# DESIGN/BUILD OF A FORMULA SAE VEHICLE (CHASSIS, SHELL AND INSTRUMENTATION)

(Paper G1.1)

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## ABSTRACT

The group is responsible for the design of the chassis, shell and cockpit instrumentation of the car. The chassis is designed to be able to contain the various components of the car. It is also designed to hold the driver, and hence the safety of the chassis has to be a major aspect of the chassis design. Finite Element Analysis will be used to analyse the strength and stiffness of the chassis to ensure that it meets the proper requirements. The shell is designed mainly to provide a cover for the components within the chassis, driver included. Since the car will only manage an average of approximately 40km/h, aerodynamics of the shell will be negligible and hence will not be considered. A crush zone is the front-most part of the car is designed to be energy absorbing to provide additional safety in the event of an accident. Other safety equipment such as the driver's helmet, shoes, arm restraints and roll bar padding have to be obtained while keeping in mind that the team's budget is relatively low. Cockpit accessories, which provide driver - car interaction such as the tachometer and gearshifts have also been designed or purchased to keep cost at a minimum.

**KEYWORDS**: Chassis, Shell, Instrumentation, Crush Zone, Finite Element Analysis.

## INTRODUCTION

The Formula SAE (Society of Automotive Engineers) competition is a purpose built competition for budding young engineers to peat their design skills against each other in an engineering contest. The vehicle has to undergo a range of different performance tests, such as the acceleration event and the autocross event, at the main event in December. The objective is to score as many points as possible in all performance tests. However, as the number of points awarded in each category differs, the main objective is to score well in the endurance race, which provides the most points out of all the performance tests.

The group is responsible for the design of the chassis, shell and the cockpit instrumentation. The design of these components mainly deals with the proper interaction of all major components of the car, as well as the drivers' safety mechanisms that are usually defined by the Formula SAE Competition Rules. Due to the limited budget and time constraints, the designs have been geared towards simplicity and cost effectiveness.

## 1.0 CHASSIS

The chassis has been modelled mainly to satisfy the constraints provided by the other components of the car, such as the power train and suspension. The chassis contains two roll hoops, which provide rollover protection for the driver in the event of an accident. These roll hoops have to be braced accordingly as stated in the Formula SAE rules, due to strength concerns. The chassis also contains side protection, which consists of three structural members as shown in figure 1. The chassis has also been designed to fit the tallest possible driver and the $95^{th}$ percentile male, as defined by the Formula SAE rules. Other areas of the chassis, most notably front of the front roll hoop and rear of the main roll hoop, are designed to provide space and mounting points for suspension and power train elements. Proper bracing and triangulation in the form of diagonal members are added to the chassis to provide higher stiffness and driver safety. Side pods have also been included in the chassis design to provide support for some power train components, and to provide additional torsional strength to the chassis. The chassis is made of tubular mild steel, with a 26.9mm X 2.6mm dimension for the roll hoops and a 25.4mm X 1.6mm dimension for the other members of the chassis. The performance of the chassis in terms of strength and deflection are analysed with Finite Element Analysis, and is further discussed in the next section.

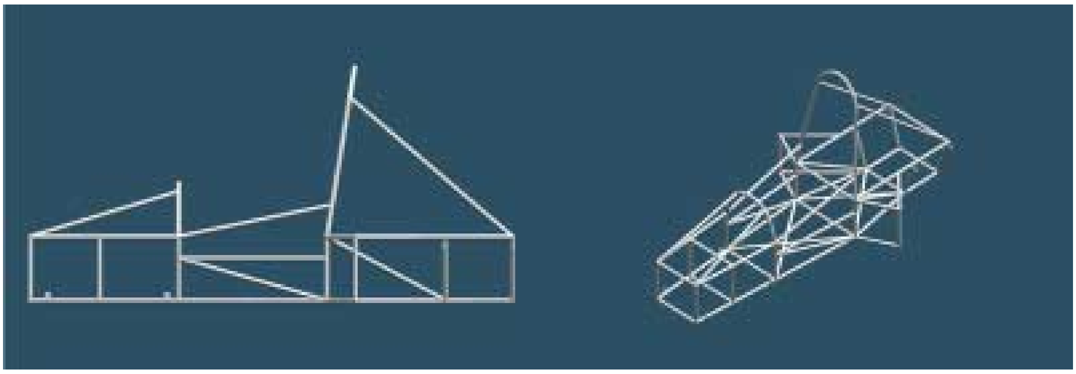

Figure 1: Chassis Model

## 2.0 FINITE ELEMENT ANALYSIS (FEA) OF CHASSIS

Strength, rigidity and stiffness are the main concerns of constructing a supportive chassis for a vehicle. The chassis should be able to withstand the appropriate loads on and off the racetrack to ensure a high level of safety and performance. FEA provides a useful tool to analyse these concerns effectively because it enables the user to study the behaviour of the model and make modifications before the commencement of chassis manufacturing.

