use tracks to improve the tractive performance. Steel and rubber are the two kinds of materials which are often used for tracks. Tractor tracks are mainly used to increase the drawbar pull and eliminate the slippage during the operation under worse tractive conditions due to higher soil moisture content. Semetko, Janoško and Pernis (2002); Semetko, Janoško and Pernis (2004) and Molari et al. (2020) researched the drawbar properties of four-wheel drive, four-wheel drive ballasted, half-tracked and fully tracked tractors. Their results showed a better tractive efficiency for the solution with four rubber tracks with respect to the other axles. Ge, Wang and Kito (2016) studied the tractive performances of steel and rubber grouser shoes under different soil moisture contents. Based on experimental results, they concluded that the steel single grouser shoe performed better than the rubber single grouser shoe in traction for the soil used in this study. The increase in tractor load is the measure often used to improve the tractive efficiency because it increases the net traction ratio. On the other hand, the high weight of tractors negatively affects soil compaction after field traffic (Forster et al., 2020; Maly and Kučera, 2014; Maly et al., 2015). As mentioned above, employment of a special wheel using various steel elements represents a way of improving the interactions of forces with the ground. This paper presents an original design of spike tyres for tractors to be operated without the additional ballast weight. Tractors frequently work at optimal wheel slip, however, operation at the maximum wheel slip cannot be expected. Using the special driving wheels, tractor movement can be provided in this situation. The study objectives were to experimentally test and compare the spike tyres to the standard tyres at 100%-wheel slip.

Mounting apparatus fabricated for the study of tractor tyre:

A mounting apparatus fabricated for the study of tractor tires is a device that holds a tractor tire in place so that it can be studied under controlled conditions. These apparatuses can be used to study a variety of factors, such as the tire's performance, wear, and grip.

There are many different designs for tractor tire mounting apparatuses, but they all share some common features. Typically, they consist of a frame that supports the tire, a mechanism for applying a load to the tire, and a system for measuring the tire's response to the load.

1.2 History of Modelling and 3D Printing of Tractor Tyre Early Tractor:

Known as 'the Fens', the north eastern area around the Isle of Ely in Cambridgeshire is known for its rich soil. It's long been an important agricultural centre and is particularly good at growing potatoes and vegetables. It was also home for generations of the Aveling family, including young Tom Aveling, better known as the father of traction-engines. Back in 1856, Thomas produced the first steam plough. He would go on to hold 8 patents, although most were for his later work in the development of steam rollers.

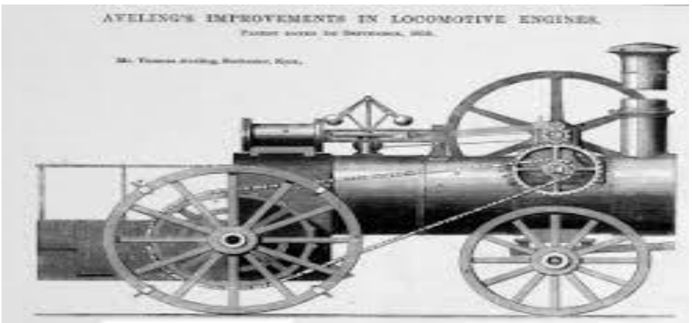

Fig 1.2 Evaluation of tractor tyre

Whilst the concert of using steam power to help move machinery on farms was started with the work by Aveling, it wasn't until 1892 that the world was to be introduced to something resembling something we might more readily recognise as a tractor. American John Froelich had a small business threshing crops for farmers throughout Iowa and the Dakotas. It was tedious, slow work with the constant risk of a spark from the steam powered machine could ignite the entire crop. John figured he might have the answer though, and proceeded to mount a gasoline engine onto the steam engine's running gear. It worked and his new tractor happily chugged along at 3mph. The invention led to the Waterloo Gasoline Traction Engine Company. It was the first successful tractor company and made machines until 1918. Then it was bought by a plow manufacturer looking at getting into tractors. That company? John Deere.

Steel wheels & lugs

Those early machines were no doubt beneficial to speeding up things in the agricultural world. The arid, relatively land of the midwest was no issue for their steel wheel. Elsewhere the land was softer though. The steel wheels would lack traction, wasting energy from the small horsepower engines. For a time, the answer was to use steel lugs. One of the largest lines in lugs was being offered by Australian company, Ronaldson-Tippett. By the 1920's they had adapted several American tractors and were set to become the largest manufacturer of tractors in Australia. These huge lugs more closely resembled spikes and came in multiple configurations, some providing over 11cm of ground penetration.

