Design and analysis of a single-seat frame to implement omnidirectional traction with high efficiency in its maneuverability in tight spaces

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Design and analysis of a single-seat frame to implement omnidirectional traction with high efficiency in its maneuverability in tight spaces

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***Abstract*— This essentially based on the design and analysis of a frame by means of software, for this project design an Aisi 1020 structural steel will be used, this frame will be subjected to the tests required to be approved as a Formula SAE competition vehicle.**

Taking as a priority the safety and ergonomics of the driver, several sketches were made for the development of the same, it is in this way that it is intended to obtain a frame that can present similar characteristics as that of a competition vehicle, but with a lower cost material. Starting from the dimension of a mecanum wheel which will give it omnidirectional movement and the size of an average person, a frame with a pleasant perspective structure was developed to later implement an omnidirectional all-wheel drive that will give better maneuverability in spaces.

Carrying out a wireframe design with a linear appearance and giving properties to each section, we proceed to carry out the analyzes that guarantee adequate performance in different scenarios.

With the study of this type of steel, it can be implemented in new and innovative designs that do not have a high budget and that resemble the performance of a high-performance vehicle.

Keywords-Frame; Design; Analysis; omnidirectional;

I. INTRODUCTION

The chassis is the basic structure of the vehicle. In a more strict sense, the chassis is the supporting structure of the vehicle. However, in vehicle technology, what is often understood by chassis is actually the frame (that is, the supporting structure) complete with suspension, steering, and accessories that attach directly to the frame.[1]

Therefore, the frame must be strong enough to absorb the static and dynamic loads generated by these mechanical components.[2] since the chassis frame is the backbone and its main objective is to safely transfer the certain loads in all designed operating situations.[3]

For the design of this car it was considered to make a tubular frame which is formed by a network of tubes welded together which will take a cage shape.

Another consideration is that at present the parking space in the interior of the cities is a common problem, even if the size of the space is sufficient, it is not guaranteed that the driver will be able to park there. [4]

It is here when using a mecanum wheel that is a very efficient omnidirectional movement mechanism, due to its ease of turning, and its body is not made up like a common tire, but rather by a series of passive rollers that rotate freely and facilitate this action. [5]

In this way, a vehicle that is articulated in an omnidirectional manner is able to carry out rotational and translation movements independently and simultaneously.

These omnidirectional articulated vehicles are currently widely used in various places such as hospitals, factories, sheltered workshops for people with disabilities and in confined spaces.[6] [7] [8]

With this innovation in the automotive field, implementing four wheels called "mecanum" will allow greater control of the designed frame. [9]

II. METHODOLOGY

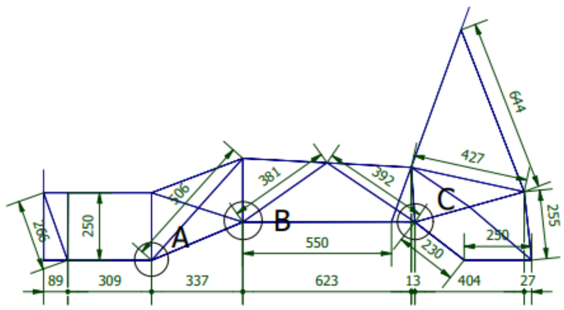
With an engineering criterion to begin the design of this frame, it was taken into account that it will be articulated with 4 mecanum wheels of 10 [in] diameter with a weight of 9 [lb] and support a load of 400 [lb] each of them. In addition, it must guarantee that the performance is the most efficient and optimal by supporting the 95% percentile weight of a person of 176.37 [lb] who will drive the vehicle that will be subjected to tests required by the SAE.