### 2.1 Methodology

Strand7 is selected as the primary FEA package to perform the chassis analysis due to its availability and user-friendly nature. The chassis is mainly modelled from beam or plate elements; where possible brick elements are avoided due to its long computing time.

#### 2.1.1 Loads

Estimating loads is particularly complex when modelling parts or assemblies that undergo large scale motion. To solve problems with motion, many FEA vendors use a two step approach. First, a kinematic package obtains loads (reaction forces and moments at the joints), which represents the effects of motion. A linear-static FEA solver then calculates stresses based on the obtained loads. Unfortunately, a kinematic package that would suit the needs of this project is not obtainable, hence the loads would have to be approximated to common known situations, plus a safety factor. Summaries of loads are shown in Table 2.1 below:

| **Load cases** | **Equivalent Force/Stress Approximation** |
|---|---|
| Braking | $F_x$ = -1.5kN, $F_y$ = -6kN |
| Cornering | $F_y$ = -4.5kN, $F_z$ = 2kN applied at centre of gravity of the frontal partial volume. |
| Driver pressure | Normal pressure -5.8268e3Pa at seat plate |
| Acceleration | $F_z$ = 6kN, $F_y$ = -6kN |

Table 2.1 Equivalent Forces In Difference Cases

2.1.2 Interpretation of Results

Looking at the available results, the overall deflection especially in y-axis is within the acceptable limits. Also, the axial stress (tensile) of all beam members cannot exceed the ultimate tensile stress.

2.1.2.1 Torsion and Bending Strength

| **Test Case** | **Description** | **Torsion required to twist chassis 1° in x-Axis** |
|---|---|---|
| Torsional rigidity | Rear of Chassis restrained on a wall, exerting a force on the front of the chassis | 2.0kN |
| Torsional rigidity | Side of Chassis restrained on a wall, exerting a force on the other side of the chassis | 2.5kN |
| Torsional rigidity | Centre of Chassis fixed, exerting a coupling force at both ends of the chassis | 2.0kN |

Table 2.2a Torsion Test

| **Test Case** | **Description** | **Moment required to twist chassis 1° in z-axis** |
|---|---|---|
| Bending | Chassis is bent by exerting moments on the same plane | $5x10^5$ Nmm |

Table 2.2b Bending Test

2.1.2.2 Stresses and Deflections

| **Cases** | **Maximum Absolute Deflection (mm)** | **Maximum Absolute Stress (MPa)** | |
|---|---|---|---|
| Dead Weight | 0.0717 | 0.290 | Tension |
| Braking | 1.0614 | 13.87 | Tension |
| Cornering | 0.7472 | 12.10 | Tension |
| Driver’s Weight | 0.1975 | 1.150 | Tension |
| Accelerating | 0.7944 | 18.57 | Tension |

Table 2.3 Stresses In Difference Cases

2.2 Conclusion

Overall results indicate that the values or concern are within the acceptable limits, in fact the deflection or stress magnitudes are not near ground or excessive limits. Buckling is neglected because the obtained compression stresses are averaging significantly lower than tension stresses.

## 3.0 SHELL

The purpose of the shell is to provide a cover for the inner components of the car, including the driver. It also serves a purpose to increase the aesthetical look of the car, as well as to provide an area for sponsors' stickers, car numbers and miscellaneous items that has to be shown on the external part of the car.

### 3.1 Aerodynamics

Due to the restrictions on the car and the nature of the racing track, the maximum speed and average speed of the car would be approximately 110 km/h and 40km/h respectively. Due to these low speeds, aerodynamic effects on the car would be negligible [1]. Hence, aerodynamic structures such as wings will not be considered in the design of the car.

### 3.2 Crush Zone

The crush zone is located in the front most part of the car, directly in front of the front bulkhead. The crush zone functions to absorb the energy of the impact if a frontal collision occurs. Rules and regulations concerning the crush zone are covered under the Formula SAE rules. This section not only contains information about the crush zone but also the bulkhead. However, it must be said that the rules on the crush zone are very vague and no loads or deflection criteria need to be meet. Hence, the design of the crush zone thus far has been to ensure that the crush zone is affordable, light and easy to manufacture whilst being energy absorbent.

## 4.0 INSTRUMENTATION

A summary of instrumentations that are required is shown in the tables below :

| S/No | Component | Requirements | Cost ($) |
|---|---|---|---|
| 1 | Tachometer | 4 Cylinders, Honda 2000 Model or compatible | 550 |
| 2 | Speedometer | 4 Cylinders, Honda 2000 Model or compatible | Included with 1 |
| 3 | Temp. Gauge | 4 Cylinders, Honda 2000 Model or compatible | Included with 1 |
| 4 | Oil Press. Gauge | 4 Cylinders, Honda 2000 Model or compatible | Included with 1 |
| 5 | Brake Light | Minimum 15 W | 15 |
| 6 | Master Switch | 6 Pin With Relay X 2 | 85 |
| 7 | Master Switch Identifier | Battery Switch Triangle X 2 | 3.3 |

