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A Methodological Study to Analyze and Design the Car Chassis

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Abstract: The car's chassis is also called a structure that locates and mounts all the vehicle's components. It also creates a secure environment for the occupants. The chassis will provide torsional and flexural rigidity to the vehicle that makes the chassis one of the most crucial elements of the vehicle. Therefore, the front impact, rear impact, side impact, front torsional, rear torsional, vertical bending, lateral bending analyses were performed. The contribution of chassis is not limited to supporting the vehicle's component, but it extends to providing better performance and aesthetics. Therefore, the design of the car chassis must be done accordingly. The current paper deals with the study of the design and analysis of the race car. The deformation, stress, and Factor of safety were considered as the evaluation parameters which were obtained by Finite Element Analysis (FEA) in Ansys software. To design the chassis, the SolidWorks software was utilized.
Keywords: Car Chassis, Design, FEA, Material Comparison.

I. INTRODUCTION

A pressed-steel frame—the vehicle's chassis—formed the backbone on which the engine, wheels, axle assemblies, transmission, steering mechanism, brakes, and suspension parts were attached in most passenger automobiles through the middle of the twentieth century. During a manufacturing procedure known as body-on-frame construction, the body was flexibly fastened to the chassis. This approach is still used today for heavy-duty vehicles like trucks, which benefit from having a strong central structure that can withstand the stresses required in activities like hauling freight, as well as the absorption of engine and axle movements made possible by the combination of body and frame. The example of the chassis is shown in figure 1. The example figure was taken from Autodesk online gallery [1, 9].

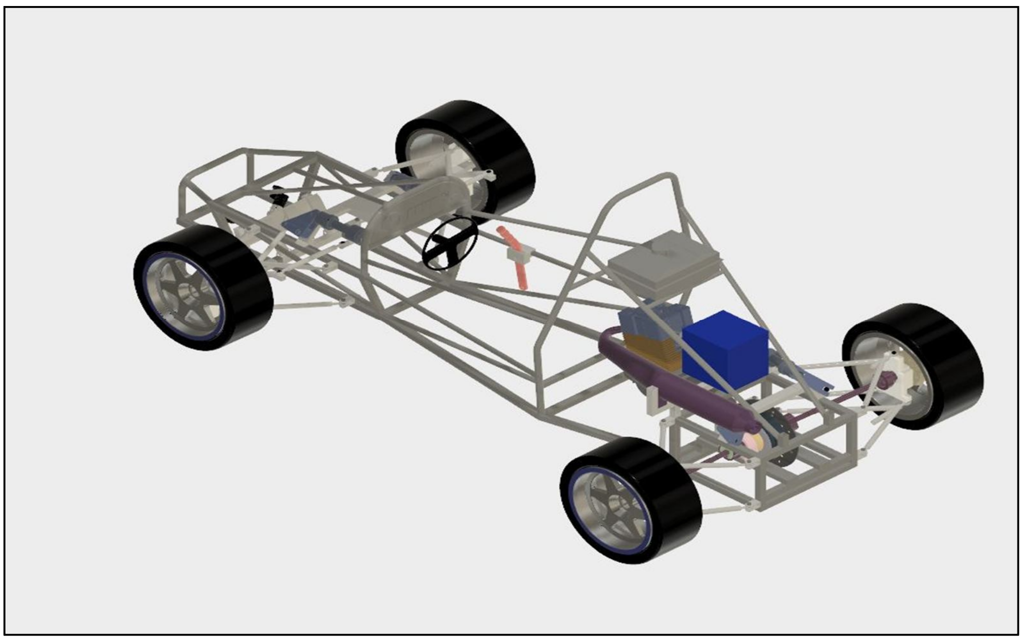

Figure 1: Racecar chassis

The chassis frame and the body are merged into a single structural piece in modern passenger automobile designs. The steel body shell is reinforced with braces in this design, known as unit-body (or unibody) construction, to make it robust enough to withstand the pressures applied to it. Some cars have used separate frames or partial "stub" frames to obtain greater noise-isolation qualities. In addition, the heavier-gauge steel used in newer component designs absorbs energy during collisions and limits infiltration in accidents. The present study deals with the design and various static structure analyses under finite element analysis of the race car chassis in the Ansys software which was 3D modelled in the SolidWorks software [2].

