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Technical-Economic Study for the Manufacture of a Chassis for the Formula Student

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Abstract

This article analyzes the manufacturing costs of a Formula Student chassis. A technical-economic analysis of the value of the materials is made, using 4130 steel and carbon fiber used in the chassis. It does not take into account the cost of personnel, which is done by students who make the proposal for the competition. The final value is very important because it allows the incorporation of more students with prospects of generating automotive companies in the region of Norte de Santander in Colombia, at the same time establishes the possibility of seeking funding to achieve the complete construction of the chassis.

Keywords: Student chassis, chassis cost, SAE chassis construction.

I. INTRODUCTION

The Student Formula or SAE, as a university competition involves making a fairly high economic investment for developers, becoming the main obstacle to its manufacture. Students must be clear about the cost involved in developing a chassis for this competition and have a total ignorance of what it may eventually cost.

That is why to achieve the objective, researches are presented where the investment cost, market acceptance and marketing are analyzed [1], due to the importance in the final score that the projects may have. One of the problems is the cost of materials that increase if they must be imported, especially in Colombia where there is not a varied supply of materials, affecting the cost and becoming a larger expense.

According to the competition the costs may vary, an example is if you want to participate in the Formula Student at Silverstone England for the year 2019, which could be worth 2 thousand dollars in Ecuador and varies according to the country [2]. A material cost analysis for the construction of a low SAE type chassis in Mexico can be worth $15089.01. A more complete budget should be divided into the price of the material, workshop work, construction of structure and personnel cost where there are mechanical engineers to do the work. In a chassis design and optimization in Spain work has been done in previous years with a forecast of 34 hours for staff, totaling 1190 euros, in the materials used tubes of diameter 26.8 mm and 3.2 mm thick, for a total of 29 tubes and a cost of 12208.42, tubes of diameter 27 mm and 4 mm 13416.43, bars of 2.7 mm section and 26.5 mm with a value of 15539.76, the price of the tubular structure is 177.10, covering the total to be invested to build and optimize the chassis for the Student formula [3]. An interesting experience in Germany was the time it takes for the total construction of the driverless db019 single-seater, with a time of 2 months and 3 shifts per day at the Technische Universität München, TUfast Racing Team [4], [5].

In Colombia budget researches are varying by the devaