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Determination of Ergonomics for Formula Student vehicle

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***Abstract*— An ergonomic setup was introduced for the Formula Student vehicle design. The concept was the installation of ergonomics jigs for greater feedback in the least possible budget. The idea was to finalize the entire ergonomics (human factors) data; which processes to be more effective in chassis design. The ultimate goal was to design a chassis which is optimized in terms of size in such a way that it does not effect the drivers comfort.**

Keywords*— *Chassis, Cockpit Design, Ergonomics, Formula Student, Jigs

I. INTRODUCTION

A. Background

Formula Student is a student design competition organized as 'Formula Bharat' and 'Supra SAEINDIA Student Formula' in India. The objective of the participating team is to develop a race-car as a part of a contract as a that the team gets, being assumed as a fictional manufacturing company. The targeted market is a group of amateur weekend racers. Each team is tested on the parameters of design, cost and business logic. The desired goal is not only to build a car that performs the best, but also to ensure that the driver is comfortable inside the cockpit. A major rule of the event that constraints the size optimization of the cockpit is to fit the 5th percentile female up to the 95th percentile male within the vehicle for operation. In addition to this, other rules that constraints the ergonomics design are:

1. the cockpit opening to be sufficient enough for the "Cockpit Opening Template" to pass the topmost side impact structure (in the case of space frame) or 320 mm above the lowest chassis member (in the case of alternate frame). Seat, Seat cover, steering wheel etc. may be removed to accommodate the template as mentioned in the rulebook.
   As stated in rule T3.1 Of Formula Student Germany rulebook.
2. For the footwell template, should cross the leg space without hindrance until 100 mm from the rearmost pedal face.

B. Ergonomics

Ergonomics is the scientific and analytical discipline concerned with the design or arranging workspaces, systems and products, understanding of interactions among humans and other elements of a system so that it fits the humans who use them. It is the profession that applies theory, principles, analytics, data and methodology to design in order to optimize human well-being with respect to interaction with other systems and overall performance.

II. PROBLEM

Problems related to the ergonomics determination were identified. These were: determination of seat inclination, pedal box position, dashboard controls and shifter location in consideration with team's drivers and SAE's body dimension for the 95th percentile male. The conclusion was agreed to be made based on a jigs setup that acts as a mock-up chassis.

III. DRIVERS' FEEDBACK

A generalized feedback form was given to each driver for its input in the design. Following questionnaire was developed: -

1. Rate the significance of the placement of vehicle controls; state any potential fatigue the driver might experience from the placement.
2. Rate the significance of a seat that can adjustable: can be shifted backward and forwards as desired in the cockpit to adjust to the different heights as per the different drivers on the team.
3. Rate the burden of fatigue of the driver's arms. Suggestions to reduce/remove it.
4. Rate the burden of fatigue to the driver's legs. Suggestions to reduce/remove it.
5. Rate the burden of fatigue to the driver's back. Suggestions to reduce/remove it.
6. What is the driver's seating position? (Upright seating posture with legs angled down or reclined back with the legs at an elevated angle? Sample pictures below in fig. 6(a) and 6(b).
7. Describe the steering wheel angle of approach to the driver. Is it parallel the driver's chest or does it approach at another angle?
8. What will be the position of the driver's arms while driving? Describe.
9. What will be the position of the driver's legs while driving? Describe
10. Where is the position of the transmission shifter within the cockpit? Describe.

The answers from this form were recorded and the following answers were observed:

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TABLE 1: Questionnaire for the Drivers

Rate the significance of the placement of vehicle controls; state any potential fatigue the driver might experience from the placement.	2.94
Rate the significance of a seat that can adjustable: can be shifted backward and forwards as desired in the cockpit to adjust to the different heights as per the different drivers on the team.	0.76
Rate the burden of fatigue of the driver's arms. Suggestions to reduce/remove it	3.44 Major feedback concluded to maintaining proper arm angle
Rate the burden of fatigue to the driver's legs. Suggestions to reduce/remove it	3.27 Keep the legs straight as much as possible
Rate the burden of fatigue to the driver's back. Suggestions to reduce/remove it	4.27 Problem experienced during endurance events
What is the driver's seating position? (Reclined back with the legs at an elevated angle or upright seating posture with legs angled down?) Sample pictures below in figs. 6(a) and 6(b).	67.27% for reclined 32.77% for upright
Describe the steering wheel angle of approach to the driver. Is it parallel the driver's chest or does it approach at another angle?	Should be at an angle in a way that the steering is raised towards the driver
What will be the position of the driver's arms while driving? Describe	The upper arm making an acute angle with the chest plane and an obtuse angle at the elbows
What will be the position of the driver's legs while driving? Describe	A minimum knee bend is required such that the ankle acts as a pivot point for the proper actuation
Where is the position of the gear shifter within the cockpit Describe.	Lever shifter is preferable and its placement on the left is helpful

