Design and Analysis of EV Go-Kart Wheel Hub for Weight Reduction

Jagdish[1]; Shantharaja M.[2]

[1] M. Tech Student, Department of Mechanical Engineering,
University of Visvesvaraya College of Engineering,
Bengaluru, Karnataka, India.

[2] Professor, Department of Mechanical Engineering,
University of Visvesvaraya College of Engineering,
Bengaluru, Karnataka, India.

Abstract: Wheel hubs are critical load bearing components in electric go kart systems, directly influencing vehicle safety, handling, and unsprung mass. With increasing emphasis on lightweight design in electric mobility, conventional metallic wheel hubs present limitations in terms of weight reduction potential. This study presents the design and finite element based structural evaluation of a front wheel hub for an electric go kart using carbon fiber reinforced polyamide as an alternative to aluminium alloy. The wheel hub geometry is developed using an industrial reference and modelled using three-dimensional computer aided design. Structural performance is evaluated through finite element analysis by considering static loading, transient loading, and braking torque conditions representative of real operating scenarios. Aluminium alloy and carbon fiber reinforced polyamide are analysed using identical geometry, boundary conditions, and loading configurations to enable a consistent comparison. The results indicate that the composite wheel hub exhibits stress levels comparable to aluminium while demonstrating acceptable deformation behaviour under all loading cases. Under transient and braking conditions, the composite material shows improved stress distribution characteristics, attributed to its inherent material damping and flexibility. In addition, the significantly lower density of carbon fiber reinforced polyamide offers substantial weight reduction potential without compromising structural safety. The findings of this study demonstrate the feasibility of using carbon fiber reinforced polyamide as a lightweight alternative to aluminium for electric go kart wheel hub applications and provide a foundation for further experimental and fatigue-based investigations.

Keywords: *Electric Go Kart, Wheel Hub Design, Carbon Fiber Reinforced Polyamide, Lightweight Materials, Finite Element Analysis, Composite Structures.*

I. INTRODUCTION

A. Background

The rapid development of electric mobility has intensified research efforts toward improving vehicle efficiency, performance, and sustainability. Electric go-karts, in particular, have gained attention as compact and performance-oriented platforms for studying lightweight design concepts, advanced materials, and numerical analysis techniques. Due to their simplified mechanical architecture and high sensitivity to mass reduction, electric go-karts serve as effective experimental and research platforms for evaluating innovative structural components and material alternatives [6], [8].

A key challenge in lightweight vehicle design is the reduction of unsprung mass, which includes components such as wheels, hubs, and suspension elements. Unsprung mass directly affects vehicle handling, traction, ride quality, and dynamic stability. Among these components, the wheel hub plays a critical structural role by supporting the wheel assembly and transmitting loads generated during vehicle operation. During service, wheel hubs are subjected to radial loads arising from vehicle weight, torsional loads during braking, and time-dependent loads caused by acceleration and road irregularities. Structural failure or excessive deformation of the wheel hub can lead to loss of wheel alignment and compromised vehicle safety [4], [16].

Conventional wheel hubs are typically manufactured from metallic materials such as steel and aluminium alloys due to their high stiffness, strength, and proven reliability. Aluminium alloys are widely adopted in lightweight and racing applications because of their favorable strength-to-weight ratio compared to steel. Several studies have demonstrated that structural optimization and material substitution using aluminium alloys can significantly reduce wheel hub mass while maintaining acceptable stress and deformation levels when evaluated using finite element analysis [11], [13], [14]. However, the scope for further weight reduction using metallic materials remains limited, particularly for applications where minimizing unsprung mass is critical.

Recent advances in polymer composite materials have introduced new opportunities for lightweight structural applications in automotive systems. Carbon fiber reinforced polyamide composites have received considerable attention due to their high strength-to-weight ratio, improved stiffness compared to unreinforced polymers, and compatibility with modern manufacturing techniques such as injection molding and additive manufacturing. Experimental studies have shown that polyamide 6 reinforced with carbon fibers exhibits substantial improvements in tensile strength, elastic modulus, and load-bearing capability, especially at optimized fiber concentrations [1], [3], [17]. Processing parameters, fiber type, and fiber content have also been shown to play a significant role in determining the mechanical performance of carbon fiber reinforced polyamide composites [2], [15].

In addition to bulk mechanical properties, the performance of carbon fiber reinforced polyamide composites is strongly influenced by fiber–matrix interfacial bonding. Studies focusing on fiber surface treatment and sizing materials have demonstrated improved load transfer efficiency, enhanced stiffness, and increased durability of polyamide-based composites [5], [10], [12]. These characteristics make carbon fiber reinforced polyamide a promising candidate for replacing metallic materials in lightweight automotive components subjected to moderate structural loading.

Despite extensive material-level research on carbon fiber reinforced polyamide composites, their application in component-level structural analysis remains limited. Most existing wheel hub studies focus on conventional metallic materials or unreinforced polymers, while only a small number of investigations explore polymer-based or composite wheel hubs [7], [9]. Moreover, studies that integrate literature-derived composite material properties into finite element analysis of realistic wheel hub geometries are scarce, particularly for electric go-kart applications where lightweight design and structural safety must be addressed simultaneously.

