RESEARCH ARTICLE OPEN ACCESS

Ergonomics of a Custom Made Solar Electric Road Vehicle

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ABSTRACT
A solar electric passenger car's gear was ergonomically designed and fabricated to have a ratio of 1:1 which was in compliance with the regulations prescribed in the document 'World Solar Challenge - Rules and Regulations 2013' and the road rules of the country. The cabin dimension of the gear was adjustable in order to incorporate various body dimensions that a passenger car is required to support. Several parameters were used to obtain an optimum design. Safety, comfort and human machine interaction was the most important aspect for the team while designing. All the features designed were analyzed and verified using CATIA a software designed for modelling solids. A final prototype was integrated to accommodate people within the range of ninety-five percentile male and five percentiles female population.
Keywords:- Cabin, Ergonomics, Solar Car, World Solar Challenge (WSC), Catia.

I. INTRODUCTION

By definition Ergonomics is a scientific discipline that uses principles of mechanical engineering to make products more comfortable for workers and consumers. The ergonomics of a vehicle is an interface where human and machine interacts. One of the most important factors of a vehicle is its packaging that demands suitable space for vehicle parts and consumers; human-space factor consideration is a must for the integration of the total design [1]. An electronic interactive device informs the driver about the vehicle's condition and executes certain commands [2]. The designers safely locate the internal equipment of the car so that it doesn't not hinder the driver and also doesn't harm the driver or passengers during impact. The passenger comfort and accessibility of the controls to run the vehicle drive the performance of the car [4] [5].
In this paper, I present a design of the cabin of a solar electric vehicle that accommodates a range of drivers within the stipulated rules keeping the passenger safety and comfort my foremost priority. The factors that affect, the ergonomics the most are seat rest angle, the seat base angle, the steering location, the brake pedal location and the position of the hip point, which were manufactured to be adjustable in nature. These were fabricated only after complete analysis for obtaining the optimum angles for the position of the seat, steering, brake pedal and accelerator pedal location.

II. METHODOLOGY

Several models of commercial cars were studied for their feature. The cabin dimension of the car was finalized, after an extensive research of passenger vehicles under WSC-Rules and Regulations 2013 along with road rules of the country. CATIA was used to obtain a preliminary design of the seat and driver's posture. However, Figure 1, demonstrate the need of a human body to determine the view of the driver, height of the seat and to decide the position of the steering.
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Fig. 1. Ergonomic setup designed in CATIA.

The initial design was prototyped by a scale of 1:1 using ply wood. Wood was chosen as its availability wasn't an issue, it is cheap and is easy to handle. The car's chassis was designed using circular steel tubes. The average height of the driver was considered to be 5' 11" or 95th percentile male as per WSC regulations.
Following objectives were set for the optimum performance:

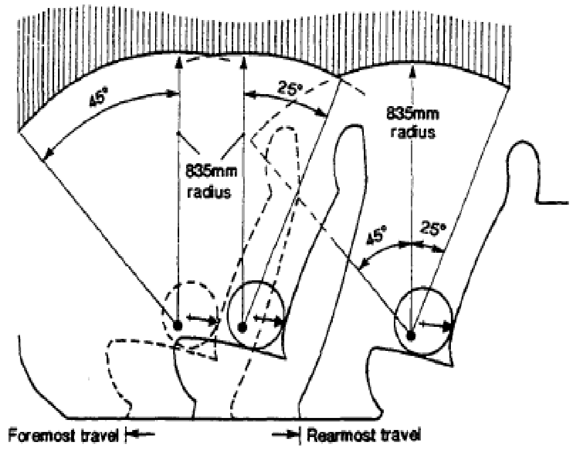
1. Seat back rest Angle

i. river remains at a comfortable position

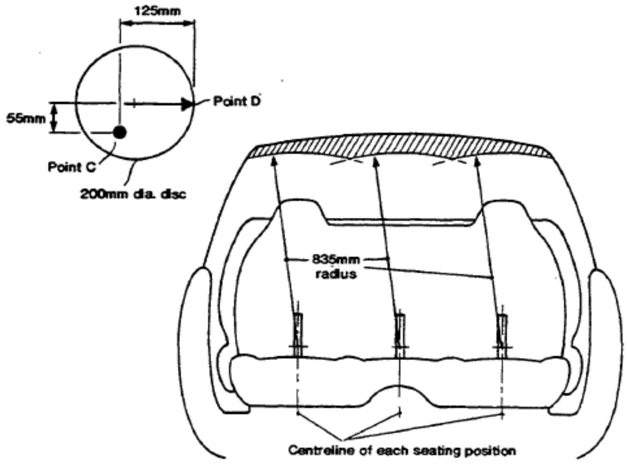
ii. Centre of gravity remains as low as possible
iii. Proper view and accessibility

2. Seat Base Angle
   i. To provide thigh support while operating pedals.
   ii. To provide proper access to brake pedals.
   iii. Steering Location.
   iv. To provide proper grip to the driver.
3. Proper width of the cabin to accommodate seat and driver.
4. Proper positioning of pedal assembly and steering wheel location. The heel location must be below the hip point for cars under the Cruiser Class.
5. To get the height of the car at regular intervals in order to get best aesthetic look.
6. Positioning of the front roll bar or A – pillars.
7. Positioning of the roll bar or the B – pillars

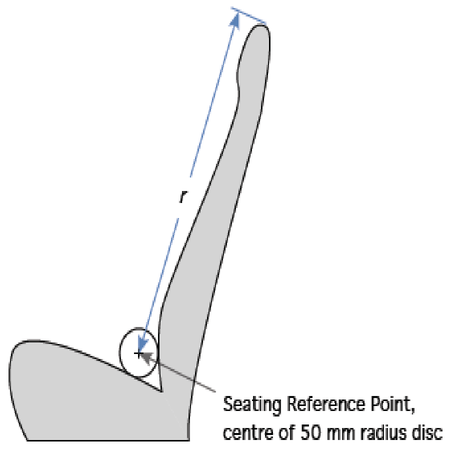
The Cruiser Class vehicles, requires the head space to be in compliance with the LK Seating rules of Australia. No structural members must be within the shaded area as shown in Fig. 2 below. All measurements are taken from the hip point.



(a)



(b)



(c)

Fig. 2. No structural members must be within the shaded area

III. APPARATUS

The prototype apparatus was built so that subjects can sit in an adjustable cabin (see Fig. 3).

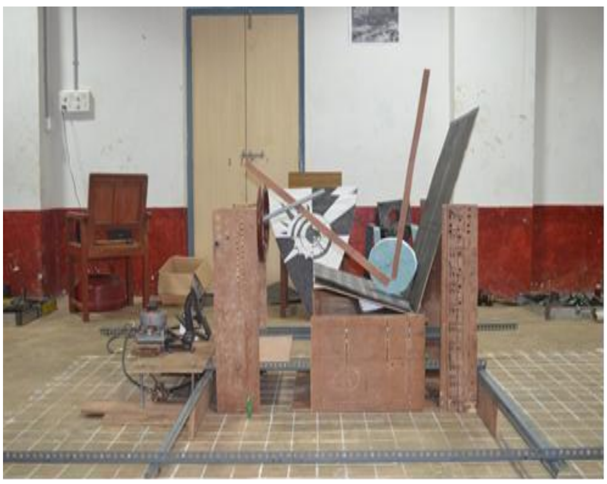


Figure 3. Demonstrates the adjustable cabin option so that the passenger can be more comfortable.

