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Design and Fabrication of Chassis with Structural System for Student Formula Racing Car

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Abstract— This study highlights the advancements in the development of a race car chassis, which serves as the structural backbone of the vehicle. The chassis plays a critical role in bearing various loads and forces, transferring them efficiently to the ground through the wheels and tires. A key challenge in chassis design is ensuring the proper placement of components to achieve optimal balance. The Formula Student Racing Car project focused on designing and fabricating a chassis that complies with competition standards and safety regulations. Balancing performance and practicality under various constraints posed significant design challenges. One of the main objectives was to construct the body frame of the Formula Student Racing Car through a series of fabrication processes, including cutting, welding, cleaning, and finishing. The final chassis, built using hollow steel bars, successfully met rigorous safety and durability requirements, sustaining no damage during testing. The project's completion within the allotted eight weeks demonstrates compliance with precise specifications, technical standards, and client expectations.

Keywords— Formula racing car, Chassis, Design and fabrication.

I. INTRODUCTION

These days Formula Race Car is the competition that interests many people. Formula Cars have extensive usage around the world. As people know, when people want to join the competition of Formula Cars, the most important part is they must have the car. The required car should have a strong body frame. An automobile's body frame called the chassis, holds the car's sub-assemblies and other parts in place. The chassis also stabilizes the car against the forces and impacts it must withstand over its lifetime. In the case

of passenger cars, the frame's construction is of the body type, and most commercial vehicles, including trucks, are produced with body-on-frame construction. The main reason for inventing these body frames is to make the Formula Car safer, more durable, and also the car's performance. The chassis must accommodate various systems, such as the frame, wheels, brakes, steering, and suspension. To maintain the rigidity of the whole structure, solutions created from expertise and modern engineering capabilities are needed in the manufacturing of a chassis [1].

There are a few key considerations including structural integrity, safety compliance, and manufacturability and cost. For structural integrity, the body frame must be structurally strong to withstand the extreme forces and vibrations experienced during high-speed racing while maintaining the driver's safety [2]. To maintain stability and control, it should be designed to reduce flexing and deformation under load. Other than that, the body frame design must abide by the safety requirements and benchmarks set by the governing bodies of racing. To ensure the driver's safety during collisions or accidents, it should include features like impact-absorbing structures, roll bars, and driver protection systems. Next, the design should be workable for assembly and manufacturing procedures, considering things like cost effectiveness, fabrication methods, and material accessibility. It should balance affordability and performance without sacrificing either safety or quality. Table I shows the summary of benchmarking that had been done with available products [2-3].

Table I. Summary of benchmarking with available products.

			
Product	Ladder frame chassis	Backbone Chassis	Tubular Chassis
Design	Racing car	Racing car	Racing car
Material	Aluminium Alloy	Carbon Steel	Steel
Features	Used in vehicles that need to tow heavy objects around, it is quite heavy.	The cylindrical tube protects the driveshaft from damage, which can also be a drawback	This chassis serves as the foundation for the entire vehicle.
Advantages	-Easier put together because parts can be easily inserted. -The construction method makes it more durable. -Parts are not permanently attached, making repairs simpler.	-The half axle has better ground contact when off-roading because of its design. -Because the chassis protects the driveshaft, off-roading is more likely to be successful. -The structure has better torsional rigidity, allowing it to withstand more twists.	-Its cage like construction makes it safer than either of the other chassis. -The balanced rigidity and weight ratio of this chassis makes the cars stronger and lighter.
Disadvantages	This body frame has weak torsional rigidity, making the car bad for cornering. It is heavyweight, which makes it not ideal for hatchbacks	If the driveshaft breaks, it must be opened because the main chassis surrounds the entire shaft, making repairs difficult. The cost of making the backbone chassis is quite high, which drives up the price of the cars they are in.	Mass production of this chassis is impossible because it takes a long time to fabricate. Tubular frames are complicated.

