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COCKPIT DESIGN ABOUT AN ERGONOMICS STUDY APPLIED A BAJA VEHICLE

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Abstract . *In the work was to design the vehicle Baja cockpit for the ergonomic requirement, taking care of the comfort of 90% of the possible pilots, as well as meeting the SAE standard. Studies were on the ergonomic analysis by the Rapid Upper Limb Assessment (RULA) method using CATIA® / RULA software. In the analysis consisted about position pilot on cockpit. Anthropometric measures were taken from a range of members of the Baja / UFV team in the good maneuverability position for each of them. This position was obtained through the positioning of the pilots in an ergometric device, with adjustable dimensions, being: height and inclination of the steering wheel, inclination and distance of the seat and height of the driver. The positions were recorded by means of image having the angulations of the body members obtained through the software SOLIDWORKS®. The anthropometric measures of the occupants were transformed into respective percentiles of the sample. The mean percentiles of each occupant were used to represent the sample analyzed and to perform comfort simulations in CATIA® / RULA. The results of the comfort condition evaluation scores served as parameters for defining the measures of the cockpit. The best cockpit measurement achieved in the simulation was evaluated with scores of two (Negligible risk, no action required), three and four (Low risk, change may be needed, both tree and four score), respectively, simulated with a relative percentile of 65%, 95% and 5%. The all score were satisfactory, since only above four score is medium risk and need change.*

Keywords: *RULA, posture assessment, musculoskeletal disorders, ergonomics, off-road vehicle*

1. INTRODUCTION

In 1976 was founded the Society of Automotive Engineers (SAE) in the t the University of Southern California (USC), the Baja SAE program is a challenge to engineering students that offers the chance to apply the knowledge acquired in the classroom , in order to increase their preparation for the labor market (SAE BRASIL, 2016). The teams participating in the competition develop an off-round vehicle following rules and limitations established by the organization, among them the accommodation of an occupant with weight 113.4 kg and 1.90 m.

The vehicle ergonomics in the competition is a factor of great relevance in the design. Since, the comfort is used as evaluation criterion and interferes directly in the performance of the rider during the dynamic tests. The dynamic competition tests are characterized by their high resistance to extreme situations. The pilot should be given the best conditions of safety and comfort. Needing a detailed ergonomic study of the vehicle so that the risk of injury is ceased and the efforts to drive the components of the cockpit (internal space) are minimal (Okamoto, 2014; Da Silva, 2013).

Based on this, the present project aims to design cockpit of the vehicle like, positioning of the seat, drives and the steering wheel meet the comfort of the pilot whose weight and height are between the percentiles of 5% to 95%, according to the SAE standard.

2. MATERIAL AND METHODS

The project was developed at the Federal University of Viçosa (UFV) in the manufacture and testing of an off-road vehicle named Baja/ UFV. In the development of the project for ergonometric analysis of the cockpit, the following steps were realized: survey of atropometric measures of the users of the UFVBaja vehicle; application of the Rapid Upper Limb Assessment (RULA) method and simulation of comfort conditions as input to the CATIA® Ergonomics Design and Analysis module.

2.1 Rapid Upper Limb Assessment (RULA) Method

The RULA ergonomic analysis method is used in the assessment of ergonomics in workplaces that has high rates of upper limb disorders. It has a reliable and quick identification of the risks related to the posture of the neck, trunk, upper limbs, and also evaluates upper limb musculoskeletal disorders as a consequence of applied external loads (Khandan et al., 2017; David, 2005). The method is analyzed by dividing the human body into two groups A and B. Group A is composed of the upper arm, lower arm and wrist. Group B consists of neck, trunks and legs (Capeletti et.al, 2015; McArtamney & Corlett, 1993).

A posture diagram was used to quantify risk exposure by means of scores. The score is progressive, with '1' indicating low risk situation and '7' indicating exposure rate of injuries. As values are assigned, the method informs an action required to mitigate the risk to which exposure occurs. Each action comprises two levels of scores (Table 1).

Table 1. Action level and respective exposure risk with based score level (McArtamney & Corlett, 1993, Dombidau Junnior et. al., 2017).

Action level	Description action level	SCORE
1	Negligible risk, no action required	1 e 2
2	Low risk, change may be needed	3 e 4
3	Medium risk, further investigation, change soon	5 e 6
4	Very high risk, implement change now	7 +

In this work the data input data in the RULA method were simulated several configurations of the vehicle chassis and its components until reaching an acceptable accommodation configuration for the corresponding occupants of 5% to 95% percentile of the possible user population, corresponding to a chassis design meet 90% of the vehicle's user population. Lima (2006) recommends using extreme users for project analysis and design to meet ergonomic requirements, in this case 5% and 95%.