The steel lugs proved to be a double-edged sword. They were good in the field for traction but did little to solve issues of soil compaction. That significant weight, when driven onto the fledgling road systems being developed in many countries, would crack and damage the roads. So much so, the lugs either had to be removed before travelling on them or covered with steel protection (no doubt adding more weight). At worst, it simply didn't prevent some road damage. At best, it was time-consuming and annoying.

Fig : 1.3 First rubber tractor tyre

Tractor tyres today:

The promises made of those early pneumatic tyres carry across to today's IF and VF agricultural tyres. They improve traction, allow more ground to be covered in a day and mean less fuel is required. They also tread lighter, leading to reduced soil compaction. You can only imagine how happy this will make a Floridian orange grower.

Fig : Fig 1.4 Modern tractor tyre

1.3 Software Required

Solidworks is a powerful option for modeling tractor tires specifically for 3D printing due to its strengths in several areas:

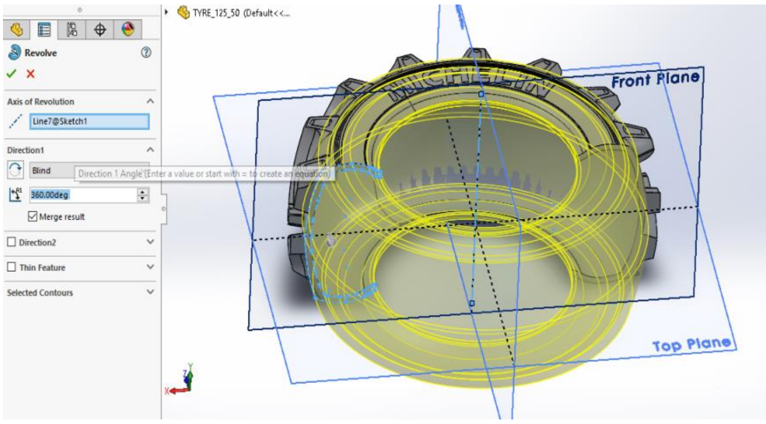

Fig :1.5 Sample design of tractor tire in solid works

Parametric Modeling: Solidworks excels at parametric modeling, which allows you to create the tire model with dimensions and relationships that can be easily adjusted. This is crucial for designing a tire that fits specific requirements and can be scaled for different sizes.

Feature Recognition: Solidworks can recognize standard features like holes, ribs, and threads, which can save you time and effort when modeling the complex tread pattern of a tractor tire.

Design for Additive Manufacturing (DFAM): Solidworks offers tools to help you analyze your model for 3D printing. This includes features to identify areas that may require support structures to prevent sagging during printing, and to optimize the infill density for strength and material usage.

3D Printing Export: Solidworks allows you to export your model in various 3D printing file formats, including STL, 3MF, and AMF. These formats are compatible with most 3D slicer software for preparing the model for printing.

1.4 Objectives

The objectives of modeling and 3D printing tractor tires can include:

Customization: Designing tires tailored to specific terrains, weather conditions, or operational requirements can optimize tractor performance.

Cost Reduction: Developing a cost-effective alternative to traditional manufacturing methods by utilizing 3D printing technology, which can potentially reduce production expenses.

Prototype Development: Creating prototypes quickly and efficiently allows for testing different designs and materials, accelerating the innovation cycle.

Material Exploration: Experimenting with various materials and compositions to enhance tire durability, traction, and resilience against wear and tear.

Complex Geometries: Utilizing 3D printing enables the fabrication of intricate tire tread patterns and structures that may be challenging or impossible to achieve with conventional manufacturing methods.

Supply Chain Optimization: Localized 3D printing of tires could reduce lead times and logistics costs associated with traditional manufacturing processes, especially in remote or underserved areas.

Environmental Sustainability: Exploring eco-friendly materials and manufacturing techniques to reduce the environmental impact of tire production and disposal.

Education and Research: Facilitating learning opportunities for students and researchers in the fields of materials science, mechanical engineering, and additive manufacturing through hands-on experimentation with tire design and production.

Overall, modeling and 3D printing of tractor tires offer a pathway to innovation, customization, and efficiency in the agricultural sector.

1.5 procedure

Certainly! Here's a step-by-step procedure for modeling and 3D printing a tractor tire:

Requirement Analysis:

Determine the specific requirements of the tractor tire, including size, tread pattern, load-bearing capacity, and intended terrain.

Consider factors such as weather conditions, temperature range, and the type of farming operations the tractor will perform.

Conceptual Design:

Sketch out initial concepts for the tire design, considering both functional requirements and aesthetic preferences.

Use CAD (Computer-Aided Design) software to create digital 3D models based on the conceptual sketches.

Detailed Design:

Refine the 3D model to incorporate specific features such as tread patterns, sidewall designs, and structural reinforcements.

Optimize the design for 3D printing, considering factors like overhangs, support structures, and printing orientation.

Material Selection:

Choose a suitable material for 3D printing the tire, considering factors such as durability, flexibility, and compatibility with the printing process.

Explore options for eco-friendly or recyclable materials to align with sustainability goals.

Simulation and Analysis:

Conduct virtual simulations to evaluate the performance of the tire design under various operating conditions.

Analyze factors such as stress distribution, deformation behavior, and traction characteristics to ensure the tire meets safety and performance standards.

Prototyping:

Produce physical prototypes of the tire using 3D printing technology.

Validate the prototypes through physical testing, including load testing, durability testing, and traction testing.

Iterative Refinement:

Gather feedback from prototype testing and iterate on the design as necessary to address any issues or improve performance.

Make adjustments to the 3D model based on test results and stakeholder input.

Finalization:

Finalize the design of the tractor tire based on the results of testing and refinement.

Prepare the 3D model for production by optimizing it for 3D printing, ensuring that it meets any specific requirements of the printing process.

Printing:

Set up the 3D printer according to the specifications of the chosen material and printing process.

Initiate the printing process and monitor the progress to ensure quality and accuracy.

Post-Processing:

Remove any support structures or excess material from the printed tire.

Perform any necessary finishing operations, such as smoothing or painting, to enhance the appearance and performance of the tire.

Quality Assurance:

Inspect the printed tire for any defects or imperfections.

Conduct additional testing, if necessary, to verify that the printed tire meets all requirements and specifications.

Deployment:

Install the 3D printed tire on the tractor and conduct field testing to evaluate its performance in real-world conditions.

Gather feedback from users and stakeholders to inform future iterations of the design and production process.

By following this procedure, we can effectively model and 3D print tractor tires that meet the specific needs of agricultural operations while leveraging the advantages of additive manufacturing technology.

1.6 Focus and Applications

Focus: The focus of modeling and 3D printing of tractor tires lies in innovating agricultural equipment components to enhance efficiency, sustainability, and performance in farming operations. This approach integrates advanced design techniques with additive manufacturing technologies to create customized tire solutions tailored to specific agricultural needs.

Application:

Customization for Varied Terrain:

Farmers often encounter diverse terrains, from soft soil to rocky surfaces. 3D printing allows for the creation of tractor tires with customized tread patterns and compositions optimized for different terrains, ensuring optimal traction and maneuverability.

Precision Agriculture:

Tractor tires designed through modeling and 3D printing can contribute to precision agriculture by enabling precise control over soil compaction. By adjusting tire design parameters such as tread depth and width, farmers can minimize soil disturbance and compaction, leading to improved crop yields and soil health.

Climate Adaptation:

With climate change affecting weather patterns and agricultural practices, there is a growing need for tires that can withstand extreme conditions such as heat, cold, and moisture. Modeling and 3D printing allow for the development of resilient tire materials that can adapt to changing climate conditions, ensuring consistent performance and durability.

Resource Efficiency:

By customizing tire designs to match specific farm equipment and operational requirements, farmers can optimize fuel efficiency and reduce energy consumption during agricultural activities. Lightweight yet durable 3D printed tires can contribute to overall resource efficiency in farm operations.

Retrofitting and Maintenance:

3D printing enables on-demand production of tractor tire components, facilitating rapid prototyping, customization, and replacement of worn-out parts. Farmers can easily retrofit existing equipment with 3D printed tires or quickly replace damaged tires, minimizing downtime and maintenance costs.

Sustainable Farming Practices:

Sustainable agriculture requires minimizing environmental impact while maintaining productivity. 3D printing offers opportunities to produce tractor tires using eco-friendly materials and manufacturing processes, reducing carbon footprint and waste generation associated with traditional tire production methods.

Education and Training:

Modeling and 3D printing of tractor tires can serve as educational tools in agricultural training programs and workshops. Students and professionals can learn about tire design principles, additive manufacturing techniques, and the integration of technology into farming practices, fostering innovation and knowledge exchange in the agricultural sector.