III. DESIGN AND SIMULATION

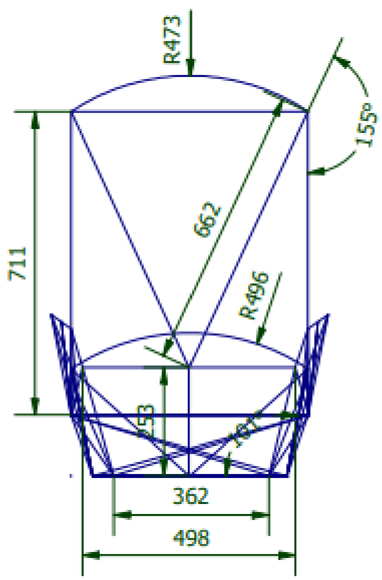
A. Desing Parameters

The geometry of the frame maintains the union of all the linked nodes, which guarantees rigidity and resistance throughout all its design elements.

With engineering criteria, this design is based on the specific dimension of the mecanum wheels, the average size of a person and its suspension system, thus being developed with a total length of 1802 [mm] and a width of 554 [mm], as can be seen in Fig. 1 one of the peculiarities that this design presents is observed in the part where the crew member operates, which rises this height to provide greater safety when moving away from the ground line and ergonomics since in this way the frame adapts to the human body.



(a)



(b)

Figure 1. Frame dimensions (a) side view (b) front view

B. FRAME

At the time of designing the frame, it was taken into account that it must comply with the parameters mainly of safety, ergonomics, provide protection to the constituent elements, system components and serve as a bench for mechanisms that are linked to it.

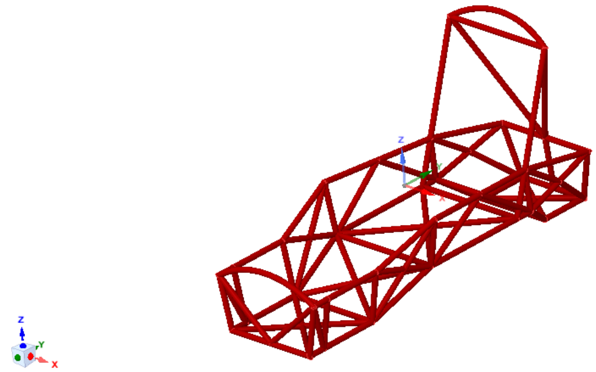


Figure 2. Frame Desing

As seen in Fig. 2, in order to properly absorb the strain energy to the applied loads, and provide sustenance for mobile components developed function properly in the design precaution there are no floating nodes and their unions are well triangulated with this is avoided a break at the time of testing.

This design has an angle of 110 ° to support the back, in the front it has a basket-type scheme which allows freedom of movement for your legs, the support part of the trochoid. (seat) of the body presents an elevation which is based to provide greater ergonomics to the driver, the side parts are designed to provide security and rigidity for the structure, in the back everything is symmetrical in order to implement additional equipment of a Safe way, along the lower part it has braces which maintain the stiffness coefficient of the structure thus supporting torsional loads on a slope.

C. Dessing Analysis

With a wired design with a linear appearance which forms the structure of the chassis, which are given section properties with a certain diameter and thickness for the construction, tests will be carried out which will prove whether its operation is correct.

To verify correct operation, test tables are added, simulating the suspension of the car, as can be seen in Fig. 3.

Figure 3. Section anchoring

D. Torsion Analysis

To carry out this torsion analysis as indicated in Fig. 4, the rear part of the frame is fixed in a fixed way with a simple support and in the front part a vector in direction Z is added in the right front suspension point and another –Z in the left front suspension point with a load of 1500 [N] each, which must withstand with a safety factor greater than 1.