Therefore, the present study focuses on the design and finite element based structural evaluation of a front wheel hub for an electric go-kart using carbon fiber reinforced polyamide as an alternative to aluminium alloy. The wheel hub geometry is developed based on an industrial reference to ensure practical relevance. Static structural analysis, transient structural analysis, and braking torque analysis are performed using identical geometry, boundary conditions, and loading configurations for both materials. The objective of this work is to assess the structural feasibility of carbon fiber reinforced polyamide for wheel hub applications and to provide a comparative evaluation against conventional aluminium under representative operating condition

B. Literature Gap and Objective

Although previous studies have investigated wheel hub design using metallic materials and extensively characterized carbon fiber reinforced polyamide composites at the material level, their application in component-level wheel hub analysis remains limited. Most existing investigations focus on aluminium or unreinforced polymer hubs, with very few studies addressing composite wheel hubs using realistic geometries and literature-supported material properties.

In addition, limited research has evaluated the behavior of composite wheel hubs under combined loading conditions relevant to electric go-kart operation. This study addresses these limitations by conducting a finite element based comparative evaluation of aluminium and carbon fiber reinforced polyamide wheel hubs under static, transient, and braking torque loading conditions.

II. MATERIALS AND METHODS

A. Material Selection and Composition

Material selection plays a decisive role in determining the structural performance and weight efficiency of load-bearing automotive components such as wheel hubs. In the present study, two materials are considered for comparative evaluation: aluminium alloy as the conventional reference material and carbon fiber reinforced polyamide as the proposed lightweight alternative. The selection is guided by mechanical performance requirements, weight reduction potential, and relevance to electric go-kart applications.

Aluminium alloys are widely used in wheel hub and wheel assembly components due to their relatively low density compared to steel, high elastic modulus, and proven reliability under automotive loading conditions. Several numerical and experimental studies have demonstrated that aluminium wheel hubs can safely withstand static, dynamic, and braking loads while offering moderate weight reduction and good dimensional stability [11], [13], [14]. For these reasons, aluminium alloy is selected as the benchmark material against which the performance of the composite wheel hub is evaluated.

Carbon fiber reinforced polyamide is selected as the alternative material due to its high strength-to-weight ratio and improved stiffness compared to unreinforced polymers. Extensive material-level investigations have reported that reinforcing polyamide 6 with carbon fibers significantly enhances tensile strength, elastic modulus, and load-bearing capability, making it suitable for semi-structural and structural automotive components [1], [3], [17]. Among various compositions reported in literature, a carbon fiber content of approximately thirty percent by weight is widely recognized

as providing an optimal balance between mechanical performance, processability, and weight reduction [1].

In this study, the composite material is considered to consist of approximately seventy percent polyamide 6 matrix and thirty percent carbon fiber reinforcement by weight. The polyamide matrix provides toughness, impact resistance, and manufacturability, while the carbon fibers contribute high stiffness and strength. Experimental studies have shown that increasing carbon fiber content beyond this range yields diminishing improvements in mechanical properties while introducing challenges related to fiber dispersion and processing [1], [2]. Therefore, the selected composition is representative of commercially relevant carbon fiber reinforced polyamide systems.

The mechanical properties of carbon fiber reinforced polyamide used in the present analysis are derived from published experimental literature. Dong et al. reported tensile strength and elastic modulus values for polyamide 6 composites reinforced with different carbon fiber contents and demonstrated that composites containing approximately thirty percent carbon fiber exhibit significantly improved stiffness and strength compared to neat polyamide [1]. Additional studies have confirmed similar property ranges and highlighted the influence of fiber orientation and processing conditions on composite behavior [3], [15], [17]. Based on these studies, representative material properties are adopted for numerical implementation.

Since carbon fiber reinforced polyamide is inherently anisotropic due to fiber orientation, an equivalent isotropic material approximation is employed for the present finite element analysis. This assumption is considered acceptable for preliminary structural feasibility studies and comparative evaluation, particularly when the objective is to assess global stress and deformation behavior rather than local failure mechanisms. Similar isotropic approximations have been adopted in previous numerical studies involving composite materials for automotive components [15], [16]. The material behavior is assumed to be linear elastic, and temperature effects, moisture absorption, and manufacturing-induced defects are neglected to maintain focus on structural comparison.

By adopting literature-derived material properties and a consistent modeling framework, the present study enables a direct and fair comparison between aluminium alloy and carbon fiber reinforced polyamide wheel hubs under identical loading and boundary conditions. This approach provides meaningful insight into the feasibility of replacing conventional metallic wheel hubs with lightweight composite alternatives in electric go-kart applications.

B. Wheel Hub Geometry and Modeling

The wheel hub geometry considered in the present study is developed using an industrially inspired design commonly employed in electric and racing go-kart applications. Adopting an industrial reference ensures that geometry reflects realistic dimensions, functional features, and load-transfer paths encountered in practical operating conditions. Rather than using an idealized academic model, the hub is designed to represent a manufacturable and application-relevant component suitable for structural evaluation.

