DESIGN, ANALYSIS & MANUFACTURING OF BICYCLE SHOCKWHEEL

Vimal Patel#1, Alice D'souza*2, Piyush Vasava#3, Rahul Patel#4, Manjeet Mukhi#5
#1,2,3,4 *Mechanical Engineering Department, Government Engineering College, Bharuch*
#5 *Chemical Engineering Department, Government Engineering College, Bharuch*
1vimalpatel107@gmail.com
2alicedsz08@gmail.com
3phvasava1911@gmail.com
4rahulpatel2985@gmail.com
5manjeetmukhi560@gmail.com

***Abstract*— Shockwheel represents an innovative departure from traditional bicycle wheel design, engineered to deliver superior comfort during off-terrain riding. Unlike conventional wheels that rely on rigid spokes, Shockwheel incorporates a loop-shaped leaf spring system. This system comprises four flexible loops, each anchored to a specially designed self-correcting hub at one end and bolted to the wheel rim at the other. The unique configuration of the hub allows for a smoother displacement profile compared to standard spoke-based wheels, resulting in a significantly more comfortable riding experience on uneven surfaces.**

In this study, a static analysis of the Shockwheel was conducted using ANSYS, a finite element analysis (FEA) tool. The simulation revealed the deformation and stress distribution patterns under static loading conditions. The results indicated that both the maximum deformation and the Von Mises stress levels remained well within permissible limits, affirming the structural integrity of the design. To validate the FEA findings, a physical prototype of the Shockwheel was subsequently manufactured and tested.

***Keywords*—**FEA, hub, leaf spring Shockwheel

I. Introduction

The bicycle has long been celebrated as a sustainable, efficient, and versatile mode of transport. However, one of its persistent limitations lies in rider comfort, particularly when navigating uneven terrains. Traditional bicycle wheels rely on rigid spokes that transmit shocks directly from the ground to the rider. Shockwheel introduces a revolutionary concept by embedding suspension directly into the wheel structure, thereby redefining the dynamics of cycling comfort and performance [1].

Unlike conventional spoke wheels, Shockwheel employs three loop-shaped springs made of advanced composite materials. These springs replace the spoke system and act as a dynamic suspension mechanism between the hub and rim. When encountering road irregularities such as potholes or bumps, the springs deform elastically, absorbing shocks and dissipating energy before it reaches the rider [2].

The hub remains conventional, supporting hub brakes and hub gears, ensuring compatibility with existing bicycle technologies. This hybrid design allows Shockwheel to integrate seamlessly into current bicycles while offering a significant leap in comfort and durability [3].

Recent studies emphasize the importance of integrating suspension into wheel structures. Li et al. analyzed in-wheel suspension systems, demonstrating significant improvements in shock absorption and structural resilience [4]. Similarly, Pandey et al. proposed a shock-absorbing wheel design for bicycles, highlighting the role of composite materials and spring mechanisms in enhancing ride quality [5]. These findings align with Shockwheel's design philosophy, situating it within a broader trend of innovation in bicycle engineering.

II. Material SELECTION

Material selection plays a crucial role in the design and performance of a bicycle chassis and its wheels, particularly in advanced concepts like the Shockwheel. The chassis, which forms the main body of the bicycle, can be constructed from a variety of materials such as carbon fiber composites, glass fiber composites, cast iron, forged iron, or stainless steel. Carbon fiber composites are favored in high-performance bicycles because of their exceptional strength-to-weight ratio and stiffness [6], though they are costly and prone to brittle failure under extreme impact. Glass fiber composites, on the other hand, provide good flexibility and shock absorption at a lower cost, making them suitable for mid-range bicycles [7]. Stainless steel is widely used for its excellent corrosion resistance and durability, while cast and forged iron, though strong, are heavier and less common in modern lightweight designs [8].

For the rear wheel, which typically retains a conventional spoke system, stainless steel is the preferred material for spokes and hubs due to its high tensile strength and resistance to rust, ensuring long-term reliability and minimal maintenance [9]. The front wheel, particularly in the Shockwheel design, requires more innovative material choices for the hub. Aluminum alloys are often selected for their lightweight properties and machinability, while stainless steel offers superior strength and wear resistance. In specialized applications, composite materials such as carbon fiber or glass fiber can be used to engineer hubs with tailored stiffness and damping characteristics [10].

