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Design and Structural Analysis of S-Glass Epoxy Composite Wheel for High-Performance Applications

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Abstract: Any vehicle's wheel is a fundamental part that directly affects structural integrity, performance, and safety. Inappropriate wheel design can cause catastrophic failure, therefore endangering the vehicle and its people greatly. Wheel performance is significantly influenced by the material used in construction. This paper utilises a structural analysis of a wheel constructed from S-Glass epoxy composite, a material with an excellent strength-to-weight ratio, making it ideal for high-performance applications. Originally developed using Creo, a potent CAD tool, the wheel is exported to ANSYS for finite element analysis (FEA). With low deformation under load, the FEA findings demonstrate the excellent structural behaviour of the S-Glass epoxy wheel. The performance of the S-Glass wheel is matched with that of wheels constructed from traditional E-Glass composite and aluminium to confirm its efficiency. The comparison shows that the S-Glass composite wheel has much reduced values of stress, strain, and deformation. These results demonstrate the superior mechanical characteristics of S-Glass composites, establishing them as a practical and potentially superior alternative for creating lightweight and durable wheels in high-performance cars.

Keywords: S-Glass Epoxy; Wheel Performance; Structural Integrity; Finite Element; Traditional Aluminium; Structural Analysis; Catastrophic Failure; Strain Analysis; Performance and Safety.

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1. Introduction

One of the most fundamental components of every car is the wheel, which is crucial for safety, performance, and aesthetics. Wheel design and manufacturing have undergone significant changes over time in response to the need for lower weight, cost-effectiveness, environmental sustainability, and enhanced performance. With particular attention to alloy wheels produced from aluminium, magnesium, and advanced composites such as S-glass and E-glass epoxy, this study investigates the structural analysis and material optimisation of vehicle wheels. Under both static and fatigue loads, the work intends to evaluate the

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mechanical characteristics, performance, and manufacturability of many wheel materials. An automobile wheel is multifarious in use. Fundamentally, it reduces friction between the vehicle and the ground, thereby enabling the vehicle to move. Beyond this, wheels carry the entire weight of the car and its occupants, withstand dynamic loads from braking and acceleration, and meet the demands of steering. Moreover, the wheel has to absorb shocks and vibrations from uneven road surfaces, thereby enhancing ride comfort and safety. Aesthetic appeal also depends critically on wheels. The whole look of a car depends much on the design and quality of the wheels [5]. Many automakers thus see wheels as both practical and design-critical parts. Moreover, modern vehicle designs are governed by several key considerations: Wheels must meet rigorous structural integrity standards for safety, and lightweight wheels improve fuel efficiency and reduce emissions. Wheels must withstand fatigue loading over long periods. Should lower production costs and promote sustainability [6]. Faster and cheaper manufacturing cycles are essential. Heat dissipation is especially important for vehicles with high braking loads [1].

Due to its low cost and robustness, steel has long been the most commonly used material in car wheels. The great weight of steel wheels, which compromises fuel economy and general vehicle dynamics, is their main disadvantage, though. Aluminium alloys were then developed as a more affordable substitute with excellent corrosion resistance, ease of manufacturing, and aesthetic appeal. Because they combine weight and strength, aluminium wheels are increasingly used in passenger and commercial vehicles nowadays. Magnesium alloys have recently attracted interest due to their even lower density compared to aluminium, thereby reducing vehicle weight and improving performance. However, magnesium's flammability and reduced corrosion resistance, unless properly managed, make it costlier and require careful handling throughout manufacturing. Moreover, creative substitutes for wheel production have emerged in the form of composite materials, such as S-glass epoxy and E-glass epoxy [22]. High-performance and electric cars would find these fibre-reinforced plastics perfect, as they exhibit outstanding strength-to-weight ratios and excellent. A wheel typically consists of three main parts: the hub, which connects the wheel to the axle and houses the bearings; the rim, which supports the tyre; and the spokes, which connect the rim to the hub and bear both dynamic and static loads. Spokes play a critical structural role in the wheel and must be lightweight, strong, and capable of efficiently dissipating heat. The materials used in spoke construction should exhibit properties such as good thermal conductivity, corrosion resistance, casting and forming capabilities, low density, high damping capacity, and ease of recycling and processing.

