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Design, Development and Analysis of Go-Kart Chassis

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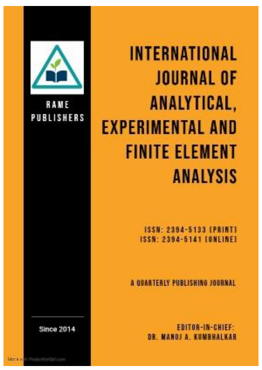

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Abstract. The design and analysis of a go-kart chassis are critical in determining the vehicle's overall performance, safety, and durability. A well-engineered chassis must provide sufficient structural integrity while remaining lightweight to maximize speed and handling efficiency. This study focuses on the systematic approach to designing an optimized go-kart chassis, considering essential factors such as material selection, weight distribution, torsional rigidity, impact resistance, and aerodynamics. The design phase begins with an in-depth analysis of various chassis geometries, comparing their advantages and limitations in terms of stability, manoeuvrability, and load-bearing capacity. The choice of material is a crucial aspect, with options such as AISI 4130 steel alloys being evaluated for their mechanical properties, including yield strength, tensile strength, and fatigue resistance. The geometric configuration is designed to achieve an optimal balance between stiffness and flexibility, ensuring efficient power transmission and improved cornering capabilities. To validate the structural integrity of the chassis, Finite Element Analysis (FEA) is employed to assess stress distribution, deformation characteristics, and overall durability under different loading conditions such as acceleration, braking, and cornering forces. The FEA simulations help identify high-stress concentration areas, allowing for necessary design modifications and reinforcements. Additionally, modal analysis is conducted to evaluate vibration characteristics, as excessive vibrations can negatively impact driver comfort and control precision. The study further explores different reinforcement strategies, such as additional bracing and optimized tubing profiles, to enhance the chassis' torsional stiffness without adding unnecessary weight. The integration of safety considerations, including crashworthiness and impact absorption, is also analysed to improve driver protection during collisions. By combining advanced design methodologies with computational analysis, this research aims to develop an efficient and high-performance go-kart chassis suitable for both recreational and competitive applications. The findings provide valuable insights into optimizing chassis design to enhance structural reliability while maintaining lightweight characteristics, ultimately contributing to improved handling, speed, and safety. The study's results can be instrumental for manufacturers and racing enthusiasts in refining go-kart chassis designs for superior performance on the track.

Keywords: Go-kart chassis, Structural analysis, Finite Element Analysis (FEA), Material selection, Impact resistance, Stress distribution, CAD simulation.

1. Introduction

Go-karting is one of the most popular motorsports that requires a properly designed chassis to achieve better performance, safety, stability, and durability. The chassis acts as the structural backbone of the vehicle, supporting all major components and significantly influencing handling characteristics, load distribution, and driving efficiency. An efficient go-kart chassis should provide adequate strength and rigidity while maintaining lightweight construction to improve speed, manoeuvrability, and overall vehicle control. Therefore, the design and analysis of a go-kart chassis have become important areas of research in automotive engineering [1].

The performance of a go-kart largely depends on factors such as material selection, chassis geometry, torsional rigidity, weight distribution, and crashworthiness. Material selection plays a crucial role in determining the strength, durability, and weight of the chassis structure. Similarly, the geometric configuration of the frame affects vehicle handling, cornering stability, and driver safety. Proper weight distribution and optimized torsional stiffness are essential to ensure balanced load transfer during acceleration, braking, and turning conditions [2].

The design process of a go-kart chassis generally involves analytical calculations, computer-aided modeling, and structural simulations to evaluate the behaviour of the chassis under different loading conditions. Finite Element Analysis (FEA) is widely used to study stress distribution, deformation, and structural integrity of the chassis during static and dynamic loading. Modal and vibration analyses are also performed to investigate the vibrational characteristics of the chassis and to improve ride stability and driving comfort [3].

Safety is another critical consideration in chassis design. The chassis must be capable of absorbing and dissipating impact energy effectively during collisions or accidents. Therefore, crashworthiness and impact analysis are important aspects in the development of a safe and reliable go-kart chassis. Various impact analyses, including front, side, and rear collision simulations, are commonly performed to evaluate the structural performance and occupant protection capability of the chassis [4].

