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Facultad Ciencias de la Ingeniería e Industrias

RESEARCH
ARTICLE

ENFOQUE UTE, VOL. 16, NO. 4, pp. 47-52, E-ISSN: 1390-6542
RECEIVED JUNE 05, 2025; ACCEPTED AUGUST 28, 2025; PUBLISHED ONLINE OCTOBER 01, 2025;
DATA OF CURRENT VERSION OCTOBER 01, 2025; PUBLISHED IN VOLUME 16,
ISSUE 4 (OCTOBER 2025).

Finite Element Analysis of a Go-Kart Chassis Prototype for the OK-J Category Under Static and Dynamic Loading Conditions

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***Abstract* — This study presents a structural evaluation of a Go-Kart chassis prototype through Finite Element Analysis (FEA), aimed at validating its mechanical integrity under both static and dynamic loading conditions. The design adheres to international CIK-FIA standards and local FEDAK regulations, utilizing ASTM A36 steel tubing with a diameter of 38.1 mm and a wall thickness of 3 mm, which is selected for its availability and cost-effectiveness in the Ecuadorian market. The ladder-type chassis was modeled with standard dimensions, 700 mm in width, 1800 mm in length, and a 1070 mm wheelbase, to be analyzed under loads corresponding to component weight, driver mass, and forces from braking, acceleration, and cornering. Mesh quality was confirmed using the aspect ratio method, yielding a value of 3.266, which ensures accurate stress distribution. Simulation results indicated that the inclusion of a reinforcing cross member limited the maximum stress to 232 MPa, remaining within the 240 MPa yield strength of the material. Maximum displacement did not exceed 0.8 mm, confirming the chassis's structural resilience. The results underscore the utility of FEA as a strategic design tool, enabling early detection of critical stress areas and optimizing structural performance previous fabrication. This research presents a replicable methodology for lightweight chassis design and highlights the importance of simulation-driven development to enhance safety, reduce weight, and improve efficiency in small-scale vehicle engineering.**

***Keywords*: Finite element analysis; Go-Kart; chassis; dynamic loads; structural simulation.**

***Resumen* — Este trabajo presenta un análisis estructural de un prototipo de bastidor para Go-Kart, desarrollado mediante el método de elementos finitos (FEA), con el propósito de evaluar su comportamiento mecánico frente a cargas estáticas y dinámicas. El diseño se fundamentó en las dimensiones estándar de la CIK-FIA, 700 mm de ancho, 1800 mm de largo y 1070 mm de distancia entre ejes, utilizando tubería de acero ASTM A36, diámetro de 38.1 mm y espesor de 3 mm, material seleccionado por su disponibilidad y relación costo-resistencia en el mercado ecuatoriano. Se modeló un bastidor tipo escalera, aplicando cargas equivalentes al peso del conductor, los componentes y las solicitaciones dinámicas generadas por frenado, aceleración y maniobras de giro. La calidad de la malla fue validada mediante el criterio del cociente de aspecto, con un valor de 3.266, lo que aseguró una buena calidad numérica. Los resultados indicaron que, tras incorporar un larguero transversal adicional, los esfuerzos máximos alcanzaron 232 MPa, permaneciendo por debajo del límite elástico del material de 240 MPa, mientras que la deformación máxima fue de 0.8 mm. Estos resultados confirman la viabilidad estructural del diseño propuesto y destacan la utilidad del análisis computacional como herramienta para optimizar el diseño de bastidor. Se propone esta metodología como base para futuras validaciones experimentales, estudios de fatiga e implementación de materiales alternativos que contribuyan a mejorar la seguridad y eficiencia estructural en vehículos de pequeña escala.**

***Palabras Clave*: Análisis por elementos finitos; Go-Kart; bastidor; cargas dinámicas; simulación estructural.**

I. INTRODUCTION

IN the realm of recreational motorsports, Go-Karts offer one of the most accessible and engaging entry points into competitive racing, driving increasing interest in their engineering and production. Central to the performance and safety of these vehicles is the chassis, which serves as the primary structural framework, ensuring rigidity and protection for both the driver and the mechanical systems. Achieving an effective chassis design involves careful consideration of material properties, structural profiles, and realistic loading scenarios to guarantee durability and mechanical integrity throughout operation [1].

Modern design processes increasingly rely on computer-aided design (CAD) software, which enables the creation of detailed 3D models, as well as finite element analysis (FEA) simulations, to validate the structural behavior of prototypes before fabrication. As highlighted by Mihalić *et al.* [2], the absence of a preliminary simulation can hinder accurate prediction of how structures respond to various loads, often resulting in over-reliance on empirical methods. This can lead to structural

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DOI: https://doi.org/10.29019/enfoqueute.1190
Associate Editor: *Victor Suntaxi*

weaknesses, higher manufacturing costs, and the need for multiple redesigns.

Applying CAD and FEA tools addresses these limitations by identifying potential stress concentrations, areas of excessive deformation, and material inefficiencies early in the design process. This combined digital approach enhances structural optimization, minimizes failure risks, and ensures that prototypes meet safety and performance requirements before physical assembly, ultimately reducing technical challenges and financial risks.

Viswanadh *et al*. [3] proposed a structural design for lightweight vehicles intended for amateur and recreational motorsport, emphasizing safety and cost-effectiveness as the primary considerations. The study focuses on the structural modeling and static analysis of a go-kart chassis made from circular beams, using finite element analysis (FEA) to assess maximum stress and deformation. A 150 kg load was applied to a model constructed from AISI 1045 steel, resulting in a peak stress of 42.326 MPa, which is well below the material's yield strength, confirming the design's safety. The research also compared alternative materials, such as aluminum and low-carbon steel, and found negligible differences in structural behavior. The results indicate that both steel and aluminum can be viable options, depending on the specific design requirements. The design also accounted for the chassis's structural flexibility, which compensates for the lack of suspension, allowing some torsion during cornering maneuvers, thus enhancing the vehicle's adaptability on the track.

Attarde *et al*. [4] conducted a material comparison study for go-kart chassis design, utilizing CAD and computer-aided engineering (CAE) tools. This analysis included simulations of chassis behavior under impact conditions, as well as modal analysis using CATIA and ANSYS software. The study evaluated four materials: AISI 4130, AISI 1026, AISI 1080, and AISI 1020. The results of the impact tests revealed that AISI 4130 was the most suitable material, maintaining a safety factor greater than 1 in both front and rear impact scenarios, while the other materials did not meet this criterion. Consequently, AISI 4130 was selected due to its strength, durability, and safety margin, with future research suggesting the potential use of advanced materials such as carbon fiber.

The research by Kumar *et al*. [5] provides a notable contribution to the structural design of lightweight vehicles, specifically go-karts, by comparing the materials used for the chassis. The study utilized three-dimensional modeling of the frame in CATIA, followed by static analysis through the FEA in ANSYS. The primary goal was to assess the chassis's mechanical behavior under front and lateral loads, comparing two materials: AISI 1018 steel and carbon fiber. The results indicate that carbon fiber exhibits lower equivalent stress levels, 10.85 MPa, and maximum deformation compared to steel, demonstrating a superior strength-to-weight ratio, rigidity, fatigue resistance, and corrosion resistance. As a result, the carbon fiber chassis offers better structural performance and safety, making it the preferred material for this application. However, it comes with a higher cost, requiring specialized handling during manufacturing.

Malla *et al*. [6] focused on the design and analysis of a go-kart chassis, emphasizing compactness, driver ergonomics, and structural efficiency. AISI 4130 steel was chosen for its strength, weldability, and hardenability. The structural design was optimized to reduce weight, with a focus on simplified welded joints. Dynamic analysis using ANSYS software was employed to evaluate the chassis's natural frequencies and displacements through modal analysis, identifying critical points to prevent resonance issues. This study highlights how efficient design, combined with computational simulations, can improve the vehicle's performance and safety in real-world competition scenarios.

Bautista [7] developed a design for an electric go-kart chassis aimed at enhancing efficiency, safety, and lightness. By using Finite Element Analysis (FEA) and CAD tools, the design focused on ensuring proper weight distribution, maneuverability, and compatibility with the vehicle's electrical components, such as the motor and battery. Additionally, driver ergonomics were considered to ensure comfort and functionality during operation. The chassis design was shown to be reliable, with a maximum deformation of 0.4209 mm and a Von Mises equivalent stress of 18.45 MPa under static loads, confirming that the chosen material, Aluminum 2014 T652, is suitable for the applied stresses. The simulation results validated that the design meets the expected reliability and performance goals.