There are two primary types of wheels: solid (cast) wheels, where the rim and spokes are manufactured as a single piece, and spoked wheels, where the rim is connected to the hub using multiple tensioned rods. While spoked wheels are typically lighter and more visually appealing, they require precise tensioning and regular maintenance to ensure optimal performance. A single broken spoke can compromise the structural integrity of the entire wheel, rendering it unrideable, especially in motorcycles or lightweight vehicles. Additionally, high-tension spokes mean fewer are used, placing greater stress on each individual spoke [4]. Since magnesium alloys have even less weight than aluminium, they are quite sought after in luxury cars and racing, where every gramme counts. Among its benefits are outstanding weight reduction, strong damping capacity, superb machining and casting qualities, as well as enhanced fuel economy and acceleration [3]. These advantages, meanwhile, have certain negative effects that need to be properly controlled at operational and manufacturing stages. Higher prices, oxidation and flammability hazards, reduced corrosion resistance, and the need for specific surface treatments to ensure durability and safety characterise these factors.

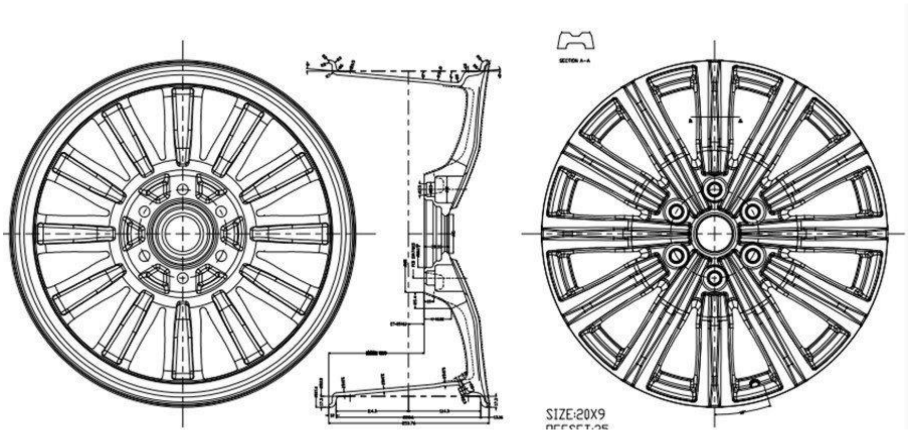


Figure 1: Alloy wheel

Lightweight and high-strength substitutes for conventional metals, composite materials have revolutionised structural applications in various fields. This work models S-glass epoxy composite wheels using Creo and investigates them in ANSYS using finite element analysis (FEA) [5]. With stronger tensile strength, better fatigue resistance, improved impact absorption, and enhanced dimensional stability compared to E-glass, S-glass is recognised for its superior mechanical properties. Under simulated loading circumstances, the S-glass wheels shown reduced deformation, low stress concentration, and improved strain resistance in FEA simulations. S-glass composites routinely exceeded the other two in terms of deformation and structural dependability when these performance criteria were matched with wheels built from E-glass epoxy and aluminium alloy. Particularly in challenging industries, such as racing, aerospace, and electric cars, where strength-to-weight ratio and dependability are vital, this emphasises their great potential for high-performance vehicle applications (Figure 1).

2. Literature Survey

Several studies have been conducted in the literature to investigate and improve the performance of wheels, focusing on aspects such as weight reduction, structural integrity, vibration resistance, and thermal performance. Researchers have explored various materials, including aluminium alloys, magnesium alloys, and advanced composites, to improve the strength-to-weight ratio and overall efficiency of wheel designs. In particular, composite materials reinforced with glass, carbon, and aramid fibres have gained attention due to their superior mechanical properties and potential for lightweighting. Among these, S-glass epoxy composites stand out for their high tensile strength, fatigue resistance, and durability, making them suitable candidates for high-performance wheel rim applications [2]. Finite element analysis (FEA) and experimental validation techniques have been widely used to simulate and evaluate stress distribution, deformation behaviour, and failure modes under different loading conditions. These studies collectively contribute to the development of safer, lighter, and more efficient wheel designs, aligning with the automotive industry's goals of enhanced performance and sustainability [2]. Bisht and Awasthi [7] conducted a comparative study of aluminium alloy (Al6061) and composite wheel rims to evaluate their strength and weight under identical loading conditions using computational modelling. A 14-inch wheel rim was modelled in Creo 3.0 and analysed in ANSYS Workbench 15.0 using the Composite PrepPost (ACP) module. Several fibre orientations of the composite materials, including [±35°], [±45°], [±55°], and [±75°], were considered to assess their structural behaviour.