Several studies have been carried out on the design, analysis, fabrication, and optimization of go-kart chassis structures. Previous research has mainly focused on static and dynamic structural analysis, material optimization, vibration behaviour, impact analysis, and weight reduction techniques. Researchers have also investigated the use of different materials and frame geometries to improve chassis performance while reducing overall vehicle weight. In addition, optimization techniques and simulation tools have been utilized to enhance structural strength, stiffness, and durability [5].

Recent developments in chassis design also include the application of advanced simulation software and multibody dynamic analysis to evaluate vehicle dynamics and stress behaviour under real operating conditions. Some studies have focused on electric go-kart chassis development and educational applications related to vehicle dynamics and structural analysis [6].

Although considerable research has been conducted on go-kart chassis design and analysis, there is still a need for developing a lightweight, strong, cost-effective, and highly durable chassis with improved safety and vibration characteristics. Many existing studies are primarily simulation-based and require further experimental validation under practical operating conditions [7]. Therefore, the present work aims to design and analyse a go-kart chassis with improved structural integrity, optimized weight distribution, enhanced safety, and better performance efficiency using suitable analytical and simulation techniques [8].

2. Material & Methodology

2.1 Gap Analysis

The go-kart chassis design gap analysis identifies areas for improvement in material selection, structural design, manufacturing processes, safety features, sustainability, and customization. Traditional materials like **AISI 4130** steel provide strength but add weight, while advanced composites and titanium alloys are underexplored. Conventional manufacturing methods introduce inconsistencies, requiring CNC machining, robotic welding, and hydroforming for precision. The lack of aerodynamic efficiency and torsional rigidity in chassis geometry affects handling and adjustable frame designs. Safety concerns include limited rollover protection and outdated driver restraint systems. Sustainability is a challenge, requiring the adoption of recyclable materials, bio-composites, and electric go-karts. Standardized, replaceable parts could enhance performance and reduce maintenance costs. Addressing these gaps through innovative materials and sustainable manufacturing practices can lead to lighter, stronger, and safer go-kart chassis.

2.2 Problem Definition

The design of a go-kart chassis is crucial for its performance, safety, durability, and handling characteristics. However, current designs face challenges in material selection, structural integrity, weight optimization, manufacturing efficiency, and safety features. Traditional materials like AISI 4130 steel add weight but affect speed, fuel efficiency, and manoeuvrability. Existing designs often lack torsional rigidity, compromising stability during high-speed cornering and uneven load distribution. The manufacturing process relies on conventional tube bending and welding, introducing structural inconsistencies and increasing production costs. Safety concerns include inadequate impact absorption, rollover protection, and advanced restraint systems. Environmental sustainability is also a concern, with traditional metal processing contributing to high carbon emissions and limited recyclability. The absence of modular and customizable chassis designs makes maintenance and upgrades difficult, increasing long-term costs for racing teams and recreational users. This research aims to address these gaps by evaluating alternative materials, employing Finite Element Analysis for stress testing, and exploring modular design solutions.

2.3 Objectives

1. To analyze the primary components and structural integrity of a go-kart chassis.
2. To investigate how chassis design aspects, including material selection, weight distribution, and torsional rigidity, influence performance and durability.
3. To evaluate how different chassis geometries impact handling, stability, and driver comfort under various driving conditions. To evaluate how different chassis geometries impact handling, stability, and driver comfort under various driving conditions.
4. To identify common chassis-related issues such as excessive flex, poor impact absorption, and structural weaknesses.
5. To recommend design modifications and material optimizations that enhance chassis strength, reduce weight, and improve overall go-kart performance.

These objectives will support the systematic evaluation and refinement of go-kart chassis design, ensuring better safety, efficiency, and racing capabilities.

2.4 Key components and Functions

A go-kart chassis serves as the structural foundation, integrating various components to ensure stability, strength, and efficient power transfer. A well-designed chassis balances rigidity and flexibility, enabling smooth handling, safety, and durability. Understanding its primary elements and their roles is crucial for design, maintenance, and troubleshooting.

Main Frame- Function: The backbone of the go-kart, the main frame supports the engine, driver, and all mechanical components. It must be lightweight yet strong, providing impact resistance and absorbing vibrations while maintaining structural integrity.
Cross Members- Function: These horizontal reinforcements enhance the chassis' torsional rigidity, ensuring even weight distribution and stability. They prevent excessive flexing, improving handling and responsiveness.
Engine Mounts- Function: Securely hold the engine in place, absorbing vibrations and preventing misalignment during acceleration. A well-designed mount reduces mechanical stress and enhances power transfer.
Floor Pan- Function: Provides a stable base for the driver, improving safety and comfort. It also adds structural reinforcement to the lower chassis section, reducing flex and maintaining rigidity.
Axle Hanger - Function: Support the rear axle, ensuring smooth power transmission. Properly aligned hangers reduce friction, enhance speed, and improve handling.
Crash Protection - Function: Absorb impact energy in case of collisions, protecting both the driver and mechanical components. Designed with materials that provide a balance of strength and flexibility.
Roll Hoop - Function: A protective structure designed to shield the driver from rollovers, improving safety in high-speed scenarios. It provides additional reinforcement to the upper chassis.

2.6 Design & CAD Model of Chassis

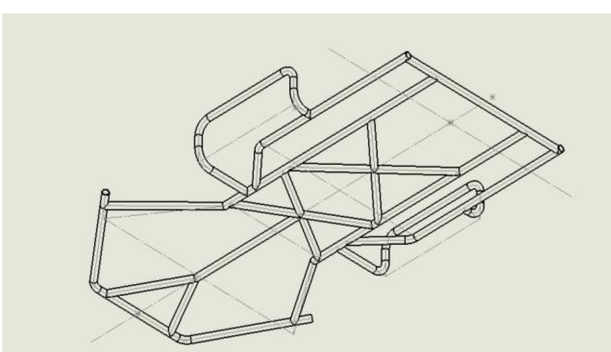

Figure 2. Isometric View of Chassis frame

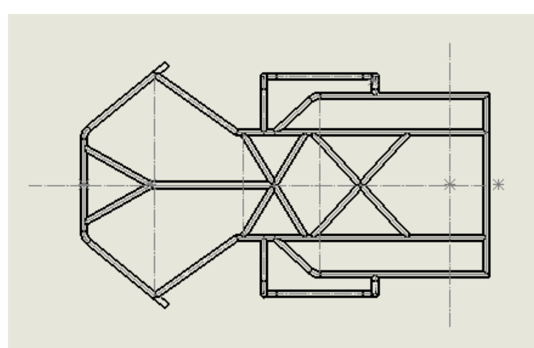

Figure 3. Top View of Chassis frame

2.7 Calculations of Pipe used in chassis

Dimensional Specifications:

Outer Dimension = **25.4mm**

Thickness = **2mm**

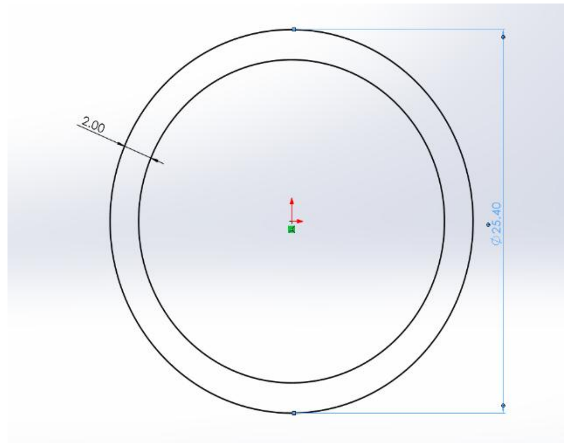

Figure 4. Pipe dimension

Calculations:

1.Bending Strength = My / I

Where, M = Bending Moment

I = Moment of Inertia

Bending Strength

$$= \frac{460 * (25.4/2)}{(\pi/64) * (25.4^4 - 23.75^4)}$$

= 1.213 Pa

2.Bending Stiffness = E * I

Where, E = Elastic Modulus

I = Moment of Inertia

Bending Stiffness

= 210 * (pi/64) * (25.4^4 - 22.67^4)

= 1567.98 * 10^3 N/mm

Volumetric Analysis for 1" pipe and 2mm Thick:

3.Mass Of Chassis = Volume * Density

= π/4 * (0.0254^2 – 0.02267^2) * 7850

= 0.8090 kg/m

3. Result And Discussion

3.1 Meshing

Auto meshing has been done in ANSYS 2024R2 software.