This study aims to evaluate the structural integrity of a go-kart chassis prototype through FEA simulations performed in CAD software, following the regulations established by the CIK/FIA karting commission. The main contribution concerns advancing safety, reliability, and performance in chassis design, while reducing reliance on costly and time-consuming physical prototyping. The central premise states that by integrating optimized structural reinforcements, the chassis will maintain stress levels below the yield strength of the selected material under both static and dynamic loading conditions. The document is structured as follows: the Materials and Methods section discusses the regulations considered in the design process, as well as the parameters used for modeling and initial conditions. The Results section presents the outcomes of the simulations under the established conditions. The Discussion section compares the results of this study with existing literature to validate the proposed prototype and the methodology used. Finally, the Conclusions section summarizes the key findings, offering the authors' insights.

II. METHODOLOGY

A. International and Local Standards

For a Go-Kart to be eligible for competition, it must meet the technical requirements outlined by the Commission Internationale de Karting (CIK) of the Fédération Internationale de l'Automobile (FIA), which regulates essential vehicle components such as the engine, chassis, brakes, and steering systems. The Ecuadorian Federation of Racing and Karting (FEDAK) ensures that all vehicles comply with both its internal regulations and the CIK-FIA standards. Specifically, the chassis must be made from tubular steel with a cylindrical section, excluding the use of titanium, and have secure connections between parts to ensure structural integrity.

B. Physical and Mechanical Parameters

In line with the regulations, several design parameters are specified, including the requirement for four wheels, the positioning of the driver, and the mandatory use of approved hydraulic brakes. These standards guarantee the vehicle's approval and ensure its safety and performance during races. Table I outlines the technical specifications set by CIK-FIA for Go-Kart prototypes [8]. According to FEDAK, for the Junior (OK-J) category, up to 200 cc, the vehicle's weight must not exceed 145 kg without the driver, and the combined weight with the driver must not exceed 185 kg.

TABLE I
DESCRIPTION OF GO-KART COMPONENTS

Component	Description	Mass [kg]
Chassis	Welded tubular frame, built in steel, high rigidity, and low weight.	30-35
Engine	Single-cylinder, 2-stroke, air-cooled, 200 cc	16.1
Steering System	Rack and pinion mechanism, rigid column, reinforced arms, and ball joints	5-7
Tires	Four standard-size 10-inch slick tires with magnesium wheels	12-16
Seat	Anatomical, adjustable for distance, 4 or 5-point safety harness.	5
Driver	Dynamic load in the standard driving position, according to design ergonomics.	60-80

C. Load Analysis

For the static analysis, the total mass of all components supported by the chassis was considered, while the driver's mass was treated as a live load, considering a value of 686.7 N. Scenarios involving rapid acceleration and sudden braking were examined to calculate the resulting forces using Newton's Second Law [9], expressed in Equation (1):

$$F = m \cdot a \tag{1}$$

Where the force (*F*) is determined by the mass (*m*), whether static or dynamic, and the acceleration (*a*), which takes a positive value during acceleration and a negative value during braking. Additionally, the lateral force generated when the vehicle changes direction, known as the turning load (F_{turn}), was considered [10]. This was calculated using Equation (2):

$$F_{\text{turn}} = \left(m_s + m_d\right) \cdot v^2 \cdot r \tag{2}$$

Where m_s and m_d represent the static and dynamic masses, respectively, *v* is the velocity of the Go-Kart, and *r* is the turn radius.

D. Computer-Aided Design (CAD)

For the design of the go-kart chassis prototype, the Ecuadorian Federation of Racing and Karting (FEDAK) establishes specific dimensional criteria. According to these guidelines, the overall chassis length must fall between 1600 and 1800 mm, with a wheelbase ranging from 1010 to 1070 mm [11]. Additionally, the maximum width must not exceed 700 mm. A 3D model of the proposed chassis prototype was created for further analysis, as illustrated in Fig. 1.

The selection of material for the chassis is based on key factors such as the balance between overall weight and mechanical strength, along with the ease of welding. Budget limitations also play a decisive role in this decision. Although literature highlights that aluminum frames offer benefits like reduced weight and good mechanical performance, they involve higher costs both in raw materials and in the welding process. As a result, ASTM A-36 steel tubing was chosen for this project. This material stands out for its relatively low cost in comparison to other structural options like aluminum or specialized alloys, while providing reliable mechanical properties with a yield strength of 250 MPa and a hardness of 180 HB[12].