The results showed that composite wheels exhibited lower deformation and stress levels compared to the Al6061 alloy wheel, indicating better performance in terms of structural integrity and weight reduction. Among the tested orientations, the [±45°] fibre winding angle demonstrated the most favourable strength-to-weight ratio, making it a promising configuration for high-performance applications. Gardie et al. [8] carried out a structural comparison between a carbon fibre-reinforced epoxy composite wheel and a structural steel wheel for lightweight automotive applications. The actual vehicle wheel was modelled using SOLIDWORKS 17 and analysed in ANSYS 18.1 under identical loading conditions. A laminated carbon/epoxy composite was selected to assess improvements in mechanical performance and weight reduction. The analysis revealed a 31.5% reduction in equivalent (Von Mises) stress and a 15.5% reduction in total deformation compared to the steel wheel [14]. Additionally, the composite wheel achieved an 80.4% weight reduction, which significantly decreased unsprung mass and improved vehicle performance. Gezu et al. [10] replaced a two-piece steel drive shaft with a single-piece E-glass fibre/epoxy composite shaft to achieve weight reduction without compromising performance. The drive shaft was modelled in CATIA and analysed using ANSYS, considering linear isotropic behaviour for steel and orthotropic behaviour for the composite. Stacking sequences were optimised to minimise bending stresses and avoid resonance. Torque transmission requirements were used to calculate shaft dimensions [20]. The analysis showed a 46% reduction in mass, confirming improved efficiency, reduced fuel consumption, and elimination of part complexity.

Zanchini et al. [11] designed a composite wheel rim for a sports car using Resin Transfer Moulding (RTM) to reduce mass and enhance bending stiffness. Finite Element Analysis (FEA) was conducted in conjunction with fatigue testing to evaluate structural performance, particularly under cornering loads. The composite design was compared to the aluminium alloy rim of the Ferrari 488 GTB, with an analysis of failure modes and stiffness degradation. Despite initial defects, the composite rim met homologation standards and safety requirements [21]. The study confirmed the viability of composite rims in reducing unsprung mass while maintaining performance. Li et al. [12] introduced a wheel–track composite chassis to enhance trafficability and stability under unstructured terrain. The design incorporates a tracked front mechanism and wheeled rear system, with theoretical analysis performed to determine its passability limits. Dynamic simulations were conducted in RecurDyn to validate these parameters [18]. The study examined the impact of terrain slope, obstacle height, and trench width on track tension and driving torque. Results confirmed that the composite chassis improves vehicle adaptability and performance across complex terrains.

Nachippan et al. [13] explored the static evaluation of natural fibre-reinforced composite wheel rims using finite element analysis (FEA). A two-wheeler wheel rim geometry was modelled, and simulations were conducted to assess deformation, deflection, and stress-strain behaviour. Three composite variants—S-Glass Fibre/Epoxy, S-Glass + Untreated Hemp Fibre/Epoxy, and S-Glass + Treated Hemp Fibre/Epoxy—were analysed. Results indicated that the S-Glass + Untreated Hemp Fibre composite exhibited the least deformation. This variant demonstrated superior static performance, making it more suitable for lightweight and biodegradable wheel rim applications. Nachippan et al. [13] designed and analysed fibre composite wheel rims to replace aluminium rims in Formula Manipal racing cars. The wheel geometry was modelled using CATIA 3DX®, and the structural behaviour was evaluated through ANSYS Composite Prep/Post (ACP) for laminate stacking and mechanical analysis [25]. Multiple material options were considered before finalising carbon fibre due to its superior properties. The finite element analysis revealed a 42% weight reduction and a 41% improvement in the factor of safety over aluminium rims. Additionally, carbon fibre rims showed better thermal performance than both magnesium and titanium alloys.