Creating a body frame design for a high-speed racing car is a complex and intricate process that requires meticulous attention to detail. It is crucial for engineers and designers to work hand in hand to ensure that the design not only meets the necessary safety standards but also provides the optimal combination of strength and feasibility. The lightweight and aerodynamic qualities of the body frame are also crucial for enhancing the car's performance on the track [4]. Collaboration between different departments, including research and development, engineering, and design, is essential in ensuring that all aspects of the design are carefully considered and integrated. Additionally, constant testing and refinement are necessary to fine-tune the design and make sure that the racing car is competitive in the high-speed racing environment. Overall, creating a successful racing car body frame requires a combination of expertise, innovation, and teamwork to achieve the desired performance and safety standards.

Therefore, a new project should be invented to solve the current problem to make the drivers of the Formula car race safer. The main criteria of an invention must follow the latest era and technology. In addition, for the driver to give the best performance during the race competition, they must have a good machine and their car's power. So, they can't win the race with bad body frames and also the car that may cause accidents and other things that we do not want to happen [5]. However, this project needs solid body frames for the formula car race to make sure that the driver is safe and can win the race with a good chassis. This project aims to develop a solid body frame to ensure the car is durable, safe, and solid during the race

competition. It will also be cost-effective and affordable for the user to produce or buy this chassis. The maintenance cost is also low, so it is suitable for students and affordable to maintain.

II. METHODOLOGY

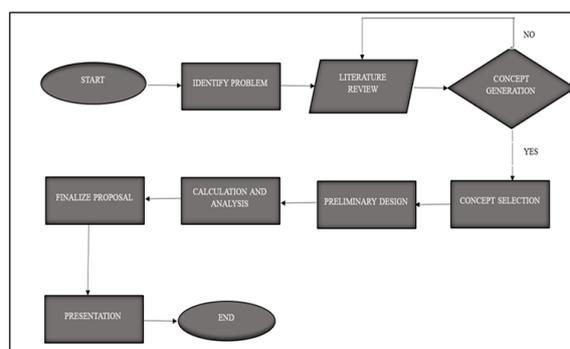
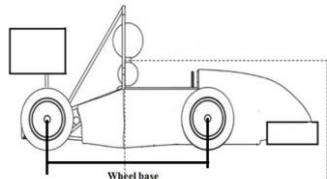


Fig. 1. Project Flowchart.

Figure 1 depicts the organized procedure for creating and developing a Formula One car, highlighting the methodical steps necessary for engineering such a sophisticated project. The process starts with pinpointing the issue, in which engineers outline the specific objectives, obstacles, and requirements for the Formula One car, such as improving speed, aerodynamics, safety, or adhering to regulatory standards. After defining the problem clearly, the next phase involves a literature review, where researchers examine existing technologies, prior designs, and scientific concepts related to automotive engineering. This stage is vital for acquiring knowledge and preventing duplication by learning from earlier designs and studies.

After completing the literature review, the team transitions into the concept generation phase, where they brainstorm and create various ideas or possible solutions for the car's design. These ideas are then assessed in relation to the project's requirements and limitations. Table II shows the general specifications for the chassis design that obtained from the race organizer. Should the concepts generated prove inadequate or inappropriate, the process reverts for additional brainstorming. Once a viable concept is recognized, the team moves on to concept selection, where they thoroughly evaluate and select the most promising idea for further development based on criteria such as feasibility, cost, and performance potential.

Table II. Chassis general specifications.

Item	Description
Vehicle Configuration	An open-wheeled, single-seater, open-top racing vehicle.
Chassis main frame	The main frame must be a space frame tube construction, with the engine vehicle at the rear of the driver. Construction materials from monocoque (carbon fiber) are allowed for the driver's cockpit. However, the main frame must be built from iron metal as the basic material
Maximum length and Width	Maximum length does not exceed 3500 mm, with a maximum width of 1800 mm.
Minimum length and Width	Minimum size is 2300mm long and 1500mm wide
Maximum Height	1600mm
Weight	Minimum weight of not less than 200kg (The vehicle only)
Roll Loop Structure	The chassis must include the main loop and the front loop as purpose of the safety structure is to protect the driver. The loop design must be incorporated into the chassis design.
Wheelbase	Vehicles should have a minimum estimated wheelbase of 1600mm to 1900mm. 