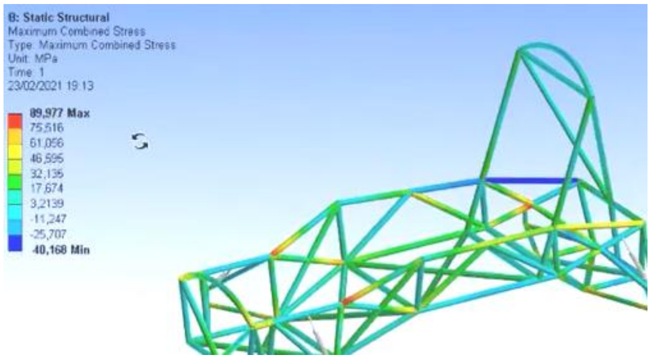


Figure 4. Maximun Tosion Analysis

When carrying out this analysis, it is verifiable that this design will obtain a maximum deformation of 5.8 [mm], this frame is maintained in an integral way by interpreting the total bending moment which is 124 [Nm] and the maximum combined stress that it gives us as result 90 [MPa] compared to the yield strength of steel which is 200 [MPa].

$$Fs = \frac{200\,[MPa]}{90\,[MPa]} \tag{1}$$

$$Fs = 2.22$$

The Eq. 1, shows the factor of safety obtained when performing a torsion analysis on the front of the frame.

E. Curvature Analysis

Given that there are no types of loads in this movement, but if a maximum acceleration of 19.6 [m / s2] in the X axis and the influence of gravity in –Z, the model is evaluated with the section properties employees.

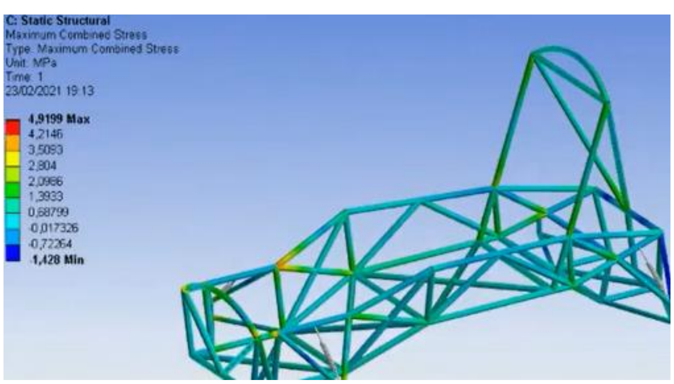


Figure 5. Curvature Analysis

When carrying out this study using the software, it was obtained that there will be a deformation of 0.13 [mm] and the maximum combined stress of 4.9 [MPa], as shown in Fig. 5.

Using Eq. 1 it was possible to verify that this frame design did not have curvature problems when it was built and carried out some type of tests, since its safety factor yielded a value equal to 40.

F. Aerodynamic analysis plus curvature

In the execution of this analysis as observed in Fig. 6, compared to the previous one, four fixed points are added that are specifically located in the anchors of the same, the aerodynamic effect is given according to the acceleration implemented.

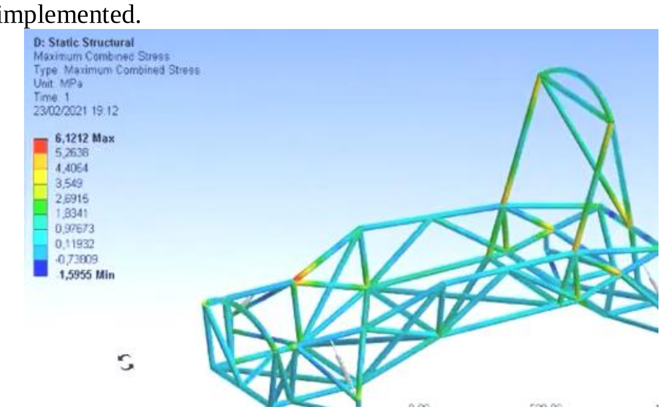


Figure 6. Aerodynamic analysis plus curvature

Once the analysis is executed, it gives us a deformation result of 0.25 [mm] and a maximum combined stress of 6.12 [MPa].

With the Eq. 1, a safety factor of 32.68 is obtained, so it can be said that the design of this frame passes the aerodynamic analysis plus curvature.

G. Frontal impact analysis

To carry out a simulation of the impact test, a force of 30,000 [N] is applied which must be uniformly distributed in all the elements of the front part, in addition to this, six fixed supports are placed in the rear part.