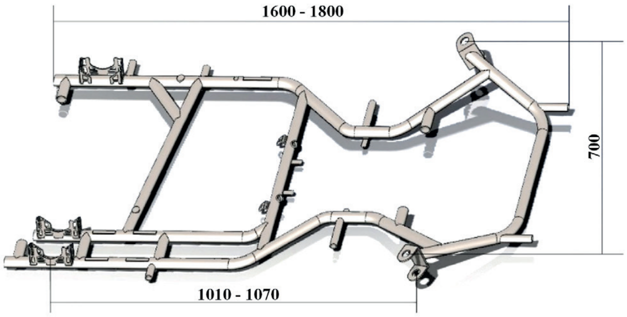

Fig. 1. Three-Dimensional Model of the Chassis Prototype.

According to FIA standards, several tubing options are suitable for steel chassis, which include diameters of 28.58 mm with a 5.2 mm wall, 35.56 mm with a 3.8 mm wall, and 38.10 mm with a 3.2 mm wall thickness. Considering local market availability, especially the limited supply of thick-walled tubes in small diameters, the selected configuration was seamless tubing of 38.10 mm (1.5 in) in diameter and a 3 mm wall thickness. The chassis model was discretized with tetrahedral elements for finite element analysis, and the simulation identified the center of mass 18.94, 11.52, and −141.69 mm, for X, Y, and Z, respectively, relative to the software's reference system, which was adopted for this study, as illustrated in Figure 2. Mesh quality was validated through the aspect ratio criterion, with a maximum obtained value of 3.266, confirming that the mesh quality remains within acceptable limits, as values below 5 are considered suitable for this type of structural analysis [13].

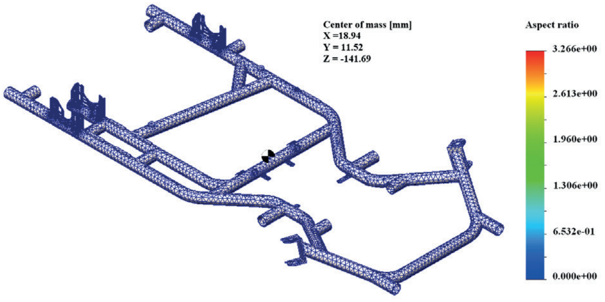

Fig. 2. Meshing the 3D model.

E. Initial Conditions

Fig. 3 illustrates the fixed joint constraints at the anchoring points of the steering spindles and the rear axle of the vehicle.

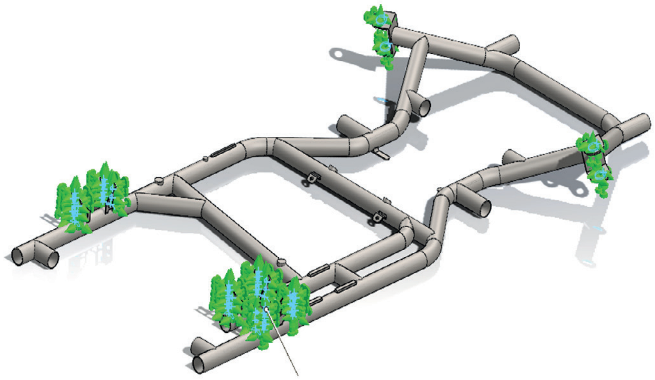

Fig. 3. Fixed geometry constraints.

Fig. 4a presents the static loads applied to the chassis, which include the weight of the chassis, engine, tires, and additional components. Figure 4b shows the distribution of dynamic loads, specifically the load corresponding to the driver.

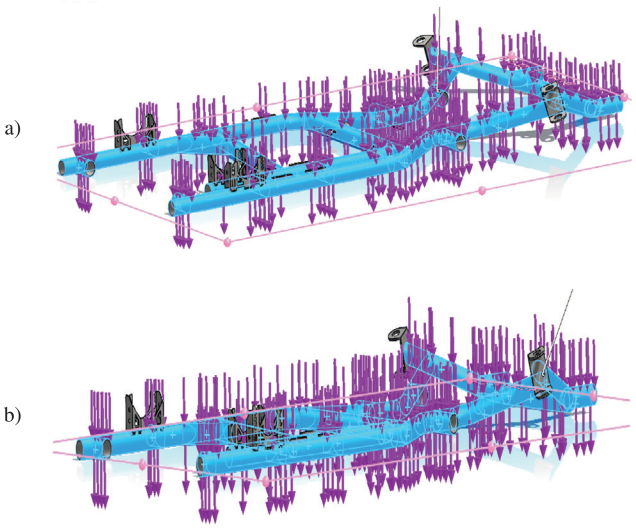

Fig. 4. Load Distribution, a) Statics, from component weight, b) Dynamics, from the driver.

Fig. 5 demonstrates the application of the turning load of 1161.6 N on the chassis, which acts tangentially to the vehicle's original direction of movement. Additionally, consideration must be given to the fixed connection points with the torque transmission.

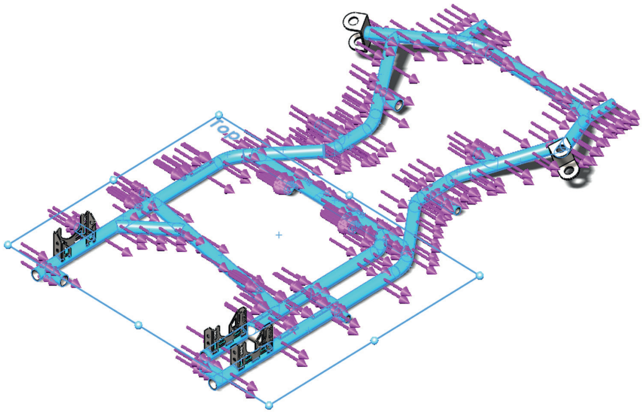

Fig. 5. Turning Load Application.

In the dynamic analysis, braking forces of 150 N are also considered, acting in the opposite direction to the vehicle's motion, as shown in Fig. 6a. This braking force impacts the chassis during sudden stops and affects both vehicle stability and chassis integrity. Fig. 6b highlights the additional forces resulting from rapid acceleration, emphasizing the need for the chassis to be designed to handle the extra forces encountered during quick maneuvers.

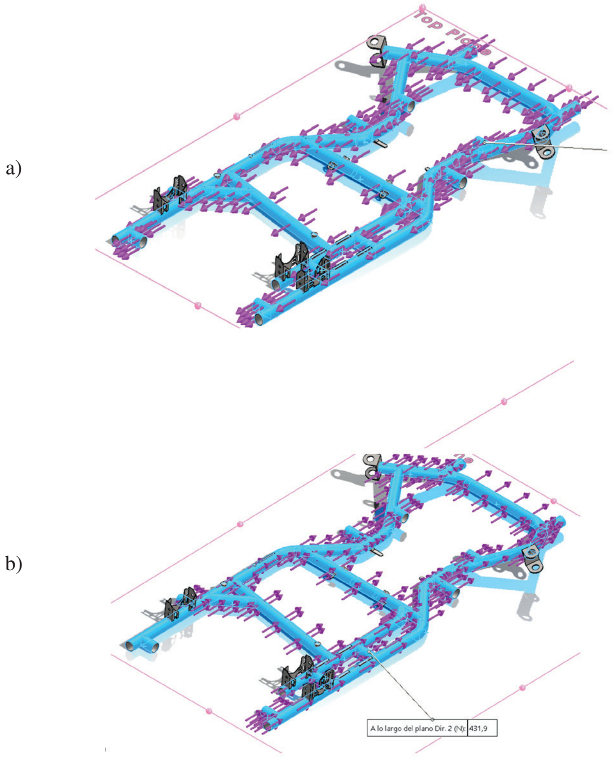

Fig. 6. Dynamic Loads, a) Braking, b) Acceleration.

III. RESULTS

Fig. 7 displays the Von Mises stress results for the chassis under a static load of 686.7 N. The design was adjusted to meet the positioning requirements of the main components and to ensure the driver's ergonomics, resulting in a maximum stress of 206.1 MPa, which remains within the material's elastic limit.