Seat rest angle, seat base angle, steering location, brake pedal, accelerator pedal, height of **hip point (H)** and **lowest point of the seat (R)** have been fabricated to be adjustable in the car. Two boards of hinged ply wood were used as supports for back and base. To adjust the seat rest angle two back supports with drilled holes were used. Similarly, to adjust the seat base angle two supports were put underneath the seat. This placing of the two side supports was important since with every change in **H-point,** every other variable changes. For every fixed **H-point** other variables were adjusted and checked for the comfort and safety of the driver. Even the viewing capacity and head clearance changes considerably with small changes to these points, hence many iterations were carried out to improve the performance of these parameters.

To maintain the comfort of the driver, the pedal assembly and steering location were adjusted around a fixed seat angles in order to obtain a desirable seat angles for the driver. The driver seat was considered to be built around an ideal 95 percentile male.

Figure 4. Iteration being carried out on Ergonomic apparatus.

IV. DATA COMPLETION

The entire data was compiled into a tabular form (see Table)

Name	Height (feet)	H point (mm)	Seat Angle (degree)	Thigh Angle (degree)	H point to dash (cm)	Width of legs (cm)	Knee Width (cm)	Steering wheel height (cm)
A	5`9``	1200,240,420	27	26	93	13	24	31
B	5`11``	1200,240,420	29	24	96	13	24	28
C	6`1``	1200,240,420	28	25	92	13	25	32
D	5`12``	1200,240,420	28	25	95	13	23	34
E	5`10``	1200,240,420	29	23	93	13	25	30

TABLE I: COMPILATION OF THE DATA

V. NOVEL IDEAS AND INNOVATION

Fixed **H-point** and the rest as variable parameters gives us a range of possibilities to obtain the optimum design.

1. The low hip point also leads to leg line of action inclined at a small angle to the horizontal, which leads to the pedal axis being inclined at a greater angle to the vertical. This leads to more horizontal pedal thereby increasing the comfort level of the driver.
2. Dash board was strategically placed in center between the driver and front passenger, this provided room for leg space and comfortable exit.
3. A 1:1 PVC chassis was made so that seat location could be fixed as per our design, giving a realistic idea about the interaction between human and car.
4. Significant amount of clearance was provided (14inch) as crumple zone with regards to the safety of the driver, also provided was some room for chassis members which enhanced the overall safety of the passengers

VI. SELECTION OF SUBJECTS

The driver selection was purely based on the driving skills. Five drivers having different physique were selected in order to have proper variation in the specifics of the gear like seat angle, front view etc. The average height close to the guidelines recommended by WSC regulations for 95th percentile male was found to be 5'11'' which is close to the guidelines recommended by WSC regulations for 95th percentile male.

VII. RESULTS AND DISCUSSIONS

The outcome of the ergonomic study is as follows:

- Optimal location of H point is chosen to be 47 inch
- Seat base angle is 25-degree.
- Seat back rest angle is 30-degree.
- Location of steering wheel.
- Pedal assembly location.
- Seat, Accelerator pedal and brake pedal location.
- Packaging of the components.
- Distance of dash board from drivers

The drivers need to have a good grip on the steering and for this the distance between the dash and driver should be well adjusted such that the steering's position is mechanically advantageous to the driver. This situation demands the **H-point** which is considered most important parameter in the seat assembly, to be developed first. In order to achieve best steering wheel angle and dash height, the maximum dash height obtained was 20 inch. As the regulations mandate that the driver should be able to see at least 4 meters, by setting this parameter as base the other dimensions were calculated using simple geometry. For the cabin design, the location of the eye of the driver with the shortest sitting height was measured. Since it doesn't account for the view of the driver as the body of the car will slope downwards to the nose but would always remain above the line of sight. Considering the situation, a two-inch clearance was accounted. Adjustable pedals were designed to accommodate variation in body shape of drivers. Figure 5, demonstrates a PVC (Poly Venial Chloride) chassis which was designed to simulate the exact seating location to test the interaction between the car and the driver.

Fig. 5. PVC chassis with ergonomic apparatus.