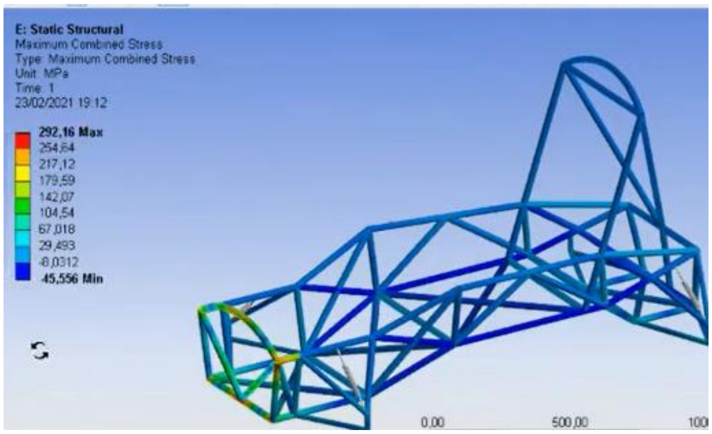


Figure 7. Frontal impact analysis

Once this analysis has been carried out, as shown in Fig. 7, the software indicates that there is a maximum deformation of 3.79 [mm]. For this, a distance of 100 [mm] was granted from the front part to the maximum limit of the occupant's feet, so this indicates that they are preserved in the event of an accident.

With a maximum combined stress of 292.16 [MPa], for this type of analysis it can be verified that it gives us a safety factor inferred to one.

So this means that before an impact under these conditions the frontal arch will undergo a deformation, because the resistance to creep of the material was exceeded, when exceeding the plastic zone we will have a permanent deformation but not a rupture of the same since its Ultimate limit for this material is 350 [MPa].

Thus giving an acceptable result due to the fact that there will be a permanent deformation that will not affect the crew member due to its 1.2 deformation.

IV. TESTE AND RESULTS

Once the total assembly of the electrical, electronic and auxiliary systems has completed as indicated in Fig. 8, that comprised the total assembly of the omnidirectional car has been completed, in addition to the analyzes carried out in the CAD system, a physical driving test is carried out in which the frame supported a load of 789.25 (lb), this load is distributed in both live and dead loads.

When conducting this test, a crew member with the weight of 176.37 (lb) meets the standard weight in which it was found that there are no deformities at all in the frame.

Figure 8. Assembled design

Once the total assembly of the car was completed, one of the most demanding parking tests was carried out, which consisted of parking the omnidirectional car in a place where a conventional vehicle could not perform it, in this way this test was considered as homologated when verifying that this vehicle could do it without any inconvenience as shown in the Fig. 9.

Figure 9 Parking Maneuverability

Table 1 Test and Data

N° Test	DATA					
	V. Max (Long)	V. Max (Lateral)	Brakin Time (Long)	Brakin Time (Lateral)	T radius	A Max.
	mph	mph	s	s	Ft	Ft/s^2
1	24,8	11,18	2	1	8,20	73,16
2	24,23	11,80	2	1	8,20	64,96
3	26,71	12,42	3	2	8,20	61,02
4	25,47	13,04	3	2	9,84	54,13
5	27,34	10,56	4	1	8,20	67.25

Table 1 shows the values with which five performance tests were performed on the omnidirectional vehicle, which yields the results that are considered acceptable for a vehicle with these characteristics.

V. Conclusions

With the unevenness made in the structure, a more efficient ergonomics for the driver can be noticed, which can allow him to drive for long periods of time without presenting excessive fatigue conditions.

Taking into account safety criteria and engineering studies, a car was developed with very high rigidity and resistance, one of the main knowledge is not to leave any type of floating node.

When carrying out the various simulations it was evident that this frame will give its occupant total safety when driving it, but without neglecting that, if it suffers a frontal impact, it will be permanently deformed but will not reach the point of rupture.

CAD systems are very useful tools which, if implemented in similar projects, will obtain efficient results when putting them into practice.

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