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DESIGN & MANUFACTURING OF FSAE CHASSIS

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ABSTRACT

The report provides a thorough set of procedures and activities leading to the design and development of the chassis and bodyworks of a Formula Student racing car as per the guidelines of the 2020 FORMULA SAE RULEBOOK.

A design methodology for the development of a Chromoly AISI-4130 mild steel space-frame chassis based on structural analysis and ergonomic considerations was implemented. Torsion analyses were carried out to achieve a fail-safe design by understanding the substantially increased forces that act on the chassis.

The commercial Finite Element Code of ANSYS® & SIMSCALE® was utilized to perform structural analysis. After proper validation through simplified models and analytical comparison, the 1-D beam model was analyzed and the results were compared with the theoretical equations. The same parameters were used to analyze the 3-D model and the stress & deformation contour plots were obtained. Material selection was considered as per the guidelines and AISI-4130 was selected. CAD modeling was done using SIEMENS NX-12® modeling software and several design iterations were performed to determine the best compromise between vehicle mass, component packaging, and weight distribution while ensuring driver's safety at all times.

Finally, ergonomic principles of anthropometry were utilized to optimize the human-machine interaction according to 95 percentile male analysis was performed to ensure the driver's comfort

I. INTRODUCTION

Formula Student (FS) is international auto-racing competition started to foster university students under the framework of a semi-professional engineering motorsport competition. By participating in these competitions, students can enhance their engineering and Marketing skills while attempting to deliver a racing car to compete with others from different engineering institutions [1].

The word chassis is used in different context by different authors and engineers at different times discussed by Aird in the book "The Race Car Chassis" (Aird, 1997) [1]. In 1970s, when coachbuilders were used in the automobile, the term "chassis" was often used to describe the frame, engine, and suspension as one single and complete unit. Essentially it described everything in a car excluding the bodywork and cabin. In some other contexts "chassis" defines only the frame of the car with the suspension and power-train being considered entirely separate items. This latter interpretation of the word is what is used throughout this project, where the terms "chassis" and "frame" mean the same thing are interchangeable. When defined as above, a chassis is a component in a car that everything else attaches to.

A monocoque chassis uses the body part as the load-bearing component and means that no separate chassis structure is needed. Rather than specific members, Entire panels carry the load, which means that a higher polar moment of Inertia (about the axis running from the front to the rear of the car) is achievable. A high polar moment of inertia about the rolling axis is a desirable property for a chassis as it is directly related to torsional stiffness. [Aird 1997]

The drawback of a monocoque chassis is that they can't be used for prototype purpose and not compatible with the small production cars, which is why a monocoque will not be used in this project

Tubular Frame Chassis:

Motor racing engineers decide to design a 3D structure as ladder type frame has bending and low performance in the racing. This type of frame chassis is composed of many circular-section tubes positions triangulated in a different direction to provide mechanical stiffness against dynamic & static forces from tyres different loadings and acts mainly in tension and compression.

In the early 50s, Mercedes-benz Design & Develops a racing car 300SLR using tubular space frame. This was world's first tubular space frame chassis racing car, 300SL Gullwing. Sill reduced the accessibility of the cockpit (cabin) up to high extent , Mercedes extends the doors to the roof so which created the "Gullwings". From the mid-60s, many high-end sports cars as well as the student racing competitions have also adopted tubular space frames to enhance the rigidity/weight ratio.

II. STRUCTURAL REQUIREMENTS

The structural requirements of the vehicle structure frame can be summarized as follows:

1. The structure must be sufficiently stiff to react to the static loads (i.e. mainly due to dead-weight) and dynamic loads (i.e. mainly due to driving over rough terrain and handling maneuvers) without excessive deformation.

2. The structure must be sufficiently strong to bear cyclic loadings without suffering from fatigue or other forms of material failure.

3. The structure should deform in such a manner under impact load conditions so as to maximize the energy absorptions in the deforming part and minimize the risk of injury to the occupants and other road users.

The first job of any vehicle structure designer is to ensure that requirement 1 is met since this is critically dependent on the overall structural layout and determines how the vehicle will handle during normal and extreme maneuvers. Basically, in order for the suspension system to perform the tasks it is designed for, it is mounting points should remain as stationary concerning the vehicle axis system as possible.