Once a concept has been selected, the subsequent stage is the preliminary design, in which the chosen idea is transformed into an initial design model, frequently utilizing computer-aided design Solidwork. This stage comprises rough sketches, fundamental calculations, and initial simulations to evaluate the feasibility of the design. After establishing the preliminary design, the team conducts calculations and analysis, which includes thorough simulations, stress assessments, aerodynamic modelling, and performance evaluations to ensure the design complies with the necessary standards and enhances performance.

The procedure then transitions to finalizing the proposal, where the enhanced design is thoroughly documented, encompassing all specifications,

materials, and manufacturing methods. This proposal acts as the foundation for the car's development and guarantees that all parties agree regarding the design's goals. Ultimately, the completed proposal is presented during the presentation phase to stakeholders, such as team executives or investors, where the team highlights the design, clarifies its advantages, and obtains approval to proceed with production. The process wraps up in the final stage once the design receives approval and is set for implementation.

This methodical approach guarantees a comprehensive and repetitive development procedure, harmonizing innovation with analytical precision to create a Formula One car that fulfils both performance and regulatory standards while incorporating the most recent advancements in engineering.

A. Detail Drawing

The assembled chassis design is illustrated in Fig. 2. It shows the final design selected as the concept and design selection of a product body frame for the formula race car. The shape of the metal is a hollow metal bar. This is because the shapes are more solid than other shapes. It is also safer and more durable for the driver and for the car itself. For the front part, it is designed for aerodynamic shape and safety for the driver if there are any accidents. The back part is used to place the drive shaft and also the engine of the car. In the middle, the driver will sit there. The final design is expected to be fabricated with affordable cost, high safety, and can function well.

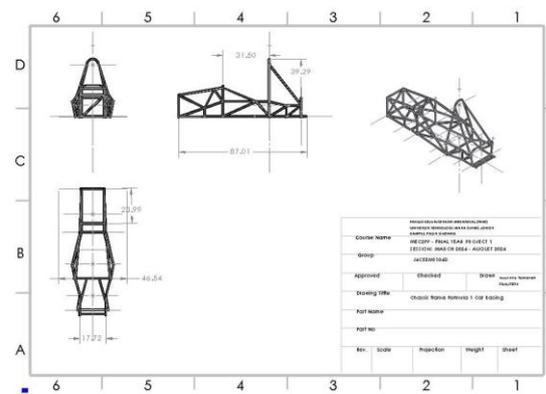


Fig. 2. Assembly drawing.

Figure 3 shows the stress results of the base of the product being sat while the driver is driving the car. The load of the driver is equal to 90 kg. The part that is stressed is the middle base of the body frame. This figure shows the body frame is safe enough for the driver. Notably, it provides an optimal balance between structural strength and lightness—both critical for maximizing vehicle performance. The frame's cylindrical configuration improves aerodynamic efficiency by minimizing drag and enhancing speed, while also facilitating seamless integration with major components such as the engine, suspension, and wheel assemblies.

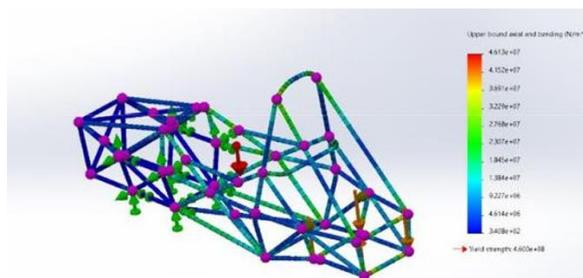


Fig. 3. Design analysis.