By focusing on these applications, modeling and 3D printing of tractor tires can revolutionize agricultural equipment design, contributing to increased productivity, sustainability, and resilience in modern farming practices.

2. METHODOLOGY

1.Define your project

2. Software selection

3. Modelling the Tractor Tyre

4. Model preparation for printing

5. 3D printing

6. Post processing

7. Evaluation and Iteration

EXPLANATION :

Modeling of Tractor Tyre:

Initial Design: The process typically begins with conceptualizing the design of the tractor tire. Engineers and designers use Computer-Aided Design (CAD) software to create a detailed 3D model. This model includes specifications such as tire dimensions, tread patterns, sidewall designs, and any other desired features.

Iterative Design: Once the initial design is created, it undergoes iterative refinement. This involves analyzing factors such as load-bearing capacity, traction, wear resistance, and overall performance. Engineers may tweak the design based on simulation results and feedback from testing to optimize the tire's performance and durability.

Material Selection: After finalizing the design, the appropriate material for 3D printing the tire is selected. Factors such as strength, flexibility, durability, and temperature resistance are taken into consideration. Common materials for 3D printing tires include thermoplastic elastomers (TPE), thermoplastic polyurethane (TPU), and rubber-like filaments.

Model Preparation: The finalized 3D model is prepared for the 3D printing process. This may involve tasks such as adding support structures to prevent deformation during printing, optimizing the orientation of the tire to minimize printing errors, and ensuring that the model is watertight and free of any geometric issues.

3D Printing of Tractor Tyre:

Preparation of 3D Printer: The selected 3D printer is set up and calibrated according to the specifications of the chosen material and the tire design. This includes loading the printing filament and ensuring that the print bed is level and properly heated.

Printing Process: The prepared 3D model of the tractor tire is sent to the 3D printer for fabrication. The printer creates the tire layer by layer, following the instructions from the CAD model. Depending on the size and complexity of the tire, the printing process can take several hours to complete.

Post-Processing: Once the printing is finished, the 3D printed tire undergoes post-processing to improve its surface finish and mechanical properties. This may involve removing support structures, sanding or smoothing any rough surfaces, and inspecting the tire for any defects.

Testing and Evaluation: The 3D printed tractor tire is subjected to rigorous testing to ensure that it meets the necessary performance standards. This includes tests for load-bearing capacity, traction, wear resistance, and durability under various operating conditions.

PROBLEM STATEMENT:

- Current methods for prototyping new tractor tire designs, such as machining or mold making, are often slow, expensive, and limit the ability to iterate on designs quickly. This hinders the development of innovative tread patterns that could improve performance and efficiency in the agricultural industry.
- 3D printing offers a potential solution by enabling rapid and cost-effective prototyping of tractor tires. However, challenges exist in accurately modelling complex tread patterns and finding 3D printing materials strong and flexible enough to handle the demands of real-world farm use.

- This project aims to develop a methodology for modelling and 3D printing tractor tires that overcomes these challenges. By creating a streamlined process for prototyping and optimizing designs, this project can accelerate innovation in the tractor tire industry, leading to improved performance, reduced costs, and faster development cycles.
- Training on tractor tire anatomy and function can be limited by the availability of physical models. Additionally, research on new materials, manufacturing techniques, and tread designs can be hindered by the time and cost associated with traditional prototyping methods.
- 3D printing offers a unique opportunity to address these limitations. By creating functional 3D printed tractor tire models, this project can provide valuable educational tools for students and professionals. Additionally, researchers can leverage 3D printing to rapidly prototype and test new tire designs and materials in a controlled environment.
- However, challenges exist in ensuring the 3D printed models accurately represent the properties of real tractor tires. Material selection and printing parameters need to be optimized to create models suitable for research and educational purposes.
- This project aims to develop a methodology for modelling and 3D printing tractor tires specifically for educational and research applications. By creating accurate and cost-effective models, this project can enhance training, accelerate research in the field of tractor tire technology, and ultimately contribute to the development of next-generation tires for the agricultural industry.

3. RESULT AND DISCUSSION

Final modelling of Tractor Tyre

Fig 3.1 Modelling of Tractor tyre

3.1.1 Modeling of Tractor Tire:

The modeling phase involved the creation of a digital representation of the tractor tire using Computer-Aided Design (CAD) software. Key parameters such as tire dimensions, tread pattern, and structural integrity were meticulously defined during this stage. Finite Element Analysis (FEA) simulations were employed to ensure the proposed design could withstand various loads and operating conditions typical in agricultural settings.

3.1.2 3D Printing Process:

Utilizing advanced additive manufacturing techniques, the modeled tractor tire was translated into a physical object through 3D printing. The process involved layer-by-layer deposition of thermoplastic elastomers or similar materials to accurately replicate the intricate geometry and features of the digital model. Various printing parameters such as layer height, infill density, and printing speed were optimized to achieve the desired mechanical properties and surface finish

3.1.3 Discussion:

- The successful modeling and 3D printing of the tractor tire demonstrate the potential of additive manufacturing technology to revolutionize the production of agricultural equipment components. By leveraging CAD software and advanced materials, intricate geometries and customized designs can be realized with unparalleled precision and efficiency. The ability to rapidly prototype and iterate designs allows for faster development cycles and optimization of performance characteristics.
- Moreover, 3D printing offers significant advantages in terms of material utilization and waste reduction compared to traditional manufacturing methods such as injection molding or vulcanization. This not only contributes to cost savings but also aligns with sustainability goals by minimizing environmental impact.

However, challenges such as material selection, process optimization, and post-processing requirements remain areas of ongoing research and development. Further advancements in additive manufacturing technologies and materials science are necessary to fully unlock the potential of 3D printing in the production of durable and reliable tractor tires.

4.FUTURE SCOPE

The future scope of designing and analyzing tractor tires encompasses several key areas poised for advancement. Firstly, the integration of advanced materials, such as nanocomposites and innovative rubber compounds, will enhance tire durability, traction, and efficiency. Additionally, the use of predictive analytics and simulation software will allow for more accurate modeling of tire performance under various operating conditions, leading to optimized designs for specific applications.Furthermore, there's potential for the development of smart tires equipped with sensors to monitor tire wear, temperature, and pressure in real-time, enabling proactive maintenance and improved safety. The incorporation of sustainable materials and manufacturing processes will also be a significant focus, aligning with global efforts towards environmental sustainability.Moreover, advancements in tire technology will likely cater to emerging trends in agriculture, such as precision farming and autonomous machinery, requiring tires that can adapt to changing terrain and operating conditions seamlessly. Collaborations between tire manufacturers, research institutions, and agricultural stakeholders will drive innovation in this field, ensuring that future tractor tires meet the evolving demands of modern farming practices while prioritizing efficiency, sustainability, and performance.

4. CONCLUSION

Tractor tractive performance affects the effective usage of engine power by an efficiency of force transmission between the driving wheels and ground. The paper presents the design, practical application, and tests of special driving wheels using spikes to improve the tractor tractive performance. The spike tyres can be used not only under agricultural conditions but can also improve the energy efficiency of all tractors, various off-road vehicles, planetary rovers, or wheeled robots under various difficulttractive conditions. The main benefits of the spike tyres are as follows: – Drawbar pulls measured in the vehicle with the spike tyres reached higher values than with the standard tyres. The statistically significant increase in drawbar pull was calculated to express the improvement of tractor tractive performance using the spike tyres. – The low weight of the spike system eliminates soil compaction in case of agricultural application. A compact design can be utilized for various mobile robots if wheel size is limited. The next research will be aimed at the improvement of drawbar properties of the spike tyres, as the potential of this design has not been fully utilized. Therefore, the influence of spike modifications on vehicle drawbar performance and an automatic control of spikes without the need of a manpower will be further studied. In conclusion, the process of solid modeling and analysis for a tractor tire is essential for ensuring optimal performance, safety, and longevity. Through meticulous design and simulation, engineers can assess various factors such as material properties, stress distribution, and load-bearing capacity.Solid modeling enables the creation of an accurate digital representation of the tire, allowing for thorough examination of its geometry and structure. This step lays the foundation for subsequent analysis.Analysis plays a crucial role in evaluating the tire's behavior under different operating conditions. Finite element analysis (FEA) helps identify potential weaknesses, areas of high stress concentration, and opportunities for improvement. By subjecting the model to simulated loads and environmental conditions, engineers can refine the design to enhance durability and performance while minimizing the risk of failure.Furthermore, the insights gained from analysis can inform decisions regarding material selection, tread pattern design, and overall tire geometry. This iterative process allows for the optimization of performance metrics such as traction, fuel efficiency, and wearliiresistance.In summary, solid modeling and analysis are indispensable tools in the development of tractor tires, enabling engineers to create products that meet the demands of modern agricultural applications with efficiency, reliability, and safety. The solid modeling and analysis of a tractor tire involves several critical steps and considerations. First, the tire's geometry must be accurately represented using CAD software, considering factors such as tread pattern, sidewall design, and overall dimensions. Then, finite element analysis (FEA) can be employed to simulate the tire's performance under various loads and conditions, including traction, compression, and deformation.During the analysis phase, factors such as material properties, operating conditions, and environmental factors must be taken into account to ensure accurate results. Additionally, the tire's interaction with the terrain, such as soil, gravel, or pavement,should be simulated to evaluate its overall effectiveness and durability.The conclusion of such a study would summarize the findings of the analysis, including insights into the tire's structural integrity, performance characteristics, and potential areas for improvement. It may also include recommendations for design modifications or material changes to optimize the tire's performance and longevity in real-world applications. Ultimately, solid modeling and analysis provide invaluable insights into the behavior and performance of tractor tires, aiding in their continual improvement and optimization for various agricultural tasks.