Shekhar et al. [9] modelled alloy wheel rims using CATIA software and analysed them under static conditions using ANSYS 14.5 with appropriate loading and boundary conditions [19]. Two spoke designs, hexagon and elliptical, were evaluated using different materials: Carbon Epoxy Composite, AL6061, and Magnesium alloy. The analysis focused on stress distribution, total deformation, and shear stress under increased pressure and radial load. Finite Element Techniques were employed to assess mechanical behaviour under real-world conditions [24]. The results helped identify the optimal combination of design and material for improved strength, safety, and manufacturability of alloy wheels. Satyanarayana and Sambaiah [15] conducted a static study on an A356 aluminium alloy wheel, where the three-dimensional model was designed in CATIA and later imported into ANSYS in IGES format for analysis. Their research focused on determining total deformation, additional stress, and shear stress using FEA software. They also investigated the lifespan, safety factor, and damage of the alloy wheel using the S-N curve, an essential input for the A356.2 materials. Their study emphasised the importance of conducting static analysis effectively to mimic dynamic loading conditions while reducing development costs for manufacturers. Huňady et al. [16] conducted static and fatigue analyses on aluminium alloy wheels using NASTRAN. The study aimed to evaluate overall deformation, additional stress, and shear stress, reinforcing the reliability of FEA in wheel performance assessments.

Si-yuan et.al studied the impact of substituting A365 aluminium with AM60A magnesium alloy. They found that the Mg alloy, with its lower elastic modulus, resulted in a more uniform service stress distribution and reduced peak concentrated stress. By modifying the spoke configuration and expanding the fillet between the spoke and ring, the redesigned Mg wheel improved reliability while reducing weight and lowering service stress levels. Merlin et al. [17] introduced a novel design for cast metal matrix wheels using low-pressure die casting simulation. The study utilised CATIA to create a three-dimensional wheel model, which was then filled with a composite material consisting of A356 aluminium alloy and 20 wt% SiC particles. The finite element model was later analysed in ANSYS to assess structural integrity, demonstrating the effectiveness of composite reinforcement in wheel design. Liangmo et.al proposed a new approach to measuring the fatigue life of aluminium wheels. Using ABAQUS, they built a static load finite element model for rotational fatigue testing. Their method extended the wheel's life cycle beyond 1.0×10^5 cycles, demonstrating the effectiveness of combining FEA with the nominal stress method for fatigue life estimation [23]. Chang et.al investigated the impact performance of aluminium wheels using ABAQUS, aiming to develop a static analytical method that could replicate dynamic loading effects. Based on models provided by a local manufacturer, their study revealed the significant influence of tyre interaction on wheel durability and suggested improvements for structural reinforcement.

3. Materials and Methodology

Three materials, aluminium alloy, E-glass epoxy composite, and S-glass epoxy composite, were chosen for the study of the intended wheel. Due to its good weight-to-strength ratio, aluminium alloy is a commonly used conventional material in wheel building. Its good weight-to-strength ratio qualifies for automotive uses where structural integrity and longevity are of great importance. Furthermore, a sensible and affordable option for the mass production of wheels is aluminium alloys, as they offer outstanding corrosion resistance and ease of manufacture. However, alternative materials, such as fibre-reinforced composites, have attracted interest as lightweight components to enhance vehicle fuel efficiency and overall performance, increasing their demand. A major consideration is weight reduction in automobile components, as smaller wheels immediately contribute to a reduced unsprung mass, thereby improving vehicle handling, braking, and fuel efficiency. Particularly those reinforced with glass fibres, composite materials present a good answer to fulfil these needs. One such fibre-reinforced material, extensively investigated and applied for its excellent mechanical properties—including tensile strength, impact resistance, and fatigue durability—is the e-glass epoxy composite.

Wheels would be appropriate for this contender since it has strong chemical resistance and are rather reasonably cost-effective. Another glass fibre variation with outstanding mechanical qualities relative to E-glass is S-glass epoxy composite. Tensile strength, fatigue resistance, and impact absorption all show better in S-glass fibres. These properties make S-glass epoxy composites particularly appealing for applications requiring improved performance under dynamic and cyclic loading conditions, such as automotive wheels subjected to varying loads during operation. While E-glass and S-glass epoxy composites were chosen to investigate the potential weight reduction and mechanical performance improvements in this work, an aluminium alloy was selected as the benchmark material. Through a comparative analysis under various load conditions, deformation, stress distribution, and structural integrity are evaluated, providing information on the viability of substituting fibre-reinforced composite alternatives for conventional aluminium wheels (Table 1).