B. Fabrication Process

The initial stage of fabrication involves accurate measurement. To minimize material waste and ensure precision, materials for the Formula One chassis must be measured carefully before cutting. Engineers begin by marking the raw materials in accordance with the design specifications, utilizing tools such as measuring tapes, calipers, and rulers. To avoid errors, all measurements are double-checked against the original drawings. This thorough approach ensures that each part aligns perfectly during assembly, maintaining both the structural strength and performance of the chassis while optimizing material usage.

The subsequent step in the fabrication process is cutting. This involves using a grinding machine to accurately cut hollow steel tubes according to specified dimensions as shown in Fig 4. These tubes serve as vital structural components in the construction of a Formula One chassis, contributing to internal reinforcement and supporting critical systems such as the suspension, engine, and safety assemblies. The cutting process ensures that each tube is shaped and sized with precision, allowing for seamless integration into the overall chassis framework. Given the high-performance demands of Formula One vehicles, where both accuracy and weight optimization are crucial, all cuts must meet tight dimensional tolerances.

The next stage in the fabrication process involves bending the pre-cut hollow metal bars, as illustrated in Fig. 5. Bending is a critical operation in the construction of a Formula One chassis, particularly for forming structural elements that require specific curves or geometrical configurations to accommodate the design constraints of the vehicle. This step ensures that each component conforms precisely to the chassis's aerodynamic, structural, and functional specifications.

Following bending, the Gas Metal Arc Welding (GMAW) technique is employed to join the hollow metal bars. This welding process is essential for assembling the pre-shaped components into a cohesive and robust frame. It ensures strong, accurate connections that are vital for the chassis's structural integrity. While the Formula One chassis predominantly utilizes hollow steel bars in its monocoque design, welding is especially important in areas requiring additional reinforcement—such as suspension attachment points, load-bearing zones, and safety-critical sections.



Fig. 4. Cutting process.



Fig. 5. Bending Process.

C. Functionality of Prototype



Fig. 6. Body frame of Formula race car.

The completed Formula Student race car's body frame is shown in Fig. 6, marking an important turning point in the vehicle's development. An integral part of the vehicle's structure, the body frame is responsible for supporting the driver, engine, suspension, and other critical parts. According to the statement, extensive testing and evaluations were conducted on the finished body frame to guarantee its functionality and operational effectiveness. This suggests that the frame's construction and design have successfully complied with the requirements, enabling the car to carry out its intended functions.

Moreover, the race car's body frame has been created to fit not only the driver but also other essential parts. This is crucial for the vehicle's overall functionality and integration, making sure that every component functions as a whole to provide the best possible performance. The mention of strength and durability testing means that the built-in body frame has been examined to confirm that it is solid and can endure a range of forces and stresses while in use. The fact that these tests produced no issues implies that the

frame has either fulfilled or exceeded the planned requirements for strength and durability. As a result, Fig. 6 presents the finished body frame of the Formula Student race car, emphasizing its durability through extensive testing, functionality, and compatibility with other parts. The constructed body frame's quality and dependability are further proven by the favorable results of the durability and strength assessments.

III. RESULT AND DISCUSSION

A. Final Fabricated Prototype



Fig. 7. Comparison from the design and final fabricated chassis.

During each stage of the product design process, including initial testing for functionality, compatibility, and durability as well as subsequent assessments to make sure the design complies with technical specifications, a final working prototype is produced. Figure 7 displays from the initial fabricated product up until the completed product with all of its components assembled. In SolidWorks, the end product almost exactly matches the original design at the start of the project.

B. Advantages, Disadvantages and Sustainability of Prototype

In the development of any new product, the goal is to incorporate various advantages while addressing the shortcomings of existing designs. Over time, technological advancements contribute significantly to overcoming these limitations. A key strength of the product development process lies in its potential for continuous innovation, allowing designers to stay competitive in the market. However, refining and resolving issues during the development phase demands significant effort, particularly when early prototypes exhibit flaws.