The front wheel hub is modeled as a cylindrical component consisting of a central bore for axle or bearing fit and an outer mounting flange for wheel attachment. Key geometric features such as hub length, bore diameter, wall thickness, and flange dimensions are selected based on standard go-kart proportions and assembly requirements. These dimensions are chosen to ensure sufficient load-bearing capability while minimizing material usage and overall component mass. A uniform wall thickness is maintained across the hub body to promote consistent stress distribution and to simplify both numerical analysis and potential manufacturing processes.

Three-dimensional modeling of the wheel hub is carried out using computer-aided design software. The modeling procedure begins with the creation of a two-dimensional profile, which is subsequently revolved about the central axis to generate the primary cylindrical geometry. Additional features, including the central bore and wheel mounting holes, are incorporated using standard solid modeling operations. Fillets are applied at critical geometric transitions, particularly near the hub–flange junction and bore edges, to reduce stress concentration and to better represent realistic design practices.

Prior to finite element analysis, the CAD model is prepared to ensure numerical stability and solution accuracy. Non-structural cosmetic features such as small chamfers and decorative fillets are removed to simplify the geometry and improve mesh quality. However, essential fillets and transitions that influence load transfer are retained. The geometry is checked for symmetry, dimensional consistency, and absence of modeling errors that could adversely affect mesh generation.

The finalized wheel hub geometry is used consistently for both aluminium alloy and carbon fiber reinforced polyamide material cases. By maintaining identical geometry across all analyses, the influence of material properties on stress distribution and deformation behavior can be isolated and evaluated without introducing geometric bias. This modeling approach ensures a fair and meaningful comparison between the conventional metallic wheel hub and the proposed composite alternative.
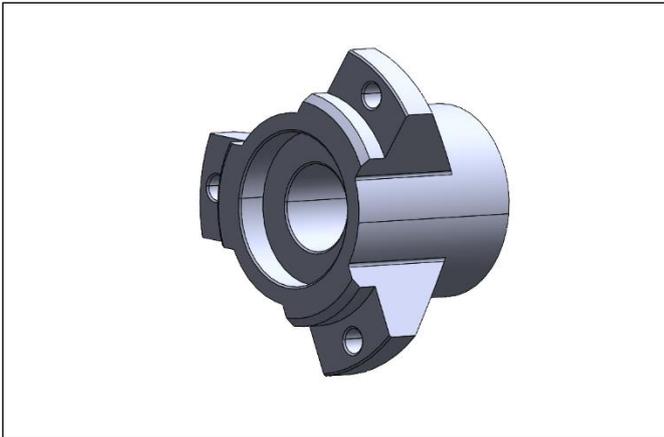
Fig. 1. Isometric View of the Electric Go-Kart Front Wheel Hub Geometry.

C. Finite Element Modeling and Boundary Conditions

Finite element analysis is employed to evaluate the structural response of the wheel hub under representative operating conditions. The three-dimensional CAD model of the wheel hub is imported into the analysis environment and discretized using three-dimensional tetrahedral solid elements. The model is discretized using three-dimensional tetrahedral elements with a global element size of approximately three millimeters, with local refinement applied in regions of expected stress concentration. Tetrahedral elements are selected due to their ability to accurately represent curved surfaces and filleted regions present in the hub geometry. A moderately refined mesh is used for the overall model, with localized refinement applied near critical regions such as the hub bore and hub–flange junction, where higher stress gradients are expected.

The wheel hub is assumed to be mounted on an axle through a bearing arrangement. To represent this condition, a fixed boundary constraint is applied to the inner bore surface of the hub, restricting all translational and rotational degrees of freedom. This boundary condition simulates a rigid hub–axle interface and is commonly adopted in wheel hub finite element studies for preliminary structural evaluation. All other surfaces of the hub are left unconstrained to allow natural deformation under applied loads.

The primary loading condition considered is a radial load acting on the wheel mounting flange, representing the static weight of the electric go-kart and driver. The radial load is applied as a uniformly distributed force over the flange surface to avoid unrealistic stress concentration associated with point loading. To capture time-dependent structural behavior, a transient loading case is also considered in which the radial load is applied gradually with respect to time. This approach enables assessment of stress response under realistic operating conditions such as acceleration and load variation during motion.

In addition to radial loading, braking torque is applied to evaluate torsional stress developed in the wheel hub during braking events. The braking torque is applied as a moment about the central axis of the hub, while maintaining the same bore constraint. This loading case is particularly important for assessing stress concentration at the hub–flange interface, which is a critical region for torque transmission.

Identical mesh settings, boundary conditions, and loading configurations are applied for both aluminium alloy and carbon fiber reinforced polyamide models. This ensures that any variation in stress or deformation results arises solely from material behavior rather than differences in geometry or analysis setup. The analysis focuses on equivalent stress and total deformation as the primary output parameters to evaluate structural safety and stiffness of the wheel hub under different loading conditions.