The springs in the Shockwheel suspension system are critical components, and their material selection directly impacts performance. Steel springs are a traditional choice, valued for their elasticity and fatigue resistance, providing predictable suspension behavior [11]. However, composite springs made from carbon fiber or glass fiber are increasingly popular in advanced designs because they are lightweight, durable, and can be customized for specific shock absorption properties [12]. Finally, the rim is commonly made of stainless steel to ensure high strength, durability, and resistance to corrosion, particularly in challenging environments. Alternatively, aluminum alloy rims are widely used in modern bicycles for their lighter weight and balance of strength and corrosion resistance [13].

In summary, each component of the bicycle—from the chassis to the wheels, hubs, springs, and rims—requires careful material selection to balance strength, durability, weight, and rider comfort. By combining traditional metals like stainless steel with advanced composites such as carbon fiber and glass fiber, the Shockwheel design achieves a unique integration of suspension and wheel structure, offering enhanced performance and reliability across diverse terrains [14][15]..

III. FORCE ANALYSIS OF BICYCLE FRAME

To determine the forces acting on the wheel hubs, a simplified bicycle chassis was modeled and analyzed using ANSYS. The rider's weight was applied at node 7, simulating the load transfer through the frame. Nodes 2, 3, 5, and 6 were defined as fixed supports to replicate the contact points with the ground as shown in figure 1. The simulation revealed that the front wheel hub experiences a force of 264.1 N, while the rear wheel hub bears a higher load of 385.9 N. These values were used as input conditions for the subsequent design and analysis of the Shockwheel.

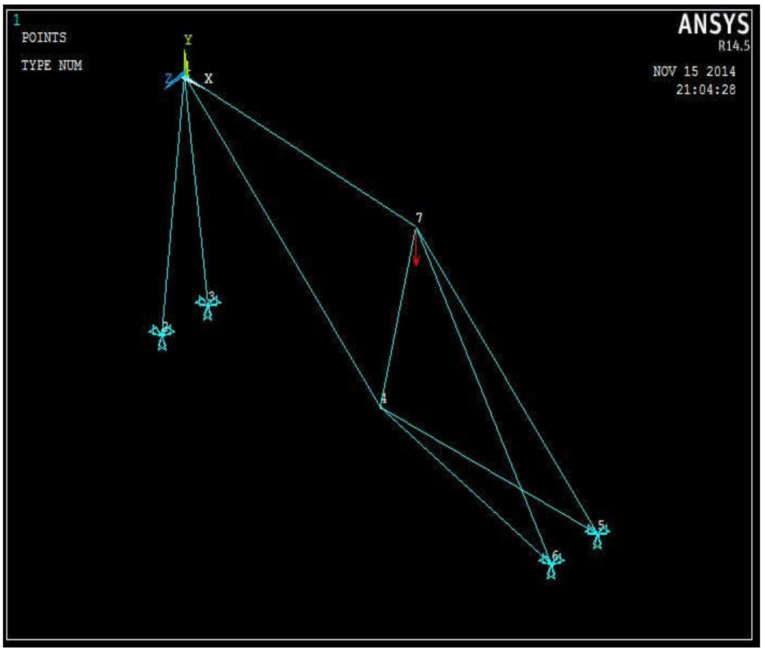

Fig. 1 Force Analysis of Bicycle Chassis

A. 3D Model of Shock Wheel

The Shockwheel consists of a square hub measuring 100 × 100 × 4 mm and four loop-shaped leaf springs mounted on each side as shown in figure 2. The design was modeled using CREO software to ensure precise geometry and assembly alignment. The square hub configuration allows for uniform distribution of forces and easy integration of the leaf springs, which are intended to flex under load and absorb shocks.

Fig. 2. Assembly of hub and spring.

B. Finite Element Analysis of Shock Wheel in Ansys.

The 3D model was imported into ANSYS for finite element analysis. The geometry was meshed using hexahedral elements to capture complex stress and deformation patterns as shown in figure 3.

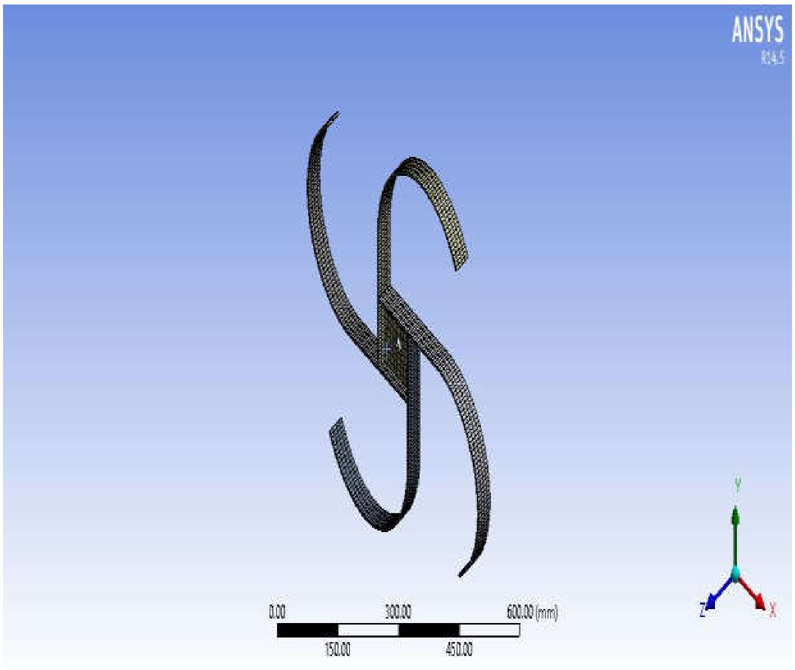

Fig. 3. Mesh Model.

IV. Boundary Conditions

A static structural analysis was performed by applying a 264.1 N load at the hub center, simulating the front wheel load as shown in figure 4. The opposite ends of the leaf springs were fixed in all degrees of freedom to replicate bolted connections to the wheel rim as shown in figure 5. This setup allowed for accurate prediction of stress concentrations and deformation behavior under realistic conditions

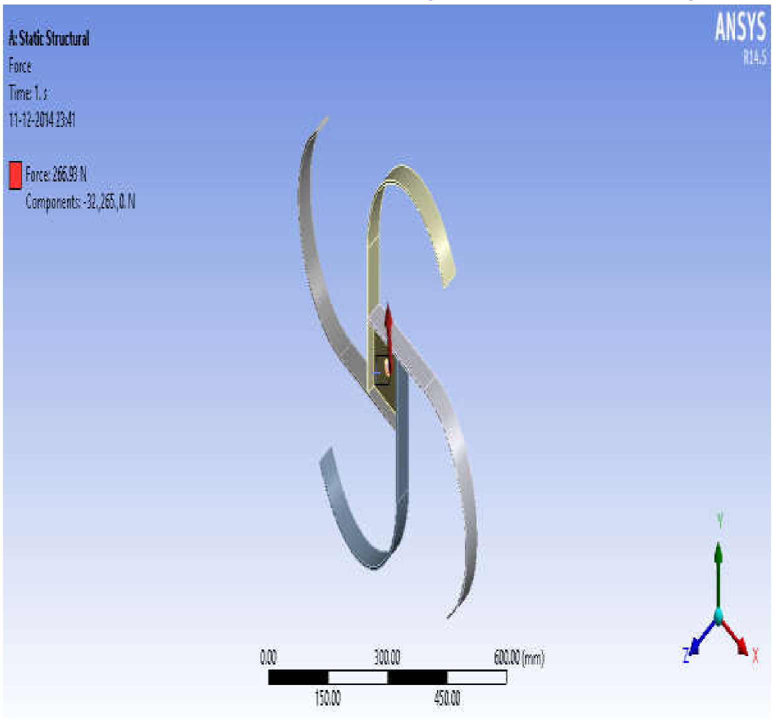

Fig. 4. Reaction Force at Hub Centre.