Product advantages refer to the value a product offers in fulfilling customer needs, preferences, and functional objectives. In the case of the Formula Student race car chassis, several notable benefits are evident are: 1) Durability and safety: This chassis emphasizes both structural strength and safety. Its design follows the principles of a Formula One vehicle, incorporating a front crash box to absorb impact in the event of a collision. Furthermore, the use of hollow steel bars—a material known for its high strength and durability—ensures the integrity of the structure. The width and base dimensions are also carefully considered to maintain stability and driver protection during racing conditions. 2) Low cost - the chassis is designed with affordability in mind, using

cost-efficient materials and minimizing unnecessary components. This results in reduced fabrication expenses while still meeting performance requirements. 3) Easy to maintain - the structure requires only periodic inspection for signs of rust and routine cleaning. Maintenance is straightforward, making it user-friendly for students or teams with limited technical resources.

While these features provide substantial benefits, it is also important to acknowledge and address the product's limitations, as the absence of certain features can hinder its overall effectiveness and user appeal. Identifying such drawbacks is essential for improving design standards and future iterations. The following are the disadvantages of this Formula Student Race Car body chassis: 1) Size: The chassis has a relatively large footprint, which can pose challenges in confined environments. Its dimensions may result in inefficient use of space, requiring careful consideration when storing or transporting the vehicle. 2) Maintenance: As the chassis is constructed from steel, it is prone to corrosion, particularly in areas exposed to moisture. Regular upkeep is necessary to prevent deterioration, which could be financially burdensome over time. 3) Difficult to fabricate: The chassis's shape and dimensions increase the difficulty of the manufacturing process. Its design demands skilled labor and precise techniques, leading to longer production times and limiting the feasibility of mass production.

In designing the body structure of a Formula Student vehicle, several key factors related to sustainability and ergonomics must be considered. These include ensuring driver safety and comfort, employing sustainable manufacturing processes, selecting recyclable or renewable materials, minimizing weight through material choice, and optimizing aerodynamic performance. Addressing these aspects not only enhances the performance and usability of the vehicle but also aligns with modern engineering practices that emphasize environmental responsibility and human-centered design.

C. Prototype of Maintenance

To ensure the Formula Student race car maintains optimal performance, it is essential to establish a systematic maintenance schedule along with a defined service life or expiration timeline. Fortunately, the maintenance procedures for this vehicle are straightforward and easy to implement. In particular, routine inspections are strongly recommended in the week leading up to any competition, involving detailed checks of all major components to identify potential issues.



Fig. 8. Maintenance routine.

Basic weekly maintenance, such as wiping down the chassis with a clean cloth, further demonstrates the simplicity of upkeep as shown in Fig 8. Storing the vehicle indoors and using a protective car cover also helps shield it from environmental exposure, thereby extending its lifespan. These accessible and effective maintenance practices highlight the user-friendly nature of the chassis design, allowing race teams to sustain high performance and reliability with minimal effort.

IV. CONCLUSION

The successful completion of the Formula Student Race Car body chassis as a senior project demonstrates the achievement of its primary objectives. The project was meticulously completed within eight weeks, meeting all technical requirements as well as relevant standards. The final product highlights the importance of user satisfaction through its numerous advantages—it is exceptionally safe, durable, and high-performing. With these qualities, the product is expected to attract strong sales, particularly among consumers interested in racing events, and has the potential to achieve significant recognition and success.

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Hazim Sharudin: Conceptualization, Writing – Original Draft Preparation; Ab Aziz bin Mohd Yusof: Writing – Review & Editing; Nurul Anis Farhanah binti Faizal: Design and Methodology, Chassis Fabrication and Testing, Data Collection and Analysis.

CONFLICT OF INTERESTS

No conflict of interests was disclosed.

ETHICS STATEMENTS

Our publication ethics adhere to the guidelines established by the Committee on Publication Ethics (COPE)

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