III. RESULTS AND DISCUSSION

The structural performance of the wheel hub is evaluated through finite element analysis under static loading, transient loading, and braking torque conditions. The results obtained for Aluminium Alloy 6061-T6 and carbon fiber reinforced polyamide 6 are compared to assess stress distribution, deformation behavior, and overall structural feasibility of the composite material.

A. Static Structural Analysis

Static structural analysis is performed to evaluate the stress response of the wheel hub under radial loading conditions representing the static weight of the electric go-kart and driver. This analysis provides insight into the load-bearing capability of the wheel hub and enables a direct comparison between Aluminium Alloy 6061-T6 and carbon fiber reinforced polyamide 6 under identical boundary conditions and loading configurations.

The equivalent von Mises stress distribution obtained for the Aluminium Alloy 6061-T6 wheel hub is shown in Fig. 2. The results indicate that the maximum stress occurs at the hub–flange junction and near the inner bore region, which are the primary load transfer locations between the wheel and the axle. The stress distribution across the hub body is relatively uniform, reflecting the high stiffness and load-carrying capability of the aluminium alloy. Similar stress concentration regions in aluminium wheel hubs have been reported in earlier numerical investigations [11], [14].
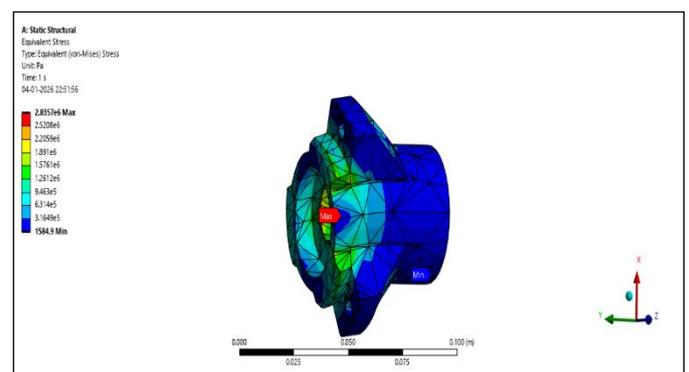

Fig. 2. Equivalent von Mises Stress Distribution of the Wheel Hub Under Static Loading for Aluminium Alloy 6061-T6.

The equivalent von Mises stress distribution for the carbon fiber reinforced polyamide-6 wheel hub under the same static loading condition is presented in Fig. 3. The composite hub exhibits a stress distribution pattern comparable to that of the aluminium hub, indicating that the geometry governs the overall load transfer mechanism. Slightly higher localized stress is observed in the composite hub, which can be attributed to its lower elastic modulus compared to aluminium. However, the stress remains well distributed without abrupt concentration, demonstrating stable structural behavior of the composite material.
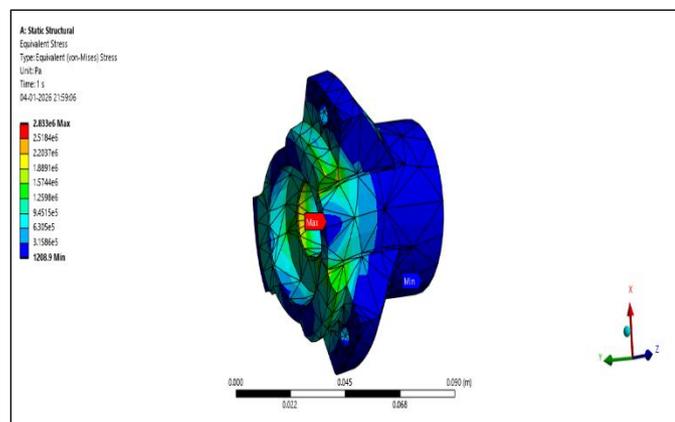

Fig. 3. Equivalent Von Mises Stress Distribution of the Wheel Hub Under Static Loading for Carbon Fiber Reinforced Polyamide 6.

A quantitative comparison of maximum von Mises stress values for both materials is illustrated in Fig. 4. The aluminium wheel hub experiences a maximum stress of approximately 2.84 MPa, while the CF–PA6 hub shows a closely comparable value of about 2.83 MPa. The near-identical stress magnitudes indicate that material substitution has minimal influence on peak stress under static loading conditions. Importantly, the stress levels for both materials are significantly lower than their respective yield strengths, confirming that the wheel hub design is structurally safe under static operating conditions for both aluminium and composite materials.
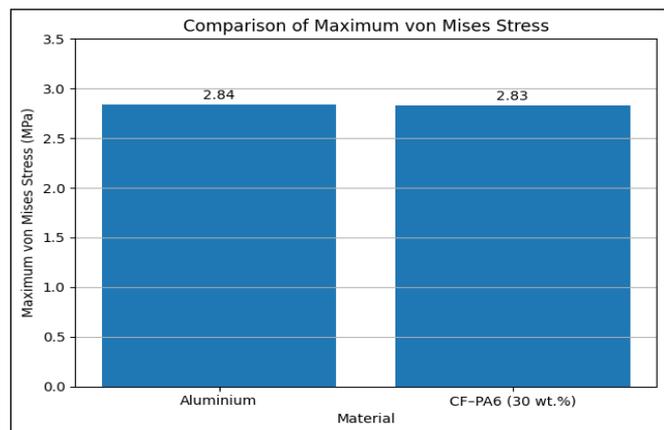

Fig. 4. Comparison of Maximum von Mises Stress of Aluminium Alloy 6061-T6 and CF–PA6 Under Static Loading.