IV. DESIGN

A CAD model was drafted for the jigs setup before the start of the actual installation. The design of the jigs for ergonomics was so conceptualized as to achieve the following objectives:

a) Maximum output from the setup

b) Fabrication of jigs from materials in inventory to minimize the budget

c) Provide maximum and easy adjustments in the chassis for better visualization of the chassis and for increasing accuracy in the process

As a result, angle brackets and ply boards were the selected material. The conceptualized design was implemented into a practical jig as the image below.

Fig. 1. Practical jigs setup.

The above setup allows flexibility in changing

a) Driver's seat inclination

b) Adjustment of front hoop and main hoop in x-axis

c) Distance of pedal box from the front hoop.

V. OBSERVATIONS

Each driver was asked to sit in the practical jig setup to finalize all the parameters of ergonomics. This was also done to cross-verify the line of sight. The theoretical line of sight was also calculated as explained in fig. 2 in addition to the estimation of the nose length. All this achieved by making frequent changes to the jigs. The front hoop was adjusted to ensure the visibility of the shortest driver.

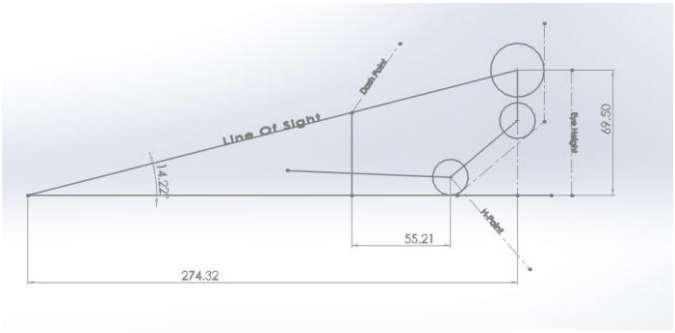

Fig. 2. Line of Sight.

Similarly, the height of the main hoop was also adjusted on the basis of the tallest driver, in consideration to the competition rule T3 that states:

When seated normally and restrained by the driver's restraint system, the helmet of a 95th percentile male and all of the team's drivers must:

(a) Be a minimum of 50mm away from the straight line drawn from the top of the main hoop to the top of the front hoop.

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(b) Be a minimum of 50mm away from the straight line drawn from the top of the main
hoop to the lower end of the main hoop bracing if the bracing extends rearwards.
(c) Be no further rearwards than the rear surface of the main hoop if the main hoop bracing extends forwards.
The cockpit template is as the following figure:

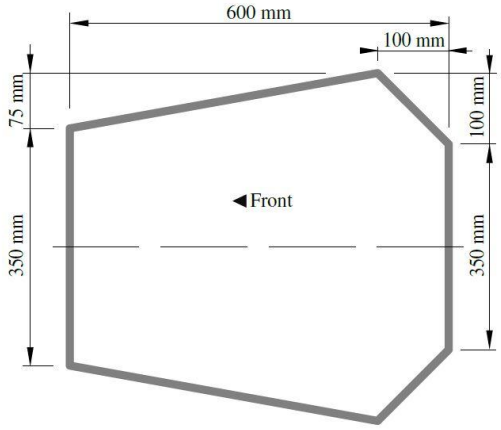

Fig. 3. Cockpit template.