III. DESIGN METHODOLOGY

During the initial design stages of a Formula racing car chassis, it is first important to consider what components must be included in the final vehicle system. The general layout of the vehicle systems and subsystems should first be established and then load bearing members of the chassis should be designed to connect the components at their mounting points. Therefore, the chassis conforms to the shape and location of the components, including, drive train, the engine mounts cockpit, suspension links, and so on. If the chassis is designed from the other aspects of designing, that is the components are placed according to the chassis design, then the structure will have many engineering flaws. The components must be supported and mounted in the most efficient manner possible, which means developing a structure that is capable of bearing the static and dynamic loads while using the minimum volume of material possible and thus reducing inertial mass. through proper research, optimized, design, simulation, and manufacturing, a sufficiently stiff frame could be built under 30 Kg. Furthermore, by applying topology optimization throughout the vehicle through the use of lighter components and composite materials, we established a goal for the total vehicle weight of 200Kg. This extreme reduction in mass would hopefully lead to improved acceleration, cornering, braking, and handling characteristics.

IV. OBJECTIVES

The main design objectives for the chassis were:

- Research of chassis & cockpit materials that can withstand the high-performance ratings of a formula-style race car.
- Design a chassis that will be able to withstand the loads from static and dynamic forces using solid modelling software.
- Perform static and dynamic force and moment analysis using finite element analysis (FEA) software.
- Optimize the chassis by reducing the high-stress concentrated areas using better triangulation of the frame members.

Finalize a chassis design that meets all requirements and regulations and begin testing of the vehicle once all the systems have been implemented into the vehicle

V. VEHICLE PLATFORM/TYPE SELECTION

Perhaps one of the critical decisions is to decide the structure type to develop. There is a cost consideration imposed by the FS. Rules and simple fabrication, it had been decided that a tubular space frame chassis would be built rather than a composite monocoque employing composite sandwich construction. This design is very efficient as thin-walled, tubular pipe exhibits high strength in compression and tension, but performs very poorly when subjected to bending loads. Although it's often difficult to make sure that each member is going to be free from bending loads, a chassis that approximates the perfect triangulation will yield the foremost desirable results

A tubular space frame Chassis was Chosen over a Monocoque/Composite despite being Heavier Because Its Manufacturing is Cost-effective require Simple Tools and simply Repairable. Monocoque Chassis is best the production The Mass Production.

VI. MATERIAL SELECTION

The chassis undergoes various kinds of forces during locomotion it has to stay intact without failure and it should be stiff enough to absorb vibration. The material selection of a chassis is an important criterion while designing and manufacturing & fabricating the car. The main priority of the design is safe for the driver and hence the material should be stiff and has great strength.

The material should not cause any failure even under extreme conditions of driving as defined in the rulebook.

weight and stiffness are the two most important properties of a chassis. the stiffness of the material by which it is built is known as young modulus (E) and the controlling mechanism for stiffness in a material is the intermolecular forces F changes by any mechanical or chemical process.

Material property Requirement

A) Physical and mechanical

- Hardness-High
- Fatigue- high fatigue resistance
- Tensile strength -high
- Creep- low
- Stiffness -high
- Compression-high resistance to compression forces
- Shear strength-high
- Density-low to medium
- Thermal conductivity & Dissipation-High
- Flammability-Very low
- Melting Point >600deg celsius

B) Chemical Properties

- Environmental Resistance
- Highly Resistant To solvents oils weather
- Dimensional-
- Flatness-Must maintain Machined Surfaces
- Surface Finish-Able to be easily machined
- Stability-Must Be stable at operating Temperature
- Tolerances -up to 0.5mm
- Availability of Materials
- Available readily on hand
- Easily ordered from warehouse Both for ongoing fabrication Process and any repair work which may be necessary during the testing period

Economic Considerations

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the project should be cheap however this is cheap is in the cost not in the performance the overall material should be cost-effective considering the procurement process formability, weldability, and machinability

Suitable Material

Steel and its alloys, Aluminium cast iron are suitable materials. exotics materials like Carbon fiber and titanium are rules out based on availability, accessibility, cost, and Fabricating Difficulties.

Material selection criteria

For Formula Student competitions, the baseline material is steel and the regulations and rules are held regarding alloy steels. It is also possible to use another material but to before using them the alternative frame rules should be considered. There are much more rules and regulations and required tests for the use of alternative materials.

Aluminium has the advantages of being lighter then steel and cheaper than composite. Yet it is very hard to find Aluminium that meets the regulations and rules.

To provide enough stiffness, larger size of Aluminium must be useful and that doesn't make Aluminium be a very convenient choice, the volume of material becomes larger and it increases the price.

Composite chassis are a very good option for teams because they are lighter and stiff but they are very hard to fabricate and are very expensive.

The most convenient choice is using steel, it is easy to machine and prepare the tube it may not require also a complex fixture for production, and its good availability too

Table-1: Comparison between suitable materials

S. no.	Material	Density	UTS	YTS	E	K	Coef. Of thermal exp.
1.	AISI4130	7860	550	450	210	77.2	11.7
2.	AISI302	7920	860	520	190	75	17.3
3.	Aluminium	2800	570	500	72	28	23.6
4.	Grey C.I.	7200	170	-	69	28	23.6
5.	Malleable C.I.	7300	345	230	165	65	12.1
6.	Carbon fiber	1550	600	580	70	5	2.10

Low carbon steel or mild steel

Low carbon or mild steel is further classified into three types basing on their composition i.e. percentage of carbon

- Dead mild steel or mild steel containing 0.5 to 0.15% of carbon
- Mild steel containing 0.15 to 0.2% carbon
- Mild steel containing 0.2 to 0.3% of carbon

Physical properties of mild steel

- High tensile strength
- High impact strength
- Good ductility and weldability
- A magnetic metal due to ferrite content
- Good malleability with cold forming possibilities

Table-2: Material Selection Matrix

Material	Density	Strength	Manufacturing	Cost	Availability	Total
Weightage (1-10)	6	9	9	8	8	
AISI 4130	2	3	4	4	4	139
AISI 302	1	4	3	3	3	117
Aluminium	4	4	1	3	3	117
Cast iron	3	1	4	4	4	127
Carbon fibre	5	5	2	1	1	109
Mild steel	2	2	5	4	3	131

AISI 4130 Seamless Tubes O.D 25.4 mm of Thickness 2.4mm,1.6mm, and 1.2 then used for the manufacturing Purpose

VII. MANUFACTURING

Manufacturing is one of the most important phases of Chassis Development. We Fabricate the Chassis by our manufacturing methods. we use a fixture made up of mild steel. There is a chronological order for the Manufacturing of the Chassis.

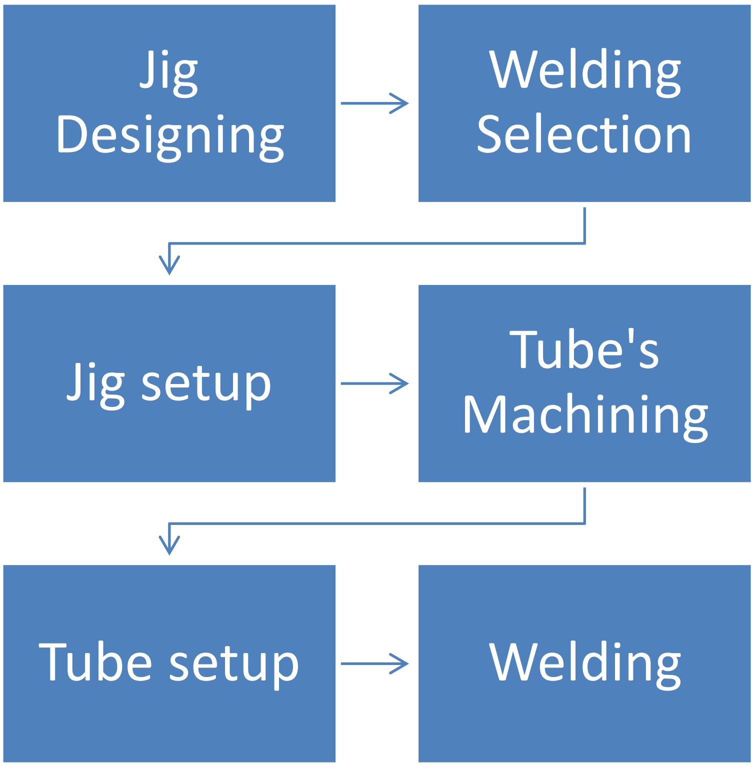

Figure-1: Manufacturing Methods

FIXTURES

Maximizing accuracy, efficiency is the key concern for manufacturing. fixtures are manufacturing aids used to increase the reliability, accuracy, and quality of the manufacturing process, whilst minimizing time, Cost and improving worker safety. Fundamentally, the purpose of fixtures and manufacturing aids is to provide an accurate, fast, and reliable manufacturing process, whilst reducing time and human error.

It is a work-holding device that holds, supports, and locates the Workpiece (Tubes) for a specific operation. We use the fixture for welding the tubes to each other. Each strip of the fixture is unique. Which is designed for a specific tube. We first notch the tube and make grooves in them that each tube can be attached to another tube having a maximum surface area.

Fundamental principles of Fixture design

LOCATING POINTS:

Good facilities should be provided for locating the job. The tubes should be inserted easily so that no time is wasted in placing the Tubes in position to perform welding. The position of Tubes should be accurate concerning the setting elements in the fixture.

FOOLPROOF:

The design of fixtures should be such that it would not permit the Tubes to inserted in any position other than the correct one

WEIGHT OF FIXTURES:

It should be of low cost and economic regarding without sacrificing rigidity and stiffness [7] .In the 5th version of our chassis, we make some improvements in the fixture design. due to the long strips of metal and holding a metal tube, fixture strips get bends towards outwards position due to Normal Axial force but this problem was solved using the T beam Theory In the previous version we have seen the effect of this phenomena in our manufacturing process and provide support behind every Jig strip to prevent it from bending in the current Version We Have used T-shape Jigs for preventing them from bending under the Tube loads.

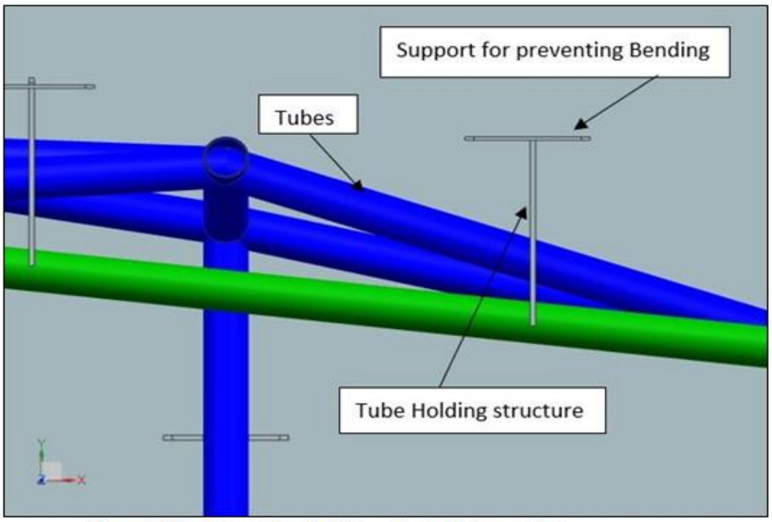

Figure2:T shape strips holding the tube in position

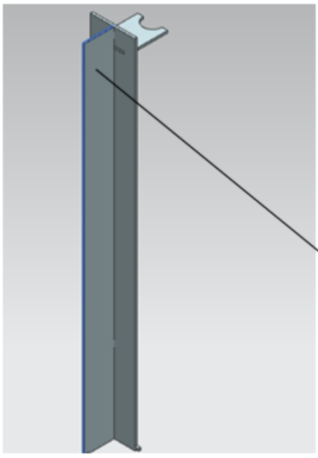

Figure 3:T JIG

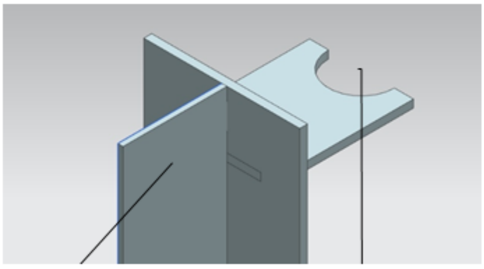

Figure 4: Holding part

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Figure 5:fins designing to keep Jigs levelled