Table 4.1 Electrical

| S/No | Component | Requirements | Cost ($) |
|---|---|---|---|
| 1 | Safety Helmet | Sport II Fibreglass, White, Small, Bell | 799 |
| 2 | Eye Protection | Impact Resistant | Included with 1 |
| 3 | Hair Covering | Nomex Open Double Layer | 55 |
| 4 | Head Restraint | Ethafoam R or Ensolite R, withstand 890 N | TBA |
| 5 | Roll Bar Padding | Window Net Roll Cage Fitting Kit | 15 |
| 6 | Shoulder Pads | Black 3", Willans | 57 |
| 7 | Arm Restraints | 2 arm D-Ring | 65 |

| | | | |
|---|---|---|---|
| 8 | Gloves | FIA Approved, shorter style | 109 |
| 9 | Suit | FIA Approved, Double Layer (14s) | 585 |
| 10 | Driver's Harness | 6 Pt Sys, FIA Approved, Klippan | 549 |
| 11 | Shoes | FIA Approved, low cut | 165 |
| 12 | Safety Triangle | Std Safety Triangle Warning | 15 |
| 13 | Mirrors | Classic, Bullet Style | 109 |
| 14 | Fire Extinguishers | Fire boss - Handheld, 1 kg Dry Powder X 2 | 44 |

Table 4.2 Safety

| **S/No** | **Component** | **Requirements** | **Cost ($)** |
|---|---|---|---|
| 1 | Steering Wheel | Black leather, Diameter 280 mm | 35 |
| 2 | Numbers | Square, Black or White | 6.6 |
| 3 | Seat | Manufactured by Workshop | TBA |
| 4 | Gearshift | Manufactured by Workshop | TBA |
| 5 | Pedals | Manufacture by Workshop | TBA |

Table 4.3 Miscellaneous

*** Note that all the prices above GST included**

The type of electrical components (items 1-4 in Table 4.1) that will be used in the car will differ depending on the pulses that are produced by the engine. Either a second hand Honda CBR display set, or, a modified set of electrical components will be used to provide these instruments. Safety Equipment for the Driver is shown in Table 4.2, and these are all in accordance to the SAE rules of safety (1986 FIA Standards). Up to date the prices have been quoted from racing and go-kart companies. Items such as fire extinguishers and the driver’s harness will be on loan from University of Adelaide and Holden respectively to reduce the cost incurred. Components such as the pedals and seat will be manufactured at the University of Adelaide workshop.

## 5.0 PROGRESS PLAN

The project has moved to a final phase and a schedule has been drafted out as shown Table 5 below. The plan is to complete the entire car by the first week of October. After this, minor adjustments on the car such as suspension settings can be done. Also, proper testing of the car can proceed after the car’s completion, which would provide the team with the opportunity to check the last minute details or troubleshoot if any problems arise before the actual race event at the beginning of December.

| S/No. | Task Name | Due Date | Sep '01 | | | | Oct '01 | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Week | | | | Week | | | |
| | | | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| | **Integration & Assembly of Parts:** | | | | | | | | | |
| 1 | Harness | 7th Sep | | | | | | | | |
| 2 | Brake m/cylinders | 7th Sep | | | | | | | | |
| 3 | Brake Pedal | 7th Sep | | | | | | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 4 | Engine Test 1 | 7th Sep | | | | | | | | |
| 5 | Seat | 7th Sep | | | | | | | | |
| 6 | Steering Components | 7th Sep | | | | | | | | |
| 7 | Crush Zone | 7th Sep | | | | | | | | |
| | | | | | | | | | | |
| 8 | Suspension | 14th Sep | | | | | | | | |
| 9 | Steering | 14th Sep | | | | | | | | |
| 10 | Engine Test 2 | 14th Sep | | | | | | | | |
| | | | | | | | | | | |
| 11 | Differential | 21st Sep | | | | | | | | |
| 12 | Rear Axles | 21st Sep | | | | | | | | |
| 13 | Front Hubs | 21st Sep | | | | | | | | |
| 14 | Crush Zone | 21st Sep | | | | | | | | |
| 15 | Sundry Items | 21st Sep | | | | | | | | |
| 16 | Brake Lines | 21st Sep | | | | | | | | |
| | | | | | | | | | | |
| 17 | Engine Mounts | 28th Sep | | | | | | | | |
| 18 | Complete Chassis | 28th Sep | | | | | | | | |
| 19 | Fuel Tank | 28th Sep | | | | | | | | |
| 20 | Body | 28th Sep | | | | | | | | |
| | | | | | | | | | | |
| 21 | Wiring | 5th Oct | | | | | | | | |
| 22 | Equipment Installation | 5th Oct | | | | | | | | |

Table 5: Progress Plan

## 6.0 ACKNOWLEDGEMENTS

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## 7.0 REFERENCES

[1] A.J. Badih and M.L. Maria, “Aerodynamic Evaluation on Formula SAE vehicles”, SAE International, Detroit.