Figure 4 presents the comparison of maximum von Mises stress developed in the wheel hub under static radial loading for Aluminium Alloy 6061-T6 and carbon fiber reinforced polyamide 6. The results indicate that both materials experience nearly identical peak stress values, with aluminium exhibiting a maximum stress of approximately 2.84 MPa and CF–PA6 showing a value of about 2.83 MPa.

Table 1. Comparison of Maximum von Mises Stress of Aluminium Alloy 6061-T6 and CF–PA6 Under Static Loading.

Material	Maximum von Mises Stress (MPa)
Aluminium Alloy 6061-T6	2.835
Carbon Fiber Reinforced Polyamide 6 (CF–PA6)	2.833

This similarity in stress levels suggests that the wheel hub geometry governs the load transfer mechanism under static conditions, while material substitution has a limited influence on peak stress magnitude. Importantly, the stress values for both materials remain significantly below their respective yield strengths, confirming structural safety under static operating conditions.

The equations are an exception to the prescribed specifications of this template. You will need to determine whether or not your equation should be typed using either the Times New Roman or the Symbol font (please no other font). To create multileveled equations, it may be necessary to treat the equation as a graphic and insert it into the text after your paper is styled.

B. Transient Structural Analysis

Transient structural analysis is performed to evaluate the time-dependent stress response of the wheel hub under variable loading conditions representative of dynamic operation of the electric go-kart. Unlike static analysis, transient analysis captures the evolution of stress with gradual load application, providing insight into the structural stability of the wheel hub during acceleration, deceleration, and load fluctuations encountered during motion.

The equivalent von Mises stress distribution for the Aluminium Alloy 6061-T6 wheel hub under transient loading is shown in Fig. 5. Maximum stress is observed near the hub–flange interface and inner bore region, with higher peak values compared to static loading due to the time-dependent nature of the applied load.
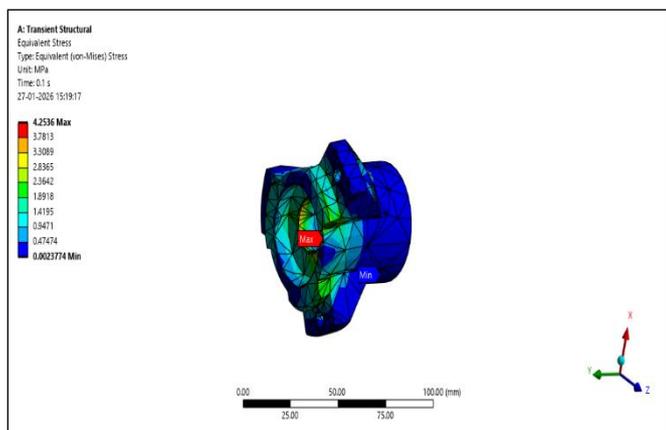
Fig. 5. Equivalent von Mises Stress Distribution of the Wheel Hub Under Transient Loading for Aluminium Alloy 6061-T6.

The equivalent von Mises stress distribution for the carbon fiber reinforced polyamide-6 wheel hub under the same transient loading condition is presented in Fig. 6. The composite hub exhibits a stress distribution pattern comparable to that of the aluminium hub, confirming that the geometry governs the overall load transfer mechanism. However, the stress is more uniformly distributed across the hub body in the composite case, which can be attributed to the lower stiffness and inherent damping characteristics of CF–PA6.
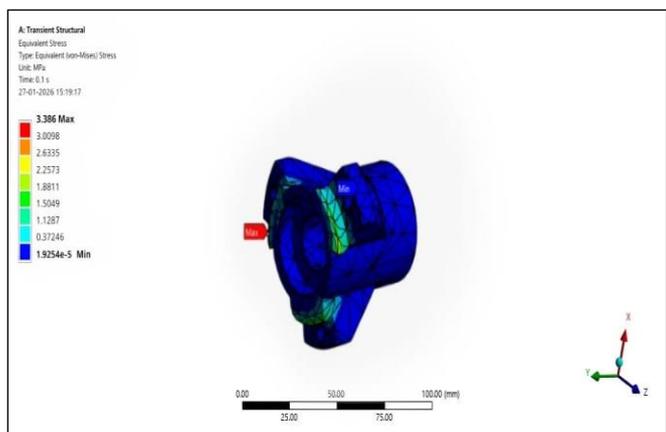

Fig. 6. Equivalent von Mises Stress Distribution of the Wheel Hub Under Transient Loading for Carbon Fiber Reinforced Polyamide 6.

A quantitative comparison of maximum transient von Mises stress values for both materials is illustrated in Fig. 7. The aluminium wheel hub experiences a peak transient stress of approximately 4.25 MPa, whereas the CF–PA6 wheel hub shows a lower maximum stress of about 3.38 MPa. This reduction in peak stress for the composite material indicates improved stress redistribution under dynamic loading conditions. Despite this difference, the transient stress values for both materials remain well below their respective yield strengths, confirming structural safety under dynamic operating conditions.
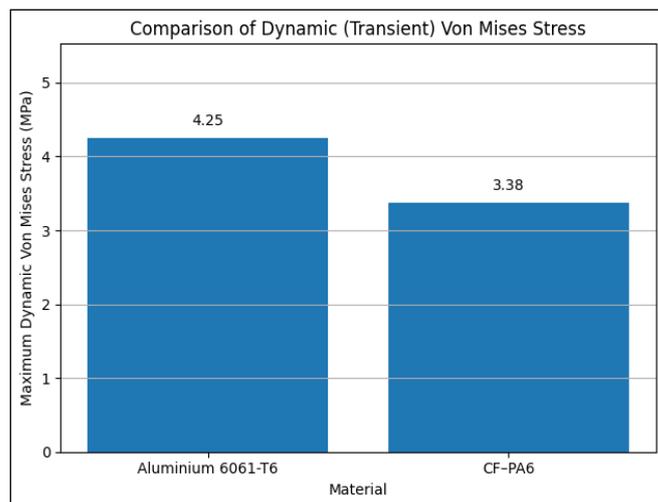

Fig. 7. Comparison of Maximum von Mises Stress of Aluminium Alloy 6061-T6 and CF–PA6 Under Transient Loading Conditions.

Overall, the transient structural analysis demonstrates that the CF–PA6 wheel hub exhibits favorable dynamic behavior compared to aluminium, with reduced peak stress under time-varying loads. This characteristic is advantageous for electric go-kart applications, where components are subjected to repeated and fluctuating loading during operation.

Table 2. Comparison of Maximum von Mises Stress of Aluminium Alloy 6061-T6 and CF–PA6 Under Transient Loading.

Material	Maximum von Mises Stress (MPa)
Aluminium Alloy 6061-T6	4.25
Carbon Fiber Reinforced Polyamide 6 (CF–PA6)	3.38

C. Braking Torque Analysis

Braking torque analysis is carried out to evaluate the torsional stress developed in the wheel hub during braking events, which represents one of the most critical loading conditions in wheel hub design. During braking, torque generated at the wheel is transmitted through the hub to the axle, resulting in combined shear and equivalent stresses, particularly in regions responsible for torque transfer.

The equivalent von Mises stress distribution obtained for the Aluminium Alloy 6061-T6 wheel hub under braking torque is shown in Fig. 6. The results indicate that maximum stress is concentrated at the hub–flange interface and near the inner bore region, which are the primary paths for torque transmission. This stress concentration pattern is consistent with the structural behavior expected in metallic wheel hubs subjected to torsional loading. The aluminium hub exhibits relatively lower deformation due to its higher stiffness, leading to a comparatively rigid torsional response.
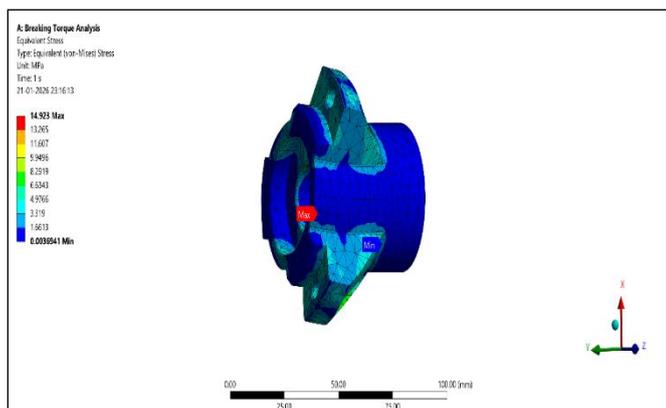
Fig. 8. Equivalent von Mises Stress Distribution of the Wheel Hub Under Braking Torque for Aluminium Alloy 6061-T6.

The equivalent von Mises stress distribution for the carbon fiber reinforced polyamide 6, wheel hub under the same braking torque condition is presented in Fig.8. The composite hub shows a stress distribution pattern similar to that of aluminium, indicating that the geometry governs the overall torque transfer mechanism. However, the composite material exhibits slightly more distributed stress over the hub body, which can be attributed to its lower elastic modulus and higher compliance. This behavior allows partial redistribution of torsional stresses, reducing localized stress concentration.
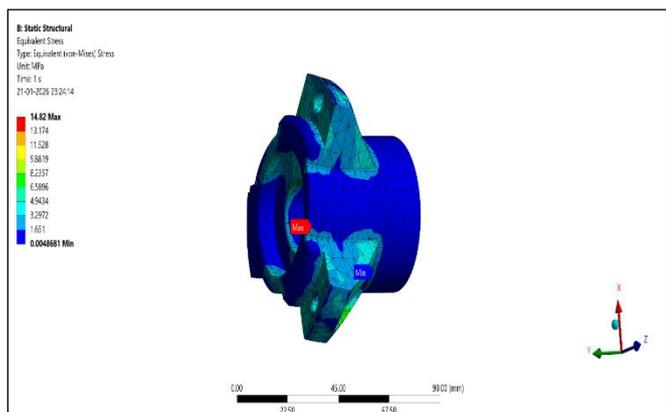

Fig. 9. Equivalent von Mises Stress Distribution of the Wheel Hub Under Braking Torque for Carbon Fiber Reinforced Polyamide 6.