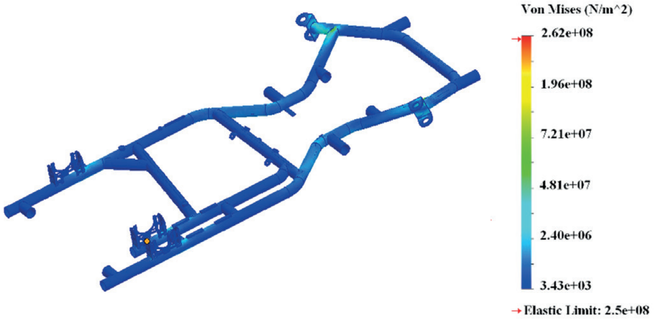

Fig. 7. Von Mises Stress for Static Load Analysis.

Fig. 8a shows the Von Mises stress for the dynamic analysis, incorporating braking forces of 350 N. Despite this additional load, the stress did not exceed the elastic limit. Fig. 8b presents the stress results for the chassis under acceleration, with the stress also staying below the elastic limit for ASTM A-36 steel.

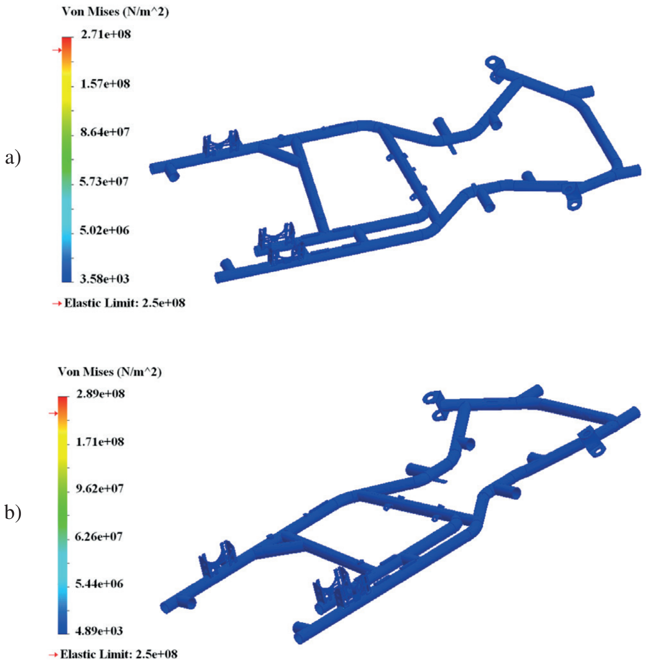

Fig. 8. Von Mises Stress for Dynamic Loads, a) Braking, b) Acceleration.

Fig. 9a illustrates the stress on the chassis when subjected to turning forces of 1161.6 N, with a maximum stress of 232 MPa, still beneath the elastic limit. Fig. 9b shows the displacements resulting from the turning load, noting that a structural design should allow displacements between 1 and 2 mm to be considered acceptable. For this analysis, the maximum deformation recorded was 0.811 mm, within the recommended limit.

IV. DISCUSSION

The finite element analysis confirmed that the chassis, manufactured using ASTM A36 steel tubing with a yield strength of 240 MPa, operates safely under both static and dynamic conditions. Under static loading, the maximum stress reached 206.1 MPa, while dynamic scenarios such as braking, acceleration, and cornering produced stresses of 215.2, 226.8, and 232 MPa, respectively. Although the cornering load produced the highest stress, it remained within safe limits, validating the structural performance of the design against the most demanding operating conditions. Compared to similar studies, such as that by Mohd-Jafri *et al.* [14], the stress and obtained deformation values have an accurate approximation, with maximum deformations limited to 0.8 mm, slightly below the 1 mm reported in their model. Initially, a critical area was detected in the rear longitudinal beam where stress exceeded acceptable values, which was resolved by adding a reinforcement beneath the driver's seat, enhancing structural stiffness and reducing stress concentrations.