Fins To keep fixture strips levelled on fixture table

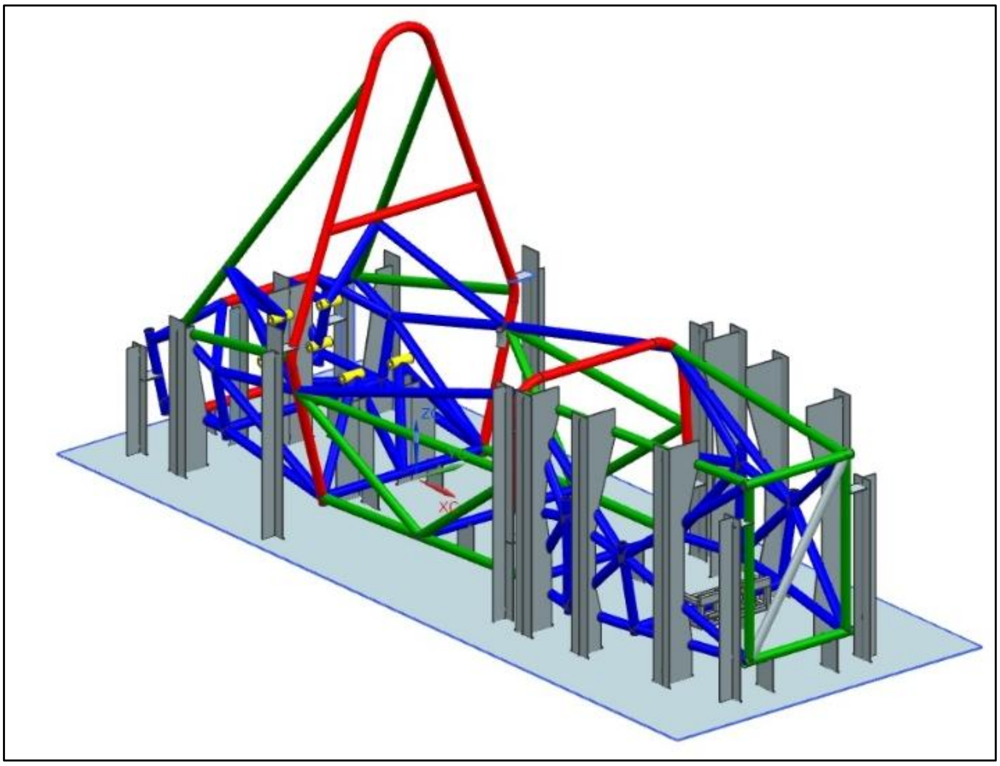

Figure 6: Isometric view of fixture designed in NX 12

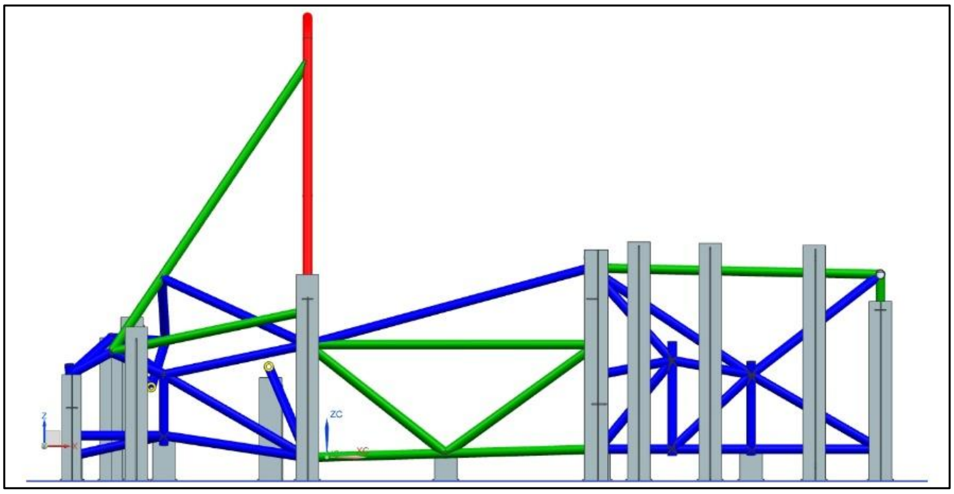

Figure7: Side view of fixture designed in NX 12

WELDING SELECTION

SELECTION OF WELDING PROCESS

When multiple choices are available to select the welding process to accomplish a particular joint it is essential to base the final decision on sound reasoning which generally involves the following considerations:

1. Technical Considerations

2. Economic Considerations.

There are various types of welding available like GTAW, GMAW, SMAW, SAW, Laser Beam Welding, Resistance welding. In a college workshop by considering all economic and technical factors. These welding processes which was feasible Namely- SMAW, GTAW, GMAW. We will take those processes into consideration for finding the best suitable method for the welding process.

WELDING POSITION:

Some welding processes like SMAW, GMAW, GTAW, etc. are compatible with all-position while others are limited to one or a few welding positions. So in the fixture, we need a welding type that should be compatible with all the positions. Process selection for weld joints may include shape and size of the joints, availability of consumables, deposition rates maintenance of equipment required, spatter and smoke caused during operation, preheating and post-weld treatment required, the skill of operator required.

ECONOMIC CONSIDERATIONS:

The main aim is to get the weld of the desired quality keeping the cost as minimum as possible.

The cost of welding comprises different components which are expressed below in the form of an equation:

$C_T = C_{WL} + C_{AL} + C_{OH} + C_c$

where,

C_T = total cost of welding,

C_{WL} = cost of direct welding labour,

C_{AL} = cost of auxiliary labour,

C_{OH} = overhead costs,

C_c = cost of consumables,

These costs will vary from one welding process to another but because arc welding processes cover the bulk of the total welding work in the world.

So after considering all the factors we used GTAW welding.

SELECTION OF FILLER MATERIAL

There are certain parameters on which a selection of filler material is based on certain parameters which can be divided into 4 categories

1. The base material to be welded
2. The welding positions
3. Design requirements
4. Shielding gas

Factor No. 1: The base material to be welded

Joining together two materials is, primarily the matter of chemistry: Which filler metal is best suitable for the base material? If the chemistry of the materials matches, the mechanical and physical properties (such as the tensile and yield strength) will also match.

As we are using mild steel alloys throughout our Chassis there is no need to select two different types of filler materials

Table-3: Chemical composition of AISI 4130

Iron, Fe	97.03 – 98.22
Chromium, Cr	0.80 – 1.10
Manganese, Mn	0.40 – 0.60
Carbon, C	0.280 – 0.330
Silicon, Si	0.15 – 0.30
Molybdenum, Mo	0.15 – 0.25
Sulphur, S	0.040
Phosphorous, P	0.035

Table-4: Mechanical properties of AISI 4130

Properties	Metric
Tensile strength, ultimate	560 MPa
Tensile strength, yield	460 MPa
Modulus of elasticity	190-210 GPa
Bulk modulus (Typical for steel)	140 GPa
Shear modulus (Typical for steel)	80 GPa
Poisson's ratio	0.27-0.30
Elongation at break (in 50 mm)	21.50%