Following data has been found after meshing of chassis:

No. of Nodes = **65517**

No. of Elements = **27532**

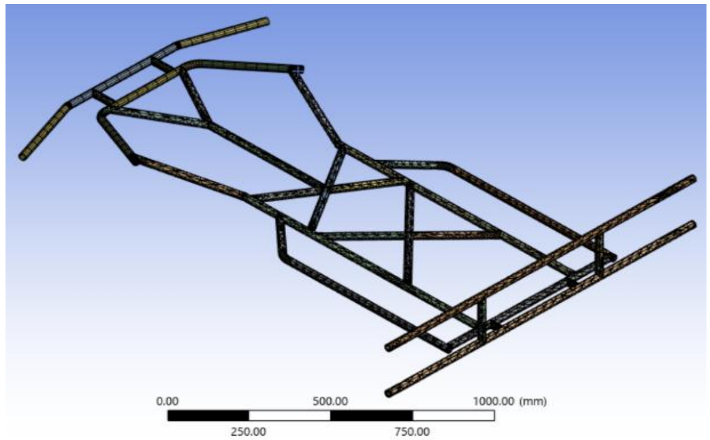

Figure 5: Mesh Chassis

3.2 Impact Analysis

The Impact forces were calculated using Newton's second law which states that the net force acting on a body is equal to the product of mass and acceleration of the body. Force = mass x acceleration.

Force = rate of change of momentum

Impulse = Force x time = change in momentum = mass x change in velocity

3.3 Front Impact

For the front impact, engine and driver load was given at respective points. The kingpin mounting points and rear wheels position kept fixed. Front impact was calculated for an optimum speed of 60 kmph. From impulse momentum equation, 5g force has been calculated. The loads were applied only at front end of the chassis because application of forces at one end, while constraining the other, results in a more conservative approach of analysis. Time of impact considered is 0.2 seconds as per industrial standards.

F x t = mx (Vi - Vf)

F x 0.2 = 180 x (16.38 - 0)