2.2 Definition of the data to ergonomic analyze

The project was developed in the UFVBaja team, located in the LABENGE / UFV. For ergonomics analyze were defined the following measure from vehicle cockpit: RRH (Rear Roll Hoop) plane inclination; Distance of the drives; Height of the drives; and Steering wheel height. And the anthropometric measurements were: Body height; Height at eye level standing and sitting; Height of the elbow; Hand and arm reach; Distance foot-ball; Seat support; and thigh height.

An ergonometric device was constructed (Fig. 1) and simulating the interior of the vehicle with adjustable settings: RRH inclination, steering wheel distance, steering wheel tilt and distance of the drives. These measures are critical points considered for the comfort of the pilot.

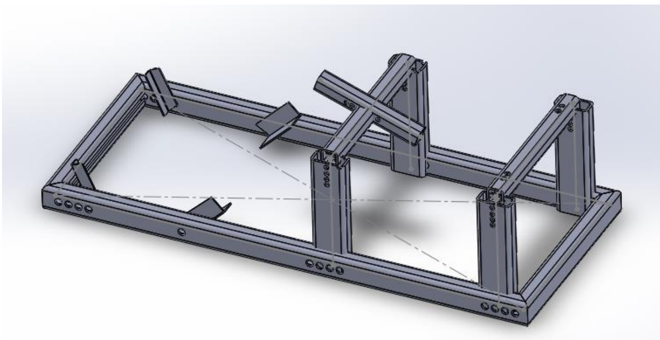

Figure 1. Isometric view of the device with possibly adjustable set points, steering wheel, pedals and seat attachment point.

2.3 Measurement and definition of the cockpit

After the construction of the device, the anthropometric measurements mentioned above, were obtained by measuring tape. These measures were obtained from nineteen possible occupants of the Baja vehicle. Each measure obtained was related to a corresponding percentile. The percentile was obtained from a table of the statistical distribution of a population of 100 thousand inhabitants obtained by Panero and Zelnik (1996). In the second step, the same occupants positioned themselves in the device, so that the maneuverability condition was considerable comfortable for each one, in which the points in the device could be regulated according to the occupant. The positions were recorded by photographs and uploaded in the SOLIDWORKS® software to obtain measurements of the angulations of the limbs of the human body (Figure 2).

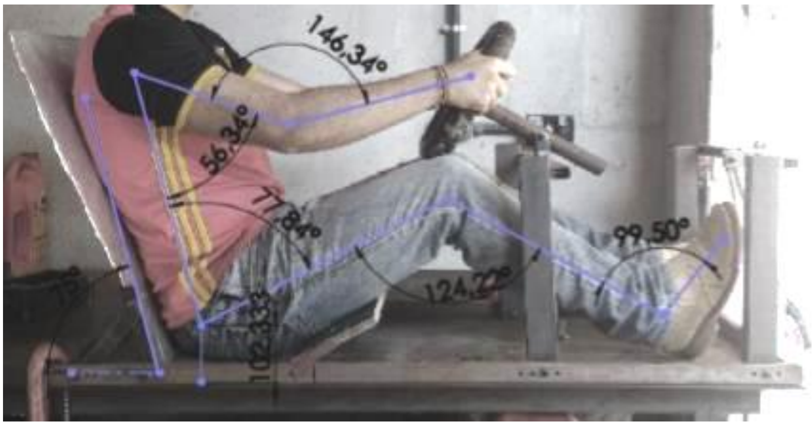

Figure 2. Getting the angles of the members of a human body by SOLIDWORKS® software.

The anthropometric measures previously collected from each occupant were related with the population table percentiles. To define only one percentile per occupant for all anthropometric measure, the mean percentile was calculated of each. To obtain only a mean percentile of the nineteen occupants, it was calculated through of the mean of the mean percentiles obtained previously. This mean percentile served to obtain a model of occupant of the Baja vehicle that was also simulated in the comfort condition, as input to the RULA module of the CATIA software.

By means of the device, the dimensions of the ideal cockpit (height, length and width) were also obtained for the sample of the nineteen occupants. Then, the mean of each measurement was calculated and the dimensions of the initial cockpit were defined.

The range of vehicle cockpit measurements was defined to serve 90% of the population, based on the average comfortable measurements for the nineteen occupants. For this, the mean and standard deviation of the sample were used, considering a normal distribution. In this case, the range of values are as following, $x1 = \mu - Z\sigma$ to $x2 = \mu - Z\sigma$, where, x1 and x2 = random variable range of the cockpit measurements; μ = average measurements cockpit of the comfortable to sample users, Z = standard deviations score, in the case, Z = 1.65 and σ = standard deviation of the sample. Noting that regardless of the value found, the regulations BAJA SAE BRASIL, establishes that the measure of the minimum distance from the point of the seat to the roof of the vehicle should be 1041 mm.