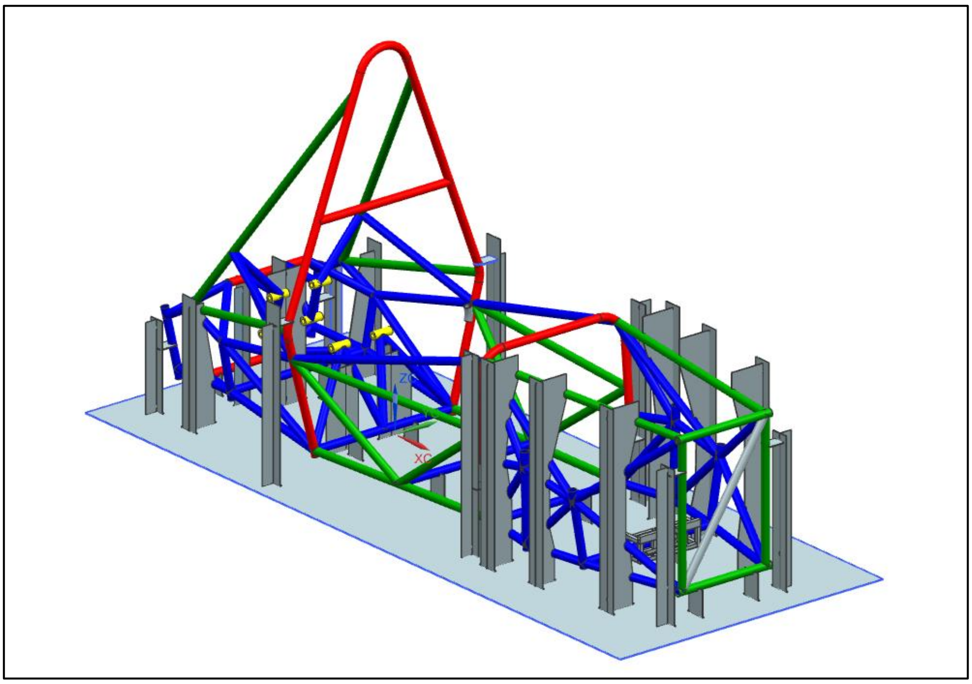

Figure 8: Welding fixture required multiple positions

Factor No. 2: The welding position

The flat position is always the most economical welding position method, followed by vertical or horizontal and, lastly, an overhead position. but as we have mentioned earlier that we have kept our Chassis tubes on the fixture so It will be very impractical for moving the fixture. The fixture's image is given in figure ,so we need to work in every position like flat, Vertical, Overhead, Inclined.

Factor No. 3: Design requirements

It is important to select a filler metal that meets the SAE rulebook design requirement

Welded strength for discontinuous material should be

§ Yield Strength (Sy) = 180 MPa

§ Ultimate Strength (Su) = 300 MPa

The selection of filler material plays an important role in the welding strength

Factor No. 5: Shielding gas

It's important to ensure the shielding gas and filler metal used for an application are compatible.

Different shielding gases have different effects on filler metal. we use argon as a shielding

By considering the above factors we have to choose the Filler metals ER70S-2 & ER70S-6 which the adequate and most compatible with the GTAW welding

There was also comparison was done between ER70S-2 & ER70S-6 And the result obtained is mentioned below

Table-5: Comparison between the ER70S-2 & ER70S-6

Wire	ER70S2	ER70S6
Tensile Strength	78,000 psi	80,000 – 90,000 psi
Yield Strength	60,000 psi	65,000 – 75,000 psi
Density	0.283 lbs/in3	0.283 lbs/in3

Wire	ER70S2	ER70S6
Price Range	Low	High
Processes Supported	MIG, TIG	MIG, TIG
Use on rusted/contaminated surfaces	No	Yes

VIII. SUMMARY

a) The wires both offer the same functionality, both being used for the same purpose of either MIG or TIG welding.
b) ü The ER70S6 offers more tensile and yield strength, albeit at a slightly increased cost. Both the wires can be used for similar jobs due to their identical capabilities.
c) The major difference between the two products is prominent when the user is operating on contaminated or rusted surfaces, in which case the ER70S6 provides better penetration and higher quality of welds.
d) The additional deoxidizers present in the ER70S6 provide better wetting, giving a flatter bead shape and the capability of faster travel speeds.
e) This is due to the higher prevalence of silicone in ER70S6 than ER70S2, the number at the end of the product name (-2 or -6) signifies the amount of the silicon present in the welding wire

ER70S-6 was used then for better welds

IX. CONCLUSION

From the initial research and rules constraint to the manufacturing the design and development of FSAE chassis is mentioned and the best practices are used in the manufacturing processes are like the used of T- shaped fixtures for providing the bending resistance to the tube holding strips material, welding and filler selection for the chassis. From the above research it is concluded that the developed chassis is following FSAE guidelines and can be ready to compete in national and international competitions

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