F=**14.7 KN**

Force applied on: Front Bumper

Fixed Position: Wheel mounting positions

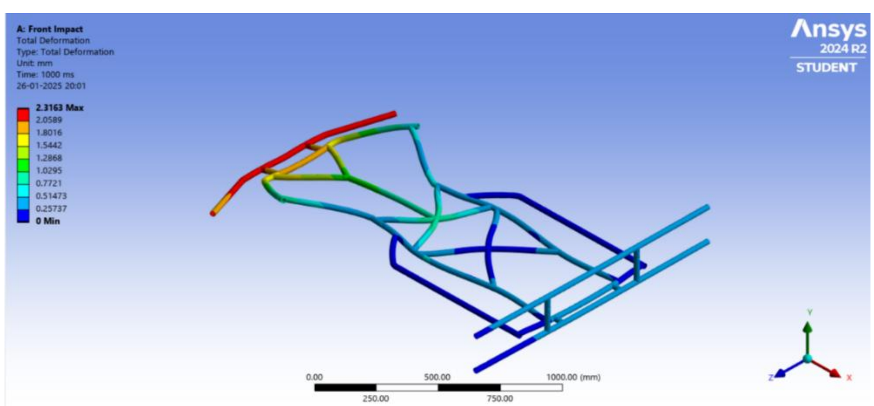

Figure 6: Total Deformation for front impact of chassis

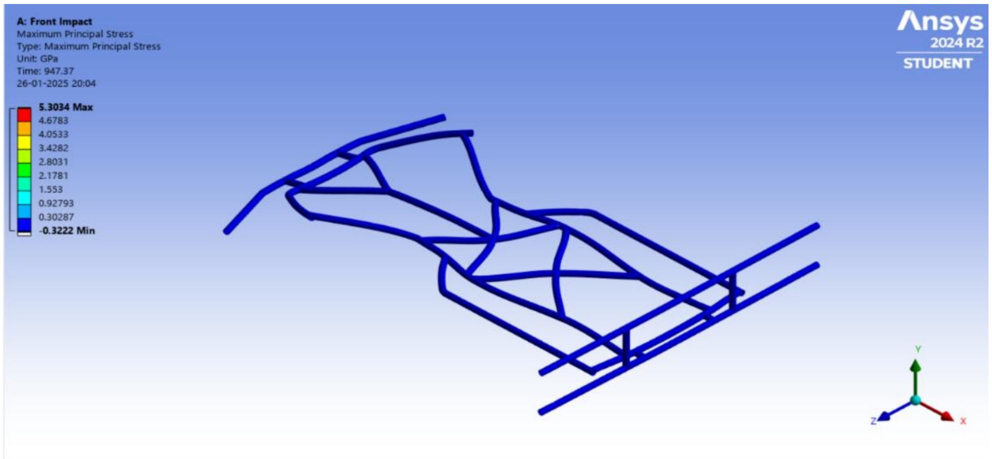

Figure 7: Maximum Principal Stress for front impact of chassis

3.4 Rear Impact:

Considering the worst-case collision for rear impact, force was calculated as similar to front impact for speed of 60 kmph. The value of 3.5g force has been calculated. Load was applied at rear end of the chassis while constraining front end and king pin mounting points. Time of impact considered is 0.2 seconds as per industrial standards.