Table 1: Chemical composition of E glass and S glass materials

Elements/Materials	E-Glass	S-Glass
SiO_2	54wt%	65wt%
Al_2O_3	14wt%	25wt%
CaO+MgO	22wt%	-
B_2O_3	10wt%	-
Na_2O+K_2O	2wt%	-
MgO	-	10wt%

The approach used throughout the paper is methodically outlined in the flow chart in Figure 2, which details every stage, from design to analysis, for an overall assessment of the wheel. The procedure begins with an exact wheel design utilising Creo software, a powerful computer-aided design (CAD) tool that enables precise 3D modelling of intricate geometry. Creo guarantees that the digital model accurately represents the real-world component being examined, allowing for the precise development of the wheel's dimensions, characteristics, and structural elements. Once the wheel design is finished, the 3D model is loaded into ANSYS Workbench, a strong engineering simulation tool used for finite element analysis (FEA), from Creo. The primary setting for investigating the structural behaviour of the wheel under various conditions is ANSYS Workbench. Meshing, or discretising the continuous wheel model into smaller finite elements, is the next important step. FEA relies on this method because it divides the complex geometry into manageable units, allowing the program to solve the governing equations of mechanics for each element, thereby predicting the response of the wheel to loads and stresses.

Appropriate boundary constraints added to the meshed model help to faithfully replicate real-world operational situations. Among these boundary conditions are those of fixed supports, load applications, and pressure distributions, which reflect the forces operating on the wheel during use, such as the weight of the vehicle, road impact, and rotational forces. Following the model and boundary conditions, the analysis utilises ANSYS Fluent, a software typically used for fluid flow simulations. In this case, it is likely to be used in conjunction with structural solvers to assess the wheel's response. Critical parameters include deformation, indicating how much the wheel bends or displaces under load, and stress distribution, highlighting locations of high mechanical stress that are likely to fail. These are computed in the analysis. These findings provide important new insights into the performance of the wheel, informing material choices and design enhancements to ensure efficiency, longevity, and safety. By combining rigorous finite element analysis with modern CAD modelling under a structured approach, a comprehensive assessment of the wheel's structural integrity can be achieved under reasonable conditions.

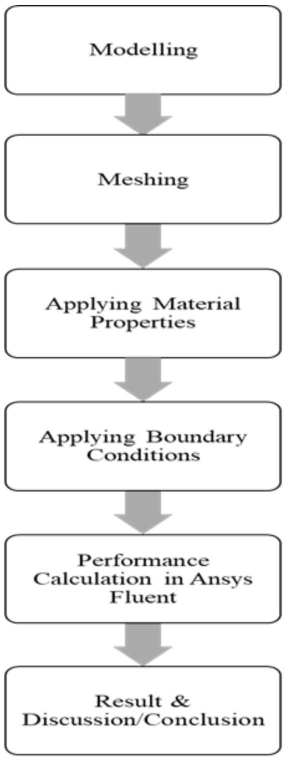
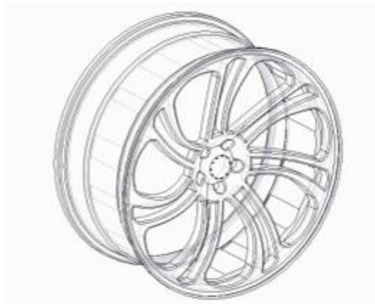


Figure 2: Flow chart of methodology

3.1. Wheel Modelling

Modelling of the wheel was performed using Creo software, a widely used tool in industries. Creo enables the accurate modelling of complex models with a high-quality surface finish. The modelled wheel is then saved in IGES format for exporting to ANSYS (Figure 3).

(a) (b)

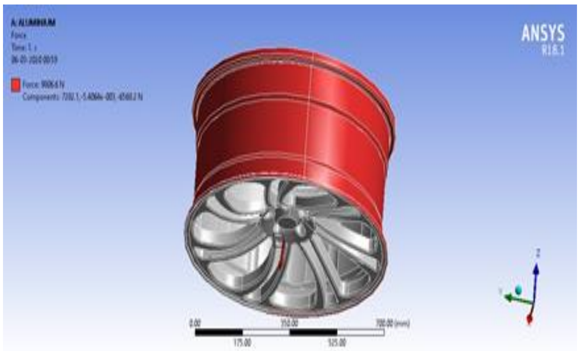


(c) (d)

Figure 3: Modelled bumper at different views

3.2. Analysis

The modelled wheel is then analysed after exporting to ANSYS Workbench. The ANSYS Fluent option is initially selected for analysis. To divide the model into fine elements for analysis, it is meshed. The element selected for meshing is tetrahedral. The fine meshing option is selected for meshing the model throughout. Then the material properties are entered for analysis. The real-world scenarios for analysis are entered in terms of boundary conditions. Then, the results required for the analysis are selected as total deformation and elastic stress. Finally, the graphs were plotted (Figure 4).