A quantitative comparison of maximum equivalent stress values for both materials under braking torque is illustrated in Fig. 9. The aluminium wheel hub experiences a maximum stress of approximately 14.90 MPa, while the CF–PA6 hub exhibits a comparable value of about 14.80 MPa. The close agreement between these values indicates that material substitution has minimal influence on peak stress under braking torque. Importantly, the stress levels for both materials remain well below their respective yield strengths, confirming structural safety under braking conditions.
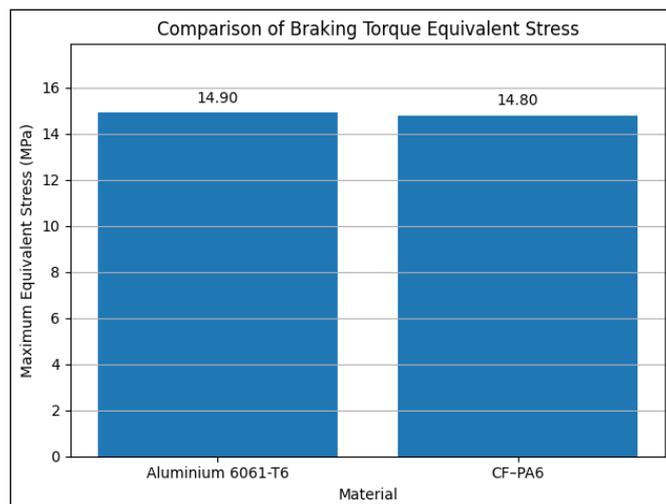

Fig. 10. Comparison of Maximum Equivalent Stress of Aluminium Alloy 6061-T6 and CF–PA6 Under Braking Torque.

Overall, the braking torque analysis demonstrates that the CF–PA6 wheel hub is capable of safely transmitting braking loads without exceeding allowable stress limits. The ability of the composite hub to accommodate torsional loading with controlled deformation highlights its suitability as a lightweight alternative to aluminium for electric go-kart wheel hub applications.

Table 3. Comparison of Maximum Equivalent Stress of Aluminium Alloy 6061-T6 and CF–PA6 Under Braking Torque.

Material	Maximum von Mises Stress (MPa)
Aluminium Alloy 6061-T6	14.92
Carbon Fiber Reinforced Polyamide 6 (CF–PA6)	14.82

IV.   CONCLUSIONS

The present study investigated the structural feasibility of replacing a conventional aluminium wheel hub with a carbon fiber reinforced polyamide-6, wheel hub for electric go-kart applications using finite element analysis. Static structural analysis, transient structural analysis, and braking torque analysis were performed under identical geometry, boundary conditions, and loading configurations to ensure a consistent and fair comparison between Aluminium Alloy 6061-T6 and CF–PA6.

The static structural analysis showed that both materials experiences nearly identical maximum von Mises stress under radial loading, with stress levels remaining well below their respective yield strengths. This indicates that the wheel hub geometry primarily governs load transfer under static conditions and that material substitution does not adversely affect structural safety.

Transient structural analysis revealed that the CF–PA6 wheel hub exhibits lower peak stress compared to aluminium under time-dependent loading. This behavior is attributed to the inherent flexibility and damping characteristics of the polymer composite, which enable improved stress redistribution during dynamic operation. These results suggest potential advantages of CF–PA6 in applications involving fluctuating or cyclic loads.

Braking torque analysis demonstrated that both aluminium and CF–PA6 wheel hubs can safely transmit torsional loads encountered during braking. Although the composite hub exhibits slightly higher deformation due to lower stiffness, the resulting stress levels remain comparable to aluminium and within allowable limits. This confirms the structural adequacy of CF–PA6 under critical torsional loading conditions.

Overall, the findings indicate that carbon fiber reinforced polyamide 6 is a structurally viable lightweight alternative to Aluminium Alloy 6061-T6 for electric go-kart wheel hub applications. The significant reduction in material density, combined with acceptable stress and deformation behavior, highlights the potential of CF–PA6 for reducing unsprung mass without compromising structural safety.

V. LIMITATIONS AND FUTURE WORK

The present study demonstrates the structural feasibility of using carbon fiber reinforced polyamide 6 as a wheel hub material for electric go-kart applications through numerical analysis. While the finite element results provide valuable insight into static, transient, and braking load behavior, certain limitations exist that offer scope for further investigation.