$$F \times t = m x (V_i - V_f)$$

$$F \times 0.2 = 180 \times (16.38 - 0)$$

$$F = 14.7 \text{ KN}$$

Force applied on: Rear Bumper

Fixed Position: Wheel mounting positions

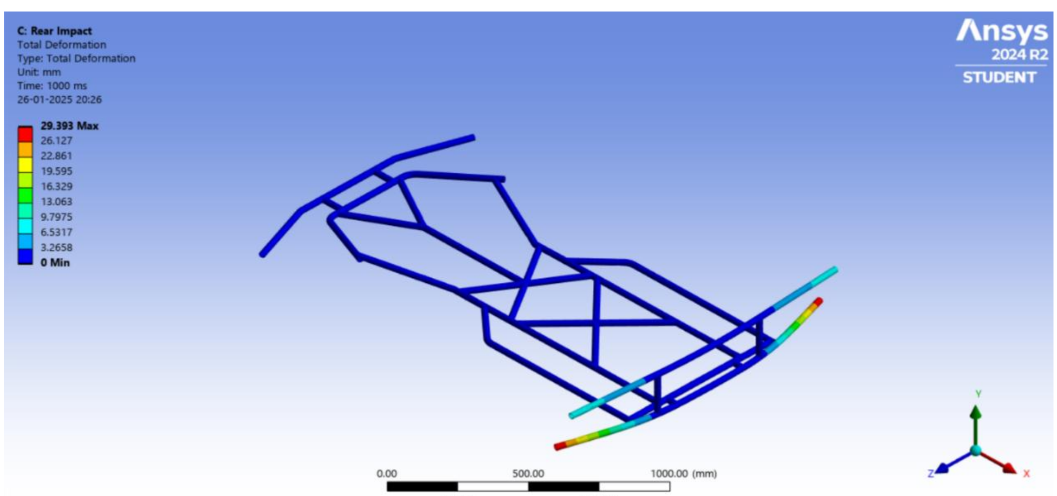

Figure 8: Total Deformation for rear impact of chassis

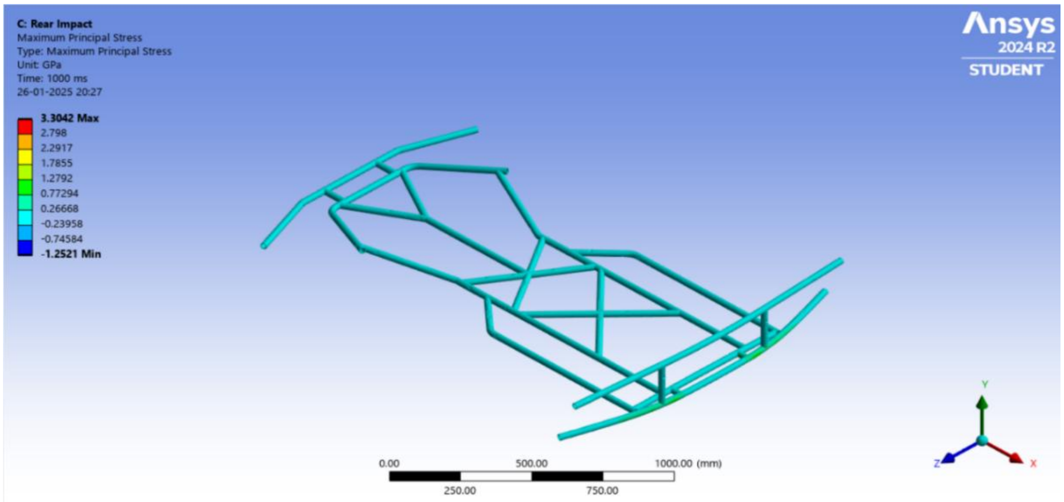

Figure 9: Maximum Principal Stress for rear impact of chassis

3.5 Side Impact:

For the side impact the velocity of vehicle is taken 60 kmph and time of impact considered is 0.2 seconds as per industrial standards. Impact force was applied by constraining left side of chassis and applying load equivalent to 5g force on the right side.