(a) (b)

Figure 4: (a) Meshed model and (b)boundary condition applied on the model

4. Results and Discussion

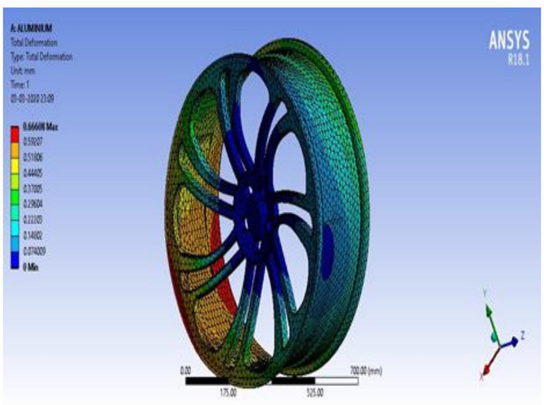
In this work, three distinct materials — aluminium alloy, E-glass epoxy composite, and S-glass epoxy composite — were investigated to identify the most suitable material for automotive wheel applications. Every material was carefully selected based on its mechanical properties, weight, and industry applicability. Wheel manufacturers make extensive use of aluminium alloy because of its low cost and good strength-to-weight ratio. Conversely, fibre-reinforced composites, such as S-glass epoxy and E-glass, have significant weight-reducing potential while either preserving or enhancing mechanical performance. Initially designed using CAD software and subsequently loaded into ANSYS Workbench for finite element analysis (FEA), the 3D model of the wheel underwent structural examination. Evaluating two important parameters under simulated loading conditions — total deformation and equivalent elastic stress, also known as Von Mises stress — was the main emphasis of the investigation.

Total deformation indicates how much the material and design can flex or bend, as measured by the overall displacement of the wheel under applied forces. Equivalent elastic stress helps pinpoint areas likely to be prone to failure or irreversible deformation and reflects the intensity of stress the material undergoes. To ensure a fair comparison, every wheel material was subjected to the same loading conditions and boundary constraints. Consistent with its rather great stiffness and strength, the aluminium alloy wheel displayed a modest degree of deformation and stress distribution. Indicating a trade-off between weight reduction and structural rigidity, the E-glass epoxy composite wheel exhibited lower weight but greater deformation and stress compared to the aluminium wheel. With minimal deformation and reduced equivalent elastic stress, the S-glass epoxy composite wheel exhibited the greatest overall performance, thereby highlighting its superior mechanical properties, including higher tensile strength and fatigue resistance.

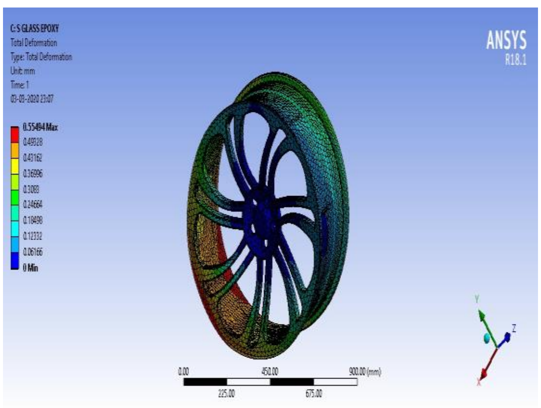
4.1. Total Deformation

Since wheels are the primary load-bearing components that immediately transfer the vehicle's weight and dynamic forces to the ground, their design and evaluation depend critically on deformation. Wheel stresses, including vertical pressures from the vehicle's mass, lateral loads during cornering, and impacts from road irregularities, arise when a vehicle is in motion. In a wheel, excessive deformation can compromise structural integrity, reduce safety, lead to poor handling, and ultimately result in component failure. Thus, under real-world operating conditions, the durability, dependability, and optimal performance of the wheel depend on studying and minimising deformation. In this work, under similar load and boundary conditions, the total deformation of wheels constructed from various materials was investigated to understand the behaviour of each material under stress. Figure 5 graphically illustrates the finite element analysis (FEA) deformation findings, with a colour gradient indicating areas of varying deformation magnitude.