II. LITERATURE REVIEW

Edmund F. Gaffney et al. [3] discussed some of the fundamental aspects of suspensions and frame design, as well as the team's strategy to designing its 1996 suspensions and chassis. The frame's job is to interconnect the front and rear suspensions while also providing connection points for the car's many components. Inconsistent handling can be caused by relative motion between the front and rear suspension attachment points. The frame must also include attachment locations that will not yield within the performance envelope of the vehicle. The suspension is designed to keep all four tyres flat on the ground throughout the vehicle's performance range, citing the necessity of rigidity in chassis design. Suspension systems are typically constructed with the premise that the frame is rigid. They discovered that a chassis that is stiff enough for the competition will not yield in the majority of circumstances. When subjected to design loads, however, some caution should be exercised to ensure that the frame's connection points do not yield. The engine mounts, for example, should be sturdy enough to limit the risk of failure. The study by Lozica Ivanovic, et al. [4] demonstrated the design of a Formula student frame as well as the analysis of the frame using the finite element method. Industrial design, they explained, is a creative activity whose purpose is to determine the formal quality of industrially produced objects. The outside shape is included in these formal features, but they specifically pertain to structural and functional parts, as well as the relationships between them, that one system creates in the entire assembly. They discovered that choosing the exterior proportions and design, as well as their compliance with all components, was critical not just for aesthetics but also for the vehicle's performance (aerodynamic, stability control, speed and acceleration). The procedure of producing the Formula student frame was discussed in the study. After the frame had been physically constructed, an experimental torsional stiffness test was performed, and the precise value of torsional stiffness was determined. The frame was subjected to dynamic frequency analysis.

The goal of David Rising, et al [5] study was to estimate the risk of injury to the driver in a Formula SAE race car after a frontal collision. The use of an impact attenuator to absorb energy in the case of a front hit is required by FSAE guidelines. These guidelines required a maximum deceleration of 20 g from a speed of 7.0 m/s (23 ft/s) but did not define a specific time or pulse structure of the descent. An early high-g pulse, a constant-g pulse, and a late high-g pulse were all tested in this study. The tests were carried out at Crash Safety Centre utilising a deceleration sledge. The driver's risk of injury was investigated in terms of neck and femur loads, head and chest accelerations, and kinematic analyses utilising high-speed video. The experiments were conducted again, this time with and without the use of HANS's device. P.K. Ajeet Babu, et al. [6] compared chassis types by evaluating them and establishing benchmarks; tubular space frame chassis are chosen by formula student teams. The torsion resistance of a ladder chassis is quite low. For businesses and manufacturers, self-support chassis is ideal for bulk production. Two of these types are useful for hand-built automobiles, such as Formula Student: space frame and monocoque. Monocoque chassis is extremely robust and lightweight. However, its complicated structure and high cost are negatives. Even while space frame constructions are slightly heavier than monocoque buildings, they are still considered light. Acceleration was critical in Formula Student races. Furthermore, the ability to hold the road must be as high as possible. In light of these considerations, space frame chassis proved to be the most practical chassis type for Formula Student teams. Singh [7] presented several concepts related to frame load distributions and deformation modes. Analytical calculations of static and dynamic load distributions were followed by a thorough examination of possible boundary conditions to be used throughout various FEA testing. Stress distributions and lateral displacements in static, dynamic, and frequency modes were investigated, and a significant factor of safety was discovered as necessary. He found that depending on the application of loads and their direction, the chassis is deformed in the following ways: Longitudinal, Lateral, Vertical, and Horizontal bending. He found that provided the torsional and vertical bending stiffness are acceptable, the chassis structure should function well. Following his research of the literature, it was discovered that FSAE car parts are often intended to endure 3.5 g bump, 1.5 g braking, and 1.5 g lateral forces. These loads must be assessed separately and in combination. Later on, He calculated an individual and overall load of numerous components, as well as the car as a whole. The baseline material used by Mohamad, et al. [8] for the Formula Student competition was steel, and the standards and rules governing alloy steels were followed. It was also feasible to employ a different material, but the other frame rules had to be addressed. For the usage of alternative materials, there are many more guidelines, regulations, and testing that must be completed. Steel and composite are the most popular chassis materials in Formula Student. More than half of teams employ steel for their chassis, despite the increased use of composites. Although aluminium has the advantage of being lighter than steel and less expensive than composite, it was extremely difficult to find aluminium that met the standards' requirements. And, to give suitable stiffness, greater sizes of aluminium must be employed, which makes aluminium an inconvenient choice. As the quantity of material increases, so does the price. For teams, a composite chassis is an excellent choice. Composite monocoque chassis is difficult to get rigid due to their small weight. However, the material proved prohibitively pricey.

The most practical option was to build a space frame chassis out of steel. The tubes were simple to machine and prepare. It's possible that production won't necessitate a complicated fixture. Any post-processing was unnecessary because the right material was used. After all, steel is inexpensive and readily available.

III. METHODOLOGY AND RESULTS

The methodology of the study is explained in the present section.