$$F \text{ x } t = m\text{x } (Vi - Vf)$$

$$F \text{ x } 0.2 = 180 \text{ x } (16.38 - 0)$$

$$F=14.7 \text{ KN}$$

Force applied on: Side Bumper

Fixed Position: Wheel mounting positions

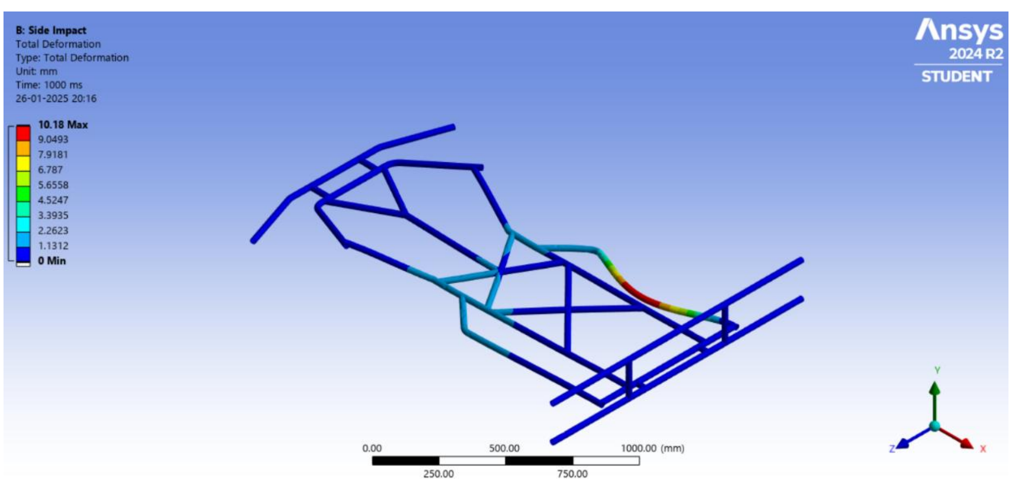

Figure 10: Total Deformation for side impact of chassis

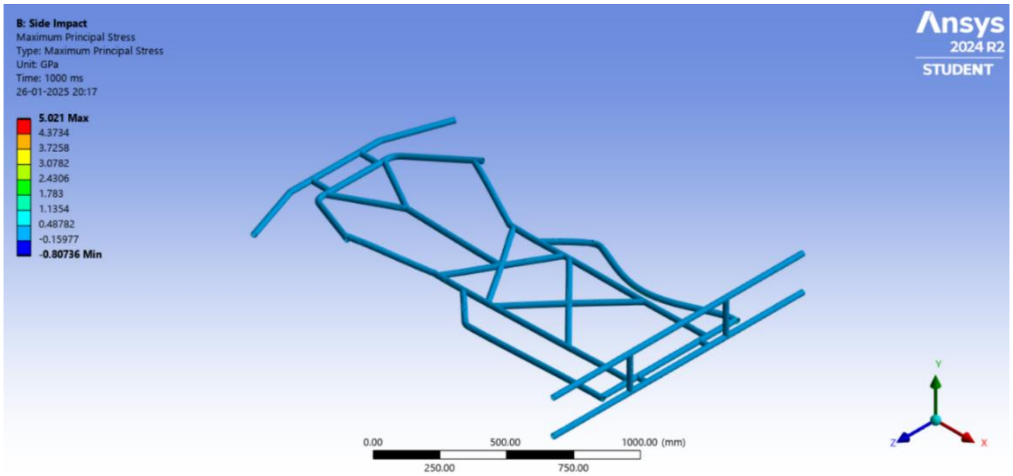

Figure 11: Maximum Principal Stress for side impact of chassis

4. Conclusion

The chassis of a go-kart is the fundamental structural component that directly influences performance, stability, and safety. A well-engineered chassis provides the necessary balance between rigidity and flexibility, allowing for efficient weight distribution and impact absorption. Designed to withstand dynamic forces during acceleration, braking, and cornering, it ensures optimal handling and durability. The choice of materials and fabrication techniques plays a crucial role in enhancing strength while minimizing weight. Additionally, proper alignment, periodic maintenance, and structural integrity checks are essential to ensure consistent performance and longevity in competitive and recreational karting.

The chassis serves as the backbone of a go-kart, connecting all essential components such as the engine, wheels, and suspension system. It plays a critical role in determining the kart's handling characteristics, directly affecting traction, responsiveness, and overall driving experience. A well-designed chassis must accommodate various track conditions and driving styles, offering both stability on straightaways and agility during tight corners. Manufacturers typically use high-strength steel tubing or lightweight alloys to construct the frame, balancing durability with weight efficiency.

The design may include reinforcements in high-stress areas to prevent deformation and enhance longevity. Additionally, factors like chassis stiffness and torsional flexibility influence how the kart reacts to different driving inputs and external forces. Regular inspection of weld joints, fasteners, and structural components is crucial to detect wear and prevent failures that could compromise safety. Proper weight distribution also ensures the kart maintains grip on different track surfaces, reducing the risk of understeer or oversteer. Adjustments to seat positioning, axle stiffness, and wheel alignment can further refine handling performance. In competitive karting, teams often experiment with chassis setups to optimize lap times, tweaking aspects like caster, camber, and ride height. Even in recreational settings, understanding chassis dynamics can help drivers enhance their skills and maximize enjoyment.

Whether for racing or leisure, investing in a high-quality chassis and maintaining it properly can significantly improve the kart's overall performance, safety, and longevity. The performance of a go-kart chassis is also influenced by external factors such as track surface conditions, tire selection, and weather variations. A chassis that is too rigid may struggle to adapt to uneven tracks, leading to excessive vibration and reduced grip, while an overly flexible chassis can compromise stability at high speeds.

This is why racers often fine-tune their chassis setup based on environmental conditions, making small but impactful adjustments to improve handling and responsiveness. Additionally, the chassis design must accommodate different engine configurations, as power output and weight distribution can significantly affect cornering dynamics and acceleration. Advanced fabrication techniques, such as TIG welding and laser cutting, ensure precision and consistency in chassis manufacturing, reducing weak points that could lead to structural failures. Engineers also incorporate aerodynamic considerations, minimizing drag while maintaining optimal downforce for improved traction. In professional karting, chassis homologation standards regulate design specifications to maintain a level playing field among competitors. Whether for casual drivers or professional racers, a well-maintained and carefully selected chassis is fundamental to achieving peak performance, safety, and overall driving satisfaction.

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