Other important measures for defining the cockpit are the H-point and the average Reference Point-x (SgRPx). The H-point was defined as 100 mm from the floor to the occupant's hip. The SgRPx was 920mm according to the SAE Standard J4004-2008, which corresponds to the distance from the H-point to the drives. The inclination of the RRH plane was also defined as being 15 °, maximum slope allowed by the regulation BAJA SAE BRASIL and diameter of the flywheel 380mm. These values were also used to define the measurements of the cockpit design in Solidworks and loaded for analysis in CATIA®.

2.4 Input for software CATIA®

The initial measurements of the cockpit and measures corresponding to the 5% and 95% percentiles were completed, where the 5% measures correspond to the lowest occupant and the 95% percentile corresponds to the largest occupant. The percentage equivalent to the usual occupants of the UFVBaja project was also found. With this, a 3D model can be generated to submit to the driving conditions method by the RULA method. The RULA module in CATIA® allows you to use one measurement for correspond percentile, along with the operating conditions the model is in. As an output, the method informs the positioning score of the members of the human body by means of colors indicating which positioning needs to be improved.

Based on the result of the analysis scores, a process was started to change the dimensions of the cockpit dimension until a satisfactory score convergence was achieved.

3 RESULTS AND DISCUSSION

The comfortable width, length and height averages for each of the nineteen sample occupants were 472.6 mm, 1215.2 mm and 852.1 mm, respectively .The anthropometric measures from the sample of the nineteen occupants are presented in Table 2, with based on the measurements of the occupants was determined the correspond value of the mean percentile of 65%.

Table 2. Mean anthropometric and standard deviation measurements obtained from the analyzed occupants (measured in meters) where: 2, 3,4,5,6,7 and 8, respectively, height of the body, height at the level of the eyes seated, height of the elbow, arm reach, hand reach, foot-leg distance and seat support.

Occupant	2	3	4	5	6	7	8
Average	1.68	1.23	1.10	0.84	0.51	0.57	0.48
S. Deviation	0.12	0.06	0.06	0.11	0.07	0.05	0.05

The Table 3 shows the vehicle length, width and height values to meet demand 5% to 95% percentiles, for the Z standard probability table correspondent of the 1.65.

Table 3. Mean, minimum and maximum values for Z = 1.65 of the length, width and height of the cockpit of Baja and their respective standard deviations, based on the comfortable measurements of the nineteen occupants, values in mm.

Cockpit measures	Mean	Standard Deviation	Minimum	maximum
Length	1215.3	44.8	1141.4	1289.2
Width	472.6	27.7	426.9	518.3
Height	852.1	29.9	802.77	902.3

From the BAJA SAE BRASIL regulation, the minimum permitted distance from the seat to the roof of the vehicle must be 1041 mm. This value was higher than the maximum found of 902.3 mm (Table 3). Therefore, ergonomic analysis is not required to varying cockpit height. From the cockpit measurements presented in Table 2.

In the first analysis with the minimum measures, a satisfactory result was obtained for the occupant percentile 5%, score two, and not satisfactory, score seven, for the extreme percentile 95% and average percentile, 65%. The dimensions of the cockpit were changed to meet the upper intervals, together with the average pilot angles, obtaining satisfactory result for all percentile. In order to minimize the effect, the diameter of the steering wheel was reduced to 300 mm and maintained the maximum dimensions of the cockpit. A new iteration was performed and obtained satisfactory results for the all percentiles.

The Figures 3, 4 and 5 shows the result of score to simulation the percentiles of the 65, 95 and 5% generated by the *Catia* program. In order to until improve the anthropometric score, the vehicle's steering wheel diameter measurement was changed to 300 mm and maintained the other cockpit dimensions. Consequently, a new simulation was performed and obtained the following results, satisfactory for the all percentiles, 65%, 95% and 5%, respectively, scores two, three and four. According Table 1, '2' score don't need any action and insignificant risk. For score '3' and '4' score are low risk and change may be needed.