A. Design

The design specification of the vehicle of the car is demonstrated in Table 1. The design was made as a 3D model into SolidWorks software. The space frame chassis design was chosen over the monocoque chassis design. Aside from being heavy, the space frame chassis is cost-effective to manufacture, and any structural damage or poor alignment may be easily remedied. The design process began with the creation of the cockpit area. The Front Hoop, Side Impact Structure, and Main Hoop were all designed in accordance with the driver's requirements and the typical 95th percentile Male Percy. The suspension and steering points were taken into account when designing the Front Hoop. The Main Hoop was designed to have a space of at least 50.8mm between a 95th percentile male's helmet and a straight line drawn from the top of the main hoop to the top of the front hoop.

In the cockpit area, a battery and fuel tank were also to be fitted. The height of the Front Bulkhead was determined by the length of the driver's legs and the position of the pedal box. The suspension points on nodes are held in place by the supports between the front bulkhead and the front roll hoop. For node connections, triangulation (truss) was utilised. The frame structure was built using triangulation to add strength and support. Triangulation is the use of triangle shapes to provide structural stability. It is especially relevant to pin or hinged structures. When a force is applied, these structures usually offer no resistance to bending moments. Members who are attempting to resist bending do not require as much strength. This connection mechanism distributes the force concentration among numerous members, preventing any single member from failing.

Table 1: Specification of the design

Chassis	Weight	32 KG
Engine	Model	Honda CBR 600f4i
	Displacement	600 cc
	Max power	92 HP
	Max torque	60NM
Vehicle Dimensions (mm)	Wheelbase	1727.13
	Front track width.	1200
	Rear track width.	1150
	Ground clearance	60

B. Material Selection

AISI 1018 material was to analyze the car chassis. During motion, the chassis is subjected to a variety of forces. As a result, a material that helps the chassis stay together without yielding is stiff enough to absorb vibrations, and can withstand high temperatures is essential. The property of the materials is shown in Table 2.

Table 2: Material Properties

Sr. No.	Properties	AISI 1018
1	Density [kg/m^3]	7.8
2	Young's Modulus [GPa]	210
3	Brinell Hardness	120
4	Yield Strength [MPa]	360
5	Ultimate Strength [MPA]	420
6	Strength to weight ratio [KNm/Kg]	55-60
7	Cost per meter	250
8	Elongation at break [%]	19

C. Finite Element Analysis

The Finite Element Analysis (FEA) was performed in Ansys software. The Static Structure Analysis was performed for the study purpose. The force was taken as the input whereas stress, deformation, and Factor of Safety (FOS) was taken as the output. The front impact, rear impact, side impact, front torsional, rear torsional, vertical bending, lateral bending analyses were performed.

For loading conditions, the maximum allowable speed of the formula student vehicle was taken i.e., 60 km/hr. The mass of the vehicle was considered as 350 kg. The time of impact collision was taken as 0.3 seconds. Then to evaluate the acceleration, equation (1) was used. Where, V_f is the velocity of the vehicle after a collision, V_i is the initial velocity of the vehicle, a is the accretion and t is the time taken for impact. Now, to evaluate the force, equation (2) was used. Where F is the force and m is the mass. Using the same force was obtained as 16668 N. Then, the G force was calculated using equation (3) i.e., 5.66. After the calculations, it was noted that in order to analyze the chassis in many aspects, a standard 6 G load will be imposed.

$$V_f = V_i + a \times t \tag{1}$$

$$F = m \times a \tag{2}$$

$$G = \frac{F}{m \times 9.81} \tag{3}$$

D. Boundary Condition

The boundary conditions for front impact analysis were by constraining rear suspension points and applying the load to the four nodes. The force applied was 5150.25 N on each node of the front bulkhead (The wight of the vehicle is 350 kg and 6G force to be applied. Afterwards the load is distributed into 4 nodes). The same is applied for rare impact analysis at the rare side of the structure. For side-impact analysis, the load is at the outermost members of either side, and the front and rear suspension points are restricted.

For front torsional analysis, the force is halved to 3G at each side because the car's weight distribution is estimated to be 45-55 percent. The four nodes on one side of the front suspension will be subjected to upward force, while the four nodes on the other side will be subjected to downward force. The load is applied to the front suspension points and the rear suspension points are fixed in this form of study. The same applies to the rear torsional analysis.

For static vertical bending analysis, along with the driver and engine compartment, a force of 3430 N is delivered vertically down. During this analysis, the front and rear suspension points are constrained. Whereas, for lateral bending analysis, the front and rear suspension points are limited, and the chassis is under load. The output i.e., deformation, stress, and Factor of safety for all the analyses are demonstrated in Table 3.