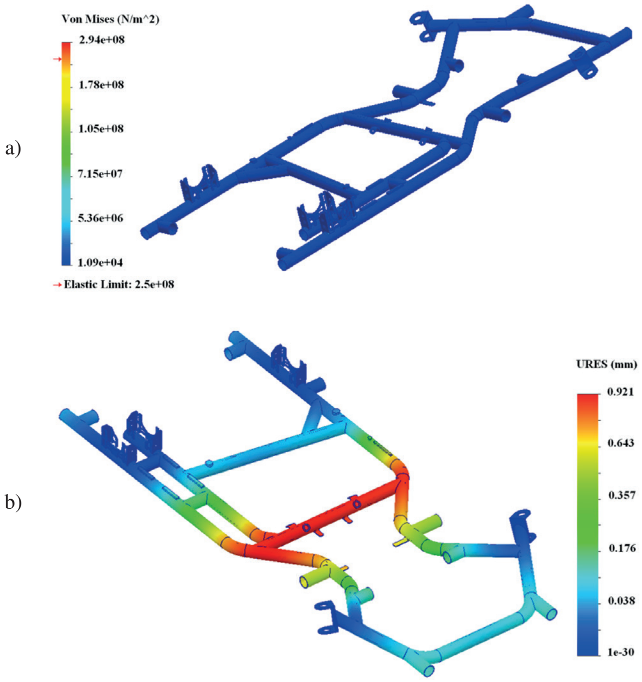

Fig. 9. Turning Load Analysis, a) Von Mises Stress, b) Displacements.

Regarding overall design performance, the chassis successfully meets weight, simplicity, and load-bearing requirements. These findings align with the conclusions of Abdullah *et al.* [15] and Sutisna [16], who highlight the importance of well-planned longitudinal arrangements to control deformations and maintain stresses within allowable ranges, by FIA standards. Nevertheless, this analysis has certain limitations, notably the absence of evaluations under impact conditions and fatigue effects, important aspects in karting due to frequent and variable load cycles. Ongoing studies are addressing these factors through dynamic and fatigue simulations using load spectra and transient models. Additionally, alternative materials such as aluminum alloys, as proposed by Srivastava *et al*. [17], are being explored to further reduce weight without sacrificing structural strength.

Fig. 10 provides a comparative overview of the stress and displacement values obtained under various loading conditions, confirming that the designed chassis performs within the safe limits defined by the yield strength of ASTM A36 steel (240 MPa). The highest stress occurred during cornering (232 MPa), followed by acceleration (226.8 MPa), braking (215.2 MPa), and static loading (206.1 MPa), with all values remaining below the material's yield threshold. Maximum displacement was recorded during the cornering load case, reaching 0.811 mm—well within the generally accepted limit of 1 mm for structural deformation. These results confirm that the chassis maintains structural integrity and stiffness under critical dynamic conditions typical of kart racing. Moreover, the incorporation of an additional cross member significantly contributed to stress redistribution and improved rigidity, demonstrating the value of finite element analysis (FEA) in enhancing design efficiency and identifying areas for structural reinforcement during the preliminary stages of development.

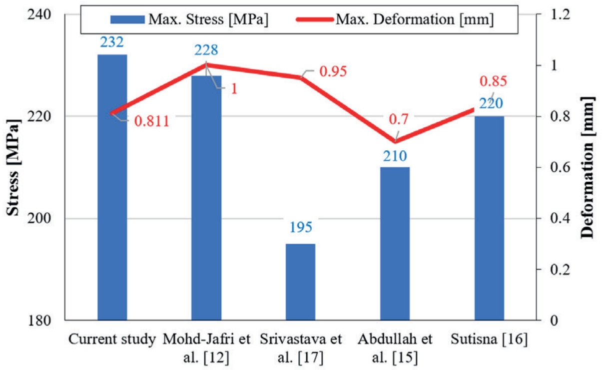

Fig. 10. Comparison of structural results of go-kart type chassis

V. CONCLUSIONS

The structural performance of the proposed go-kart chassis prototype was validated through finite element analysis (FEA), as the maximum stress levels recorded under different loading scenarios remained safely below the yield strength of ASTM A36 steel. This ensures the chassis maintains its structural integrity during typical operating conditions. The use of computational simulation proved important for verifying the design by identifying areas of potential weakness, for instance, a critical region in the rear longitudinal beam where stress concentrations exceeded permissible limits. To address this, a reinforcing beam was added, effectively improving stiffness and distributing loads more evenly.

This study provides a flexible framework for evaluating lightweight tubular chassis designs, using well-defined static and dynamic load cases tailored for go-kart applications. It is recommended that these numerical studies be supplemented with experimental testing to validate simulation accuracy, support weight reduction strategies without sacrificing structural strength, and incorporate further analyses on factors such as vibration, impact response, and fatigue behavior. These steps are vital for enhancing the safety and overall performance of the vehicle structure.

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