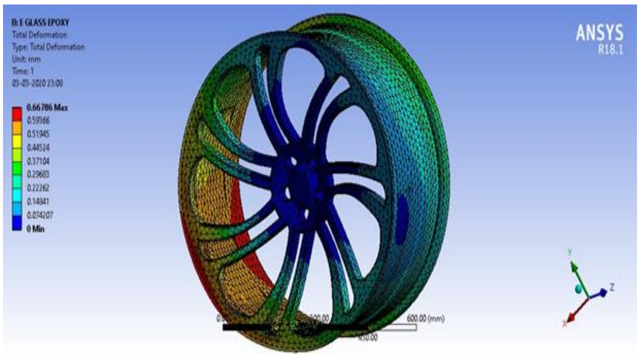
The Figure's red areas represent the zones with the most distortion. Fast identification of sensitive spots on the wheel and important stress points is made possible by this colour mapping. The study revealed that the inner components of the wheel, especially around the hub and spokes, showed notable deformation. These areas bear the most loads during operation and act as the link between the wheel and the vehicle's suspension, as predicted. The utilisation of different materials also affected the deformation patterns, thus representing variations in stiffness, strength, and load distribution capacity. Maximising wheel design depends on an awareness of these deformation properties. Designers might highlight areas of significant deformation or select materials with enhanced bending and flexing resistance. Reducing deformation increases wheel safety and longevity as well as vehicle handling and passenger comfort. Therefore, the deformation study provides important information that guides structural changes in wheel production and material selection.



(a) Aluminium wheel



(b) S-Glass Epoxy wheel



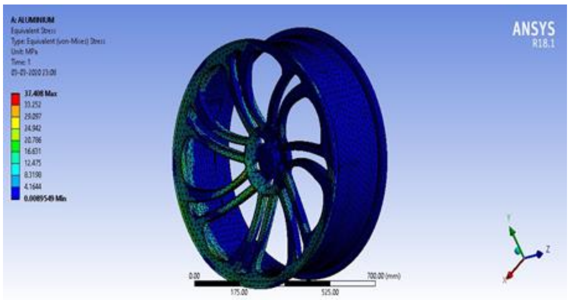
(c) E-Glass Epoxy wheel

Figure 5: Total deformation

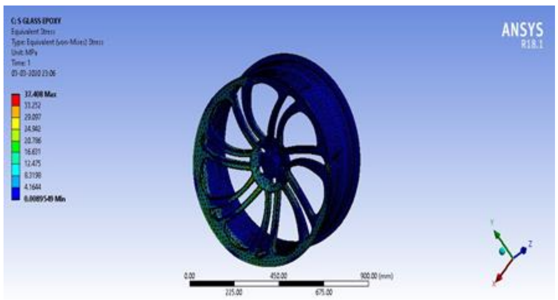
From the plotted results, the wheel made of S-glass epoxy exhibited the least deformation, measuring only 0.55 mm, compared to other materials analysed. This indicates that S-glass epoxy possesses superior stiffness and an excellent ability to distribute applied loads evenly, making it highly suitable for structural wheel applications.

4.2. Equivalent Elastic Stress

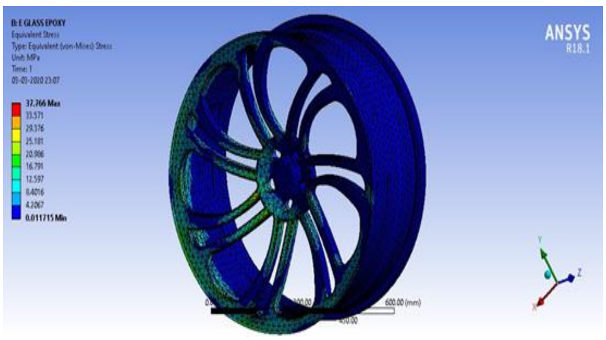
Equivalent elastic stress is a critical parameter that provides insight into how stress is distributed within a wheel structure made from various materials during mechanical loading. It reflects the stress intensity within the component and helps identify zones that are most susceptible to failure. If the equivalent stress exceeds the material's yield limit, it could result in permanent deformation or catastrophic failure. In this study, the equivalent elastic stress was analysed for wheels made of aluminium alloy, E-glass epoxy composite, and S-glass epoxy composite. The results, as depicted in Figure 6, show that the S-glass epoxy wheel experiences the highest concentration of stress, particularly in the regions of the wheel where load transmission is maximum.



(a) Aluminium wheel



(b) S-Glass Epoxy wheel



(c) E-Glass Epoxy wheel

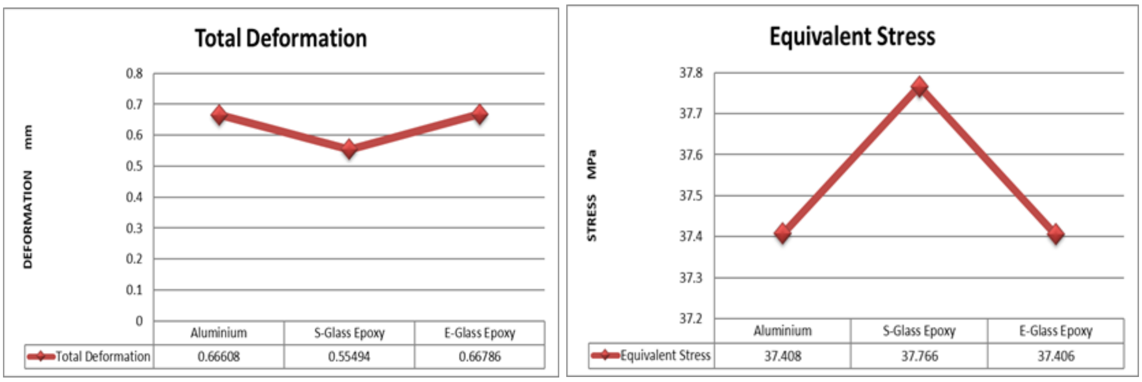
Figure 6: Equivalent elastic stress

Despite the higher stress levels in S-glass epoxy, this material exhibits remarkable mechanical strength and superior stiffness, enabling it to sustain higher stress without failure. On the other hand, E-glass epoxy showed the lowest equivalent elastic stress values, indicating better stress distribution but lower overall strength compared to S-glass epoxy. Aluminium, which is commonly used in wheel fabrication, displayed intermediate stress levels between the two composites.

Table 2: Overall result analysis

No.	Material	Total Deformation	Equivalent Elastic Stress
1	Aluminium	0.66608	37.408
2	S-Glass Epoxy	0.55494	37.766
3	E-Glass Epoxy	0.66786	37.406

The stress values for all three materials were compiled in Table 2 and graphically represented in Figure 7 for easy comparison. The graphical representation highlights that the variation in equivalent stress values among the three materials is relatively small. This suggests that all materials exhibit competent structural integrity under similar loading conditions. However, considering its high strength-to-weight ratio, ability to withstand stress, and minimal deformation, the S-glass epoxy composite emerges as a suitable candidate for high-performance wheel applications. Its higher stress tolerance, combined with reduced deformation, indicates that it can endure demanding operational environments while contributing to overall vehicle weight reduction. Thus, S-glass epoxy wheels present a promising alternative to traditional metallic wheels in automotive engineering.



(a) Total Deformation

(b) Equivalent Elastic Stress

Figure 7: Overall chart of structural analysis

5. Conclusion

The modelling and structural analysis of wheels made from different materials, namely aluminium alloy, E-glass epoxy composite, and S-glass epoxy composite, were successfully carried out in this study. The wheel model was initially created according to specified geometric parameters using CAD software and was subsequently exported to ANSYS for finite element analysis. The simulation involved applying realistic boundary conditions and meshing to evaluate deformation and stress responses under loading. The results for total deformation and equivalent elastic stress were plotted and analysed. It was observed that while the aluminium wheel showed moderate performance, the composite wheels, particularly those made of E-glass and S-glass epoxy, demonstrated competitive mechanical behaviour with only slight variations in deformation and stress values compared to the aluminium wheel. Given the significant advantage of reduced material weight, E-glass and S-glass fibre-reinforced composites emerge as suitable alternatives for wheel applications, offering both structural integrity and enhanced performance through weight reduction.

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Conflicts of Interest Statement: The authors declare no conflicts of interest, and all sources have been properly cited.

Ethics and Consent Statement: The authors confirm that ethical guidelines were followed, with informed consent obtained and participant confidentiality maintained.

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