Table 3: Results of the Analysis

Type of Analysis	Deformation (mm)	Stress (MPA)	Factor of safety
Front Impact	7.345	142.34	2.95
Rear Impact	3.045	255.45	1.64
Side Impact	11.102	287.76	1.46
Front Torsional	23.680	259.78	1.62
Rear Torsional	12.340	268.66	1.56
Static VerticalBending	0.293	147.25	2.85
Lateral Bending	2.612	291.01	1.44

IV. CONCLUSION

The present work deals with the study to analyze and design the race car chassis. In order to achieve the objective, the front impact, rear impact, side impact, front torsional, rear torsional, vertical bending, lateral bending static structural analyses were performed in ANSYS. The main objective of the study was to achieve high torsional rigidity considering the driver's safety into account. After performing the stated analysis, the objective of the study was successfully achieved with the fact that the design of the chassis was found to be safe. The stress evaluated during all the analysis was within the permissible limit. In addition, the minimum factor of safety was 1.44 during lateral bending analysis, whereas, the maximum factor of safety was 2.95 during the front impact analysis.

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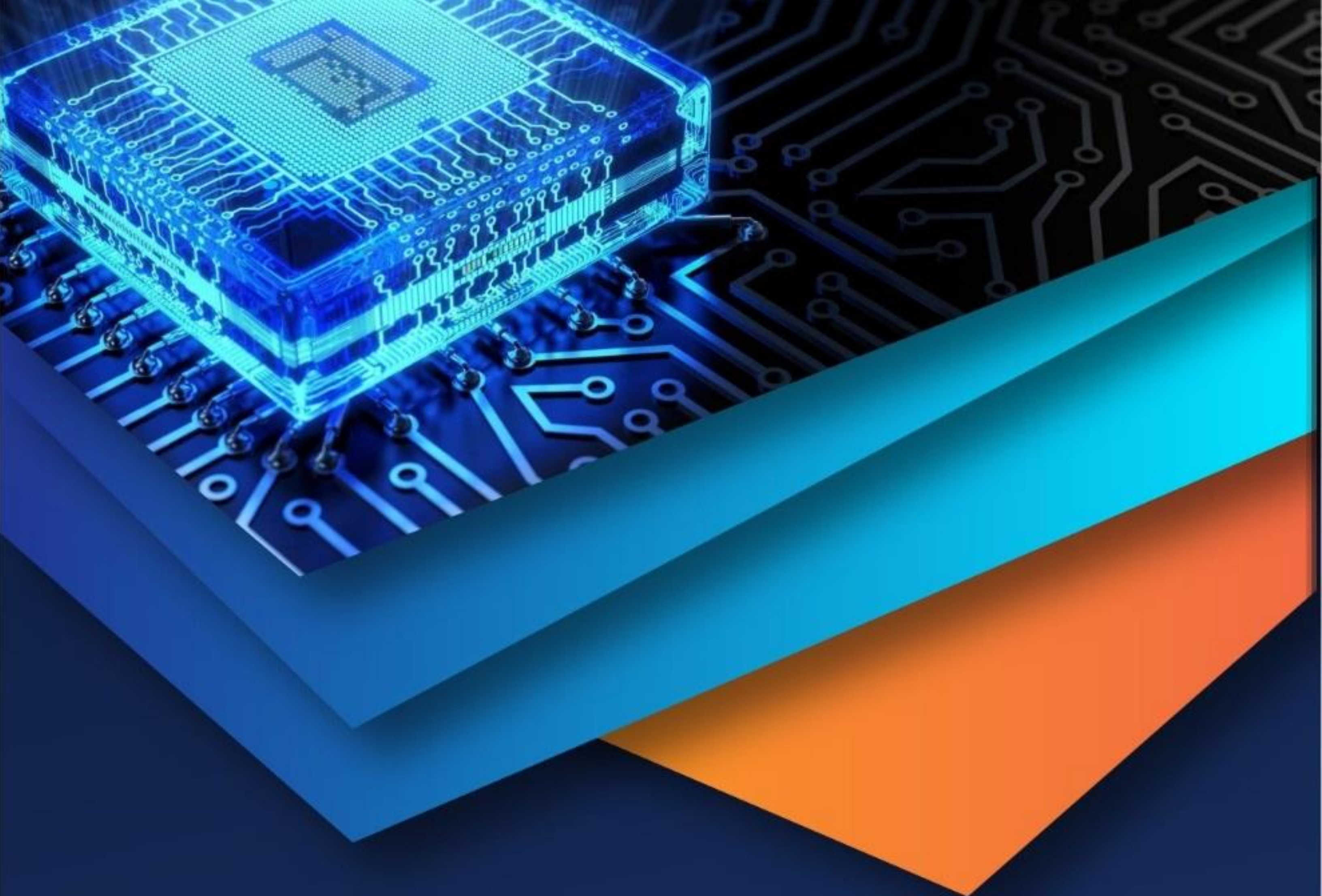

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