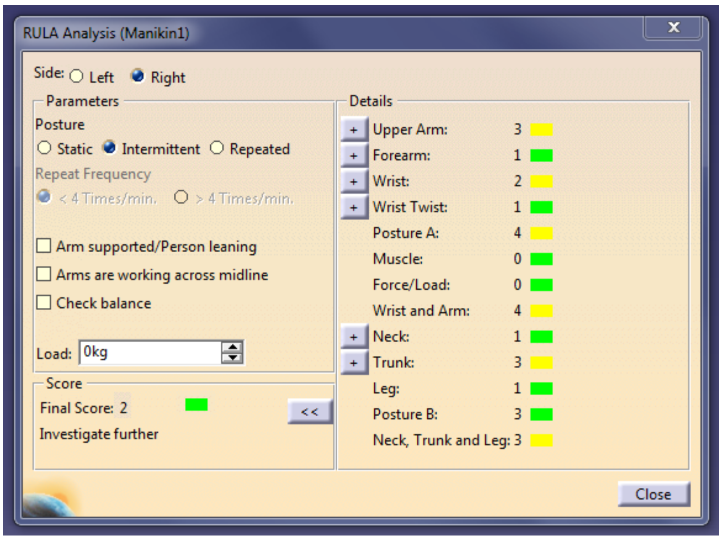

Figure 3. RULA method analysis in the interface Catia for 65% percentile user measure and score '2'.

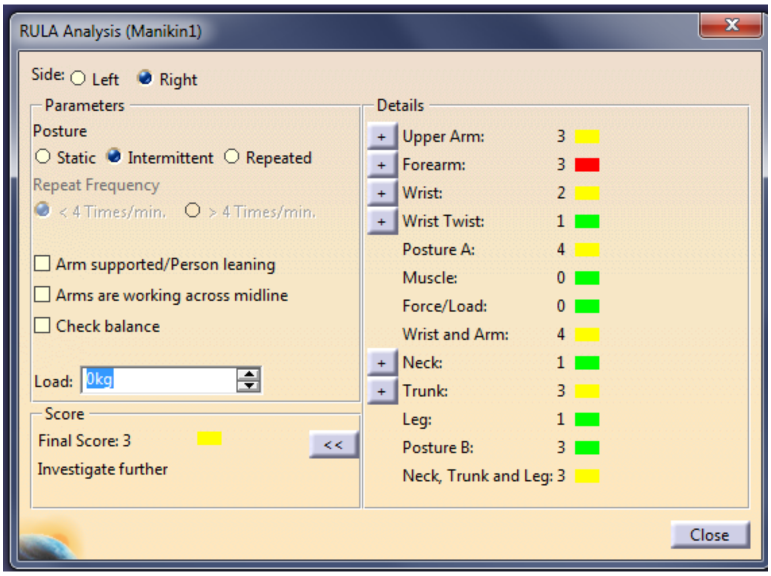

Figure 4. RULA method analysis in the interface Catia for 95% percentile user measure and score '3'.

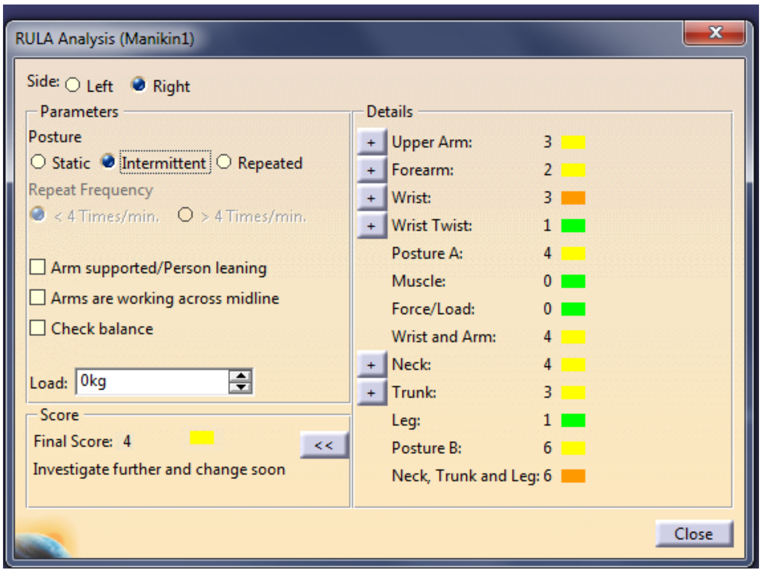

Figure 5. RULA method analysis in the interface Catia for 5% percentile user measure and score '4'.

Regarding the ergonometric analysis of the positions in the dimensioned cockpit, the study was considered with satisfactory results, since scores of two and three do not require interventions and score four is change soon. For 5% percentile, score 4 should improvements in relation to the pulse musculature. For future studies, it is suggested to study a new geometry for the steering wheel of the vehicle that meets the percentiles analyzed, thus attenuating the effects affecting the musculature of the wrist.

4 CONCLUSION

For the conditions of this work, about for ergonomic requirements, and meet demand for occupants BAJA/UFV as well as 90% of other likely occupants, the following cockpit measurements were obtained: length of 1289.2 mm, width 518.3 mm and height 1041 mm. The scores found for the 5%, 65% and 95% percentiles accommodated in this cockpit were four, two and three, respectively. The all percentile were considered satisfactory.

5 ACKNOWLEDGEMENTS

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