The material behavior of CF–PA6 is modeled using an equivalent isotropic linear elastic approximation based on published experimental data. Although suitable for preliminary structural assessment, this approach does not fully capture the anisotropic nature of fiber-reinforced composites or the influence of fiber orientation induced by manufacturing processes. Future work may incorporate anisotropic material models to more accurately represent directional stiffness and strength characteristics.

Experimental validation of the numerical results remains an important next step. Fabrication of a CF–PA6 wheel hub followed by static, dynamic, and braking tests would enable correlation with finite element predictions and strengthen confidence in practical implementation. In addition, fatigue analysis under cyclic loading conditions representative of continuous vehicle operation can be conducted to assess long-term durability and service life.

Further studies may also consider impact and crash loading scenarios to evaluate wheel hub performance under sudden or accidental load conditions. Thermal analysis associated with braking-induced heat generation can be incorporated to investigate temperature-dependent material behavior and its effect on stress distribution. Design optimization techniques may be applied to achieve additional weight reduction while maintaining structural safety. Finally, manufacturing feasibility studies using injection molding or additive manufacturing can be explored to assess production viability, cost, and scalability, as well as to extend the application of CF–PA6 to other lightweight electric vehicle components.

REFERENCES

[1]. Dong, W., Yu, Z., Sun, X., Hu, Z., E, S., Tong, F., Wang, S., and Li, X. (2025). Carbon fiber reinforced polyamide 6 composites: Impact of fiber type and concentration on the mechanical properties. *Materials*, 18(7), 1413.

[2]. Zhai, Z., Du, Y., and Wang, X. (2023). Optimization of process parameters for carbon fiber reinforced polyamide 6 composites fabricated by self-resistance electric heating technology. *Polymers*, 15(8), 1914.

[3]. Kausar, A. (2019). Advances in carbon fiber reinforced polyamide-based composite materials. *Advances in Materials Science*, 19(4), 67–84.

[4]. Sun, Y., Li, M., and Liao, C. (2017). Analysis of wheel hub motor drive application in electric vehicles. *MATEC Web of Conferences*, 100, Article ID 02003.

[5]. Yao, L., Li, M., Wu, Q., Dai, Z., Gu, Y., Li, Y., and Zhang, Z. (2012). Comparison of sizing effect of T700 grade carbon fiber on interfacial properties of fiber/BMI and fiber/epoxy. *Applied Surface Science*, 263, 326–333.

[6]. Mihalić, T., Hoster, J., Tudić, V., and Kralj, T. (2023). Concept design and development of an electric go-kart chassis for undergraduate education in vehicle dynamics and stress applications. *Applied Sciences*, 13(20), 11312

[7]. Poojari, M., Kamarthi, A., Shetty, K. K., Sanil, A. P., and Palan, K. V. (2019). Design and analysis of the wheel hub for an all-terrain vehicle with the plastic polymer nylon 6,6. *Journal of Mechanical Engineering Research and Developments*, 42(5), 119–123.

[8]. Kumar, B. V., Kumar, D. S., Bhargav, G. O. S., and Reddy, Y. B. (2024). Design of EV go-kart electrical system. *International Journal for Multidisciplinary Research*, 6(2), 1–6.

[9]. Kumar, B. V., Kumar, D. S., Bhargav, G. O. S., and Reddy, Y. B. (2024). Design of EV go-kart electrical system. *International Journal for Multidisciplinary Research*, 6(2), 1–6.

[10]. Karsli, N. G., Ozkan, C., Aytac, A., and Deniz, V. (2013). Effects of sizing materials on the properties of carbon fiber reinforced polyamide 6,6 composites. *Polymer Composites*, 34, 1583–1590.

[11]. Bandral, S., and Singh, S. (2017). Impact analysis of car alloy wheel rim using finite element analysis. *International Journal of Engineering Research and Technology*, 6(16), 1–4.

[12]. Dike, A. S. (2019). Improvement of mechanical and physical properties of carbon fiber reinforced polyamide composites by applying different surface coatings for short carbon fiber. *Journal of Thermoplastic Composite Materials*, 32(12), 1657–1673.

[13]. Zhou, W. (2025). Lightweight design of new energy vehicle wheel hub based on ANSYS Workbench. *Highlights in Science, Engineering and Technology*, 158, 119–128.

[14]. Kokate, S. B., and Kulkarni, G. R. (2019). Material optimization of wheel hub using finite element analysis. *International Research Journal of Engineering and Technology*, 6(5), 7252–7258.

[15]. Peng, X., Zhang, M., Guo, Z., Sang, L., and Hou, W. (2020). Investigation of processing parameters on tensile performance for FDM-printed carbon fiber reinforced polyamide 6 composites. *Composites Communications*, 22, 100478.

[16]. Saxena, G., Chauhan, A. S., Jain, R., and Gupta, I. (2017). Simulation and optimization of wheel hub and upright of vehicle: A review. *IOSR Journal of Mechanical and Civil Engineering*, 14(1), 42–50.

[17]. Karsli, N. G., and Aytac, A. (2013). Tensile and thermomechanical properties of short carbon fiber reinforced polyamide 6 composites. *Composites Part B: Engineering*, 51, 270–275.