6. REFERENCES

[1] The first attempt to study three areas where tractor performance and fuel efficiency can often be improved was carried out by Mike Staton et al., 1914.

[2] S.A Al-hamed et al., 2009 continued the study of tractor tire performance parameters for radial tires.

[3] Tyler Olmstead and Erika Fischer, in February 2009, studied the effectiveness of pressure pads originally designed for ergonomics in displaying real data for vertical pressure distribution when buried in soil.

[4] Hisanori Shinohara et al., in 2010, carried out an experimental analysis of tread pattern effects on tire tractive performance on sand using an indoor traction measurement system with a forced-slip mechanism.

[5] J.R. Cho et al., in 2011, presented a generalized multi-objective optimization method using a genetic algorithm (GA) to simultaneously enhance passenger comfort and the durability of a side-wall reinforced run-flat tire.

[6] V.T. Atkari, P.B. Arote, and S.B. Patil, in 2013, studied the effect of different tire inflation pressures on drawbar performance of a tractor in different gear settings.

[7] Mallikarjun Veeramurthy did research in 2013 on optimization of geometry and material properties of a non-pneumatic tire for reducing rolling resistance.

[8] A.M. Aboul-Yazid et al., in 2014, studied the effect of spoke structures on the characteristics and performance of non-pneumatic tires.

[9] Ankur Singhal et al. performed finite element analysis of pneumatic tire static load conditions on different tread patterns in 2016 to find which has good traction with the road surface.

[10] ALON is a new oxynitrile material with high impact strength and literature is available regarding its synthesis and characterization.

[11] Kshitij Nimkar et al. in 2021 optimized the cell angle of honeycomb spokes for non-pneumatic tires.

[12] Akshay Kumar A Kalahastimath reviewed airless tires in 2021 to study different types of NPT tires.

[13] Dots. Makhmudjon Melibaev et al. in 2021 determined the parameters affecting the performance of tractor tires.

[14] Liz Hutton & John O'Connor in 2021 studied tractor tire selection methods, types of tires, and factors affecting it.

[15] Kunal Dangane et al. in 2021 studied non-pneumatic tires of different designs.

[16] Z. Hryciów et al. in 2020 studied the influence of non-pneumatic tire structure on its operational properties.

[17]Cristobal Gonzalez Diaz et al. in 2014 studied the dynamic behavior of a rolling tire using experimental and numerical analysis.

[18]V.T. Atkari, P.B. Arote, and S.B. Patil, in 2013, studied the effect of different tire inflation pressures on drawbar performance of a tractor in different gear settings.

[19] Libin Rajan et al. in 2020 designed and performed a comparative analysis of non-pneumatic tires for a tractor.

[20] K. Tarakaram et al. studied modeling and analysis of NPT with different design structures using the finite element method.

[21] Vladimir Mazur in 2018 carried out experimental research in automobile NPT force heterogeneity.

[22] Nandikanti Supriya Reddy & Mr.G. Vinod Reddy modeled and analyzed NPT using ANSYS.

[23] Umesh G.C et al. in 2016 studied the design and analysis of non-pneumatic tires with honeycomb spoke structures.

[24] N. Nankali et al. in 2012 developed a 2D multi-laminated model of a tractor tire on soil and compared the analysis with a 3D model.

[25] Cho, J. R., et al. (2011). Optimum design of run-flat tire insert rubber by genetic algorithm (GA).