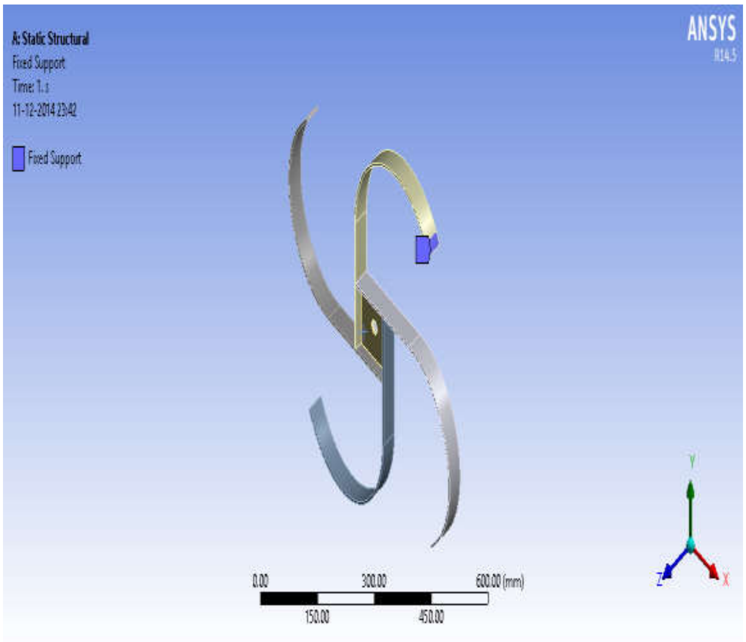

Fig. 5. Fix Support of Leaf Springs.

V. RESULT AND ANALYSIS

The FEA results indicated that the maximum deformation occurred at the hub center, measuring 7.0037 mm as shown in figure 6. This level of deflection is acceptable for composite leaf springs and contributes to effective shock absorption. The maximum stress was found to be 75.27 MPa at the junction between the hub and the leaf springs as shown in figure 7. This stress level is below the failure threshold for glass fiber composites, confirming the safety and durability of the design. The stress distribution was uniform across the spring loops, indicating efficient load transfer and minimal risk of localized failure.

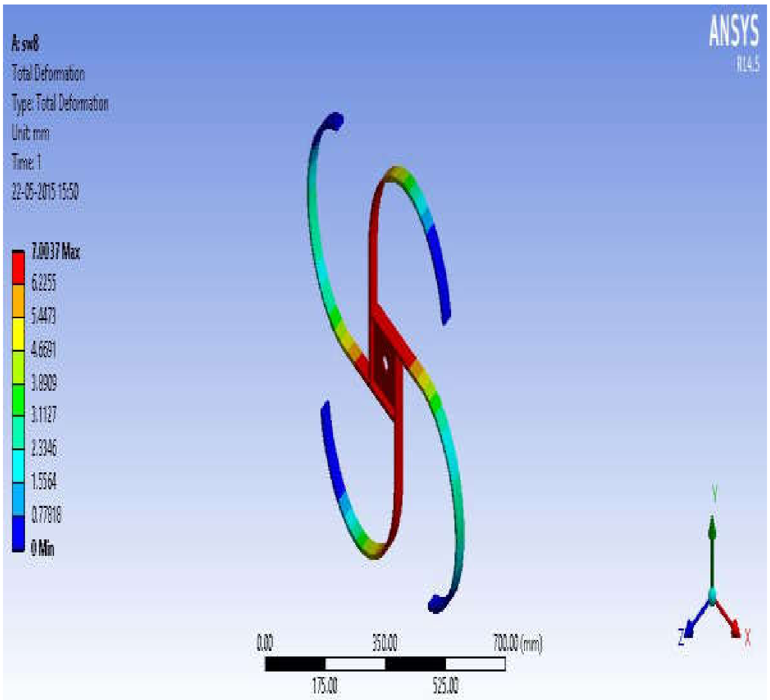

Fig. 6. Deformation Pattern of Leaf Springs.