The following observations were made:

1. The assembly of the seat, brake pedal, accelerator pedal and steering location with mounting on the chassis were tested and the interference was checked.
2. The suspension system was fabricated using the PVC pipes so that exact location of steering assembly and pedal assembly could be determined which in turn helped in fixing the location of seat.
3. Due to curved windshield members, the view ability was given special importance, so that the driver could have uninterrupted view up to four meters ahead of the car at a height of 0.75 meters above and below the eye level.
4. This gave a close estimate of the clearance between driver and top of the car which is important in case of roll over of a car and thus the safety of the driver.
5. This helped in determining the location of height of the car at regular intervals, door handle, side windows and side mirrors.

VIII. CONCLUSION

Design iterations of the cabin were tested with the subjects by adjusting the apparatus accordingly and validation was done using PVC chassis. The results of the analysis were obtained and were accordingly incorporated in the car. The study gave us the best aesthetics, safe, roadworthy, and ergonomic design of the car. The gear designed gave all the drivers accurate amount of space and comfort for driving.

ACKNOWLEDGMENT

Funding for this solar car project- Solar Mobil Manipal (www.solarmobilmanipal.in) was provided by Ministry of Small and Medium Scale Enterprises and Manipal University.

REFERENCES

[1] M. G. P. Fernandes, "Cockpits: design and development," SAE Journals, 1992.

[2] G. F. Beal, "Making the cockpit practical for pilot," SAE Journals, vol.53 , no. 8, 1945.

[3] S. Gerald, "The design eye reference point," SAE Journals, 1987.

[4] B. Jawad, "Formula SAE race car cockpit design an ergonomic study," SAE Journals, 2000.

[5] M. Fabian and G. Fedorko, "Current trends in process of design and production of automobiles," Transport and Logistics, no. 9, pp. 142-149, 2005.

[6] Ergonomické Analýzy CATIE. [Online]. Available: http://catiadoc.free.fr/online/haaug_C2/haaugbt0100.

[7] D. Whitney, Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development, New York: Oxford Univerzity Press, 2004.

[8] A. Mareš and K. Senderská, "Ergonomical modules of catia and their using," Journal of Safety Research and Applications JOSRA, vol. 2, 2011.

[9] Bodywork for a Competition Formula Vehicle. [Online]. Available:http://www.jeromearul.com/FSAE

[10] Z. Mohamed and R. M. Yusuff, "Automotive ergonomics: Passenger cars interior dimension parameters and comfort," in Proc. the ICE2007 International Conference on Ergonomics, 2007, pp. 1-4.

[11] A. Goh. Cab Design and Control. [Online]. Available:http://www.coroflot.com/livesteel/cab-design-control

[12] J. Rix, André Stork "Combining ergonomic and field-of-view analysis using virtual humans," in Proc. the International Conference on Design and Manufacturing (IConDM 2013), pp. 622-631, 2013.

[13] A. Seidl, "RAMSIS: A new CAD-Tool for ergonomic analysis of vehicles developed for the german automotive industry," Tecmath GbmH, 1997

[14] U. Jasnoch, B. Anderson, M. Koch, and J. Rix, "Beyond digital mock-ups: Human aspects in new products," in Proc. the Autofactt, USA, 1997.

[15] Car Body Design, Automotive Design and Engeneering. [Online].Available: http://www.carbodydesign.com

[16] Ergonomics in Automotive Industry. [Online]. Available: http://www.ergoworld.com/ergonomics-industryautomotive.html.

[17] Ergonomics and Anthropometrics. [Online]. Available:http://www.cardesignonline.com/design/ergonomics/index.php

[18] B. Peacock and W. Karwowski, Automotive ergonomics, Taylor and Francis, London, 1993.

[19] A. Cichański and M. Wirwicki, "Ergonomics analysis of anthropo-technical systems in the environment of catia program," Journal of Polish Cimac, 2003.

[20] Research: Driver And Passenger Ergonomics. [Online]. Available: http://mreed.umtri.umich.edu/mreed/research_ergonomics.html