The footwell template is as the following figure:

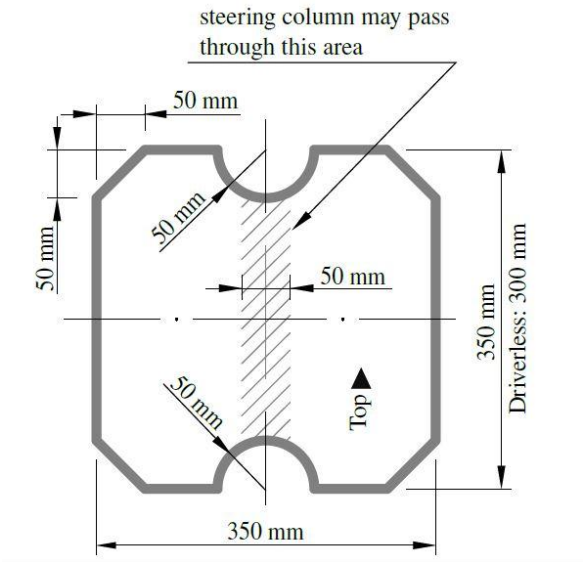

Fig. 4. Footwell template

T3.3.2 The 95th percentile male is represented by a two-dimensional figure consisting of two circles of 200mm diameter (one representing the hips and buttocks and one representing the shoulder region) and one circle of 300mm (representing the head with helmet).

T3.3.3 The two 200mm circles are connected by a straight-line measuring 490mm. The 300mm circle is connected by a straight-line measuring 280mm with the upper 200mm circle.

The Percy template should be positioned as given in the figure:

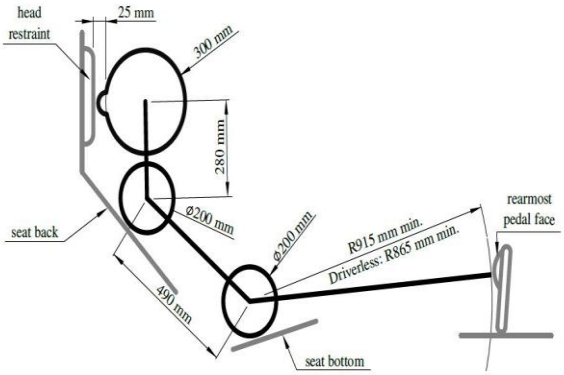

Fig. 5. Percy template

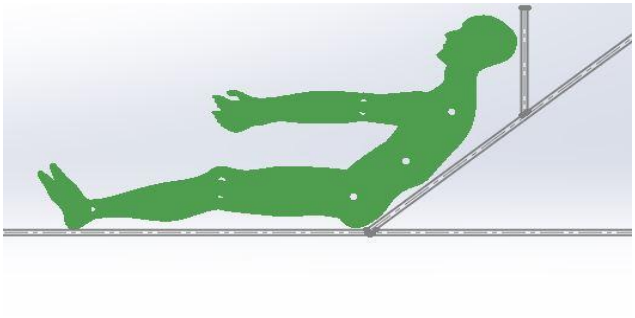

Fig. 6(a). Reclined Seating Position

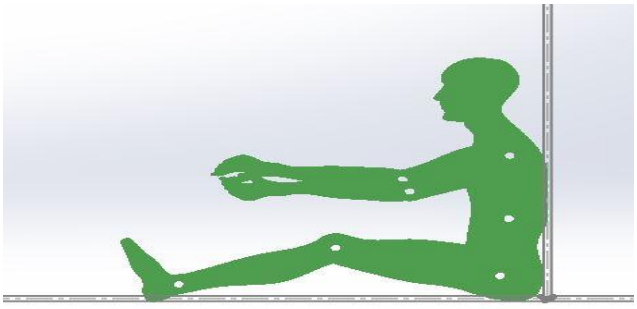

Fig. 6(b). Upright Seating Position

Furthermore, knee angles, seat inclination, and elbow angle were also noted down for different drivers. The observation data recorded are mentioned in the tables below:

TABLE 2: Table for Elbow Angle:

Driver	Elbow Angle
1	107
2	105
3	104
4	94
5	106
6	106
7	111
8	104
9	102

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TABLE 3: Table for Knee Angle:

Driver	Knee Angle
1	138
2	135
3	135
4	130
5	136
6	136
7	139
8	135
9	134

VI. CONCLUSION

The desired parameters for the ergonomics were finalized on the basis of driver's feedback and the jigs data. So, from the tables 1,2,3, the following were inferred:

Table 4: CONCLUSION

Parameter	Finalized Data
Shifter location	On the left side of the cockpit
Vehicle controls	On the right side of the dashboard
Elbow Angle	104^0
Knee Angle	135^0
Seat Inclination	50^0 from vertical
Front hoop height	46cm
Main hoop height	98cm
Expected nose length	114cm
Line of Sight	274.32cm

The final values were decided from the experiments conducted on the jigs and fixtures.

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