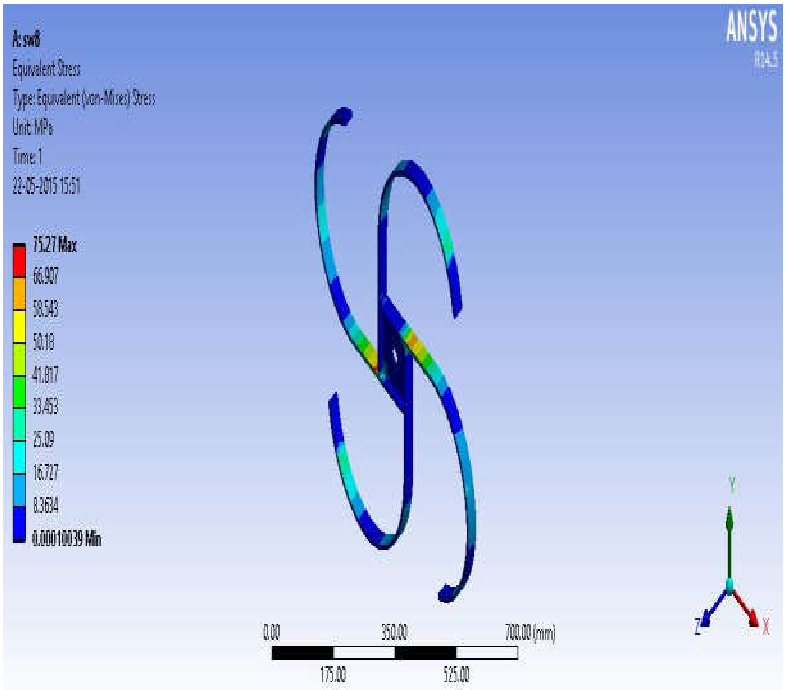

Fig. 7. Stress Pattern of Leaf Springs.

VI. MANUFACTURING OF DIE FOR LEAF SPRINGS

Die Fabrication

To fabricate the loop-shaped leaf springs used in the Shockwheel, a custom die was essential. This die was precisely designed to match the spring's geometry, ensuring consistent shape and mechanical performance during the lay-up process. Made from durable materials like hardened steel as shown in figure 8, the die allowed accurate layering of composite fibers such as carbon or glass fiber. These fibers were bonded with resin and cured under controlled conditions to achieve the desired strength and flexibility. The die not only ensured dimensional accuracy but also improved manufacturing efficiency and repeatability.

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Fig. 8. Leaf Spring Die.

Composite Leaf Spring Fabrication

Glass fiber composite leaf springs as shown in figure 9 were produced using the hand lay-up technique. Layers of glass fiber were impregnated with resin and shaped using the die, followed by curing. This method offers flexibility, low cost, and suitability for small-scale production. The resulting springs exhibited good surface finish and structural integrity.

Fig. 9. Composite Material Leaf Spring.

Hub and Final Assembly

A square hub was fabricated to support the four leaf springs. One end of each spring was bolted to the hub, while the other end was attached to the wheel rim. This configuration allows the springs to flex under load, providing suspension directly at the wheel. The final assembly was tested for fit and alignment, confirming the feasibility of the design for practical.

Fig. 10. Centre Hub of Shockwheel.

Fig. 11. Leaf Spring Fastening to Hub End.

To accommodate the four-leaf springs, a square hub was fabricated (Figures 10 and 11). One end of each spring was bolted to the hub, while the other end was attached to the wheel rim, completing the Shockwheel assembly (Figure 12).

Fig. 12. Final Assembly of Shockwheel.

VII. CONCLUSION

This research successfully demonstrates the design, analysis, and fabrication of a composite Shockwheel for bicycles. The integration of loop-shaped leaf springs into a square hub provides an innovative approach to suspension, offering reduced weight, simplified construction, and effective shock absorption.

Finite element analysis confirmed that the maximum deformation and stress were within safe limits, validating the structural integrity of the design. The manufacturing process, including die fabrication and hand lay-up of composite materials, proved to be practical and scalable. The modular design allows for customization and easy maintenance, making it suitable for various rider profiles and terrain conditions.

The successful fabrication and assembly of the Shockwheel prototype validate the simulation results and demonstrate the feasibility of using composite materials in dynamic load-bearing applications. Future work may include dynamic testing under real-world conditions, fatigue analysis of composite springs, and integration with smart sensors for performance monitoring. The Shockwheel concept also holds potential for application in other lightweight vehicles such as e-bikes and scooters, contributing to the advancement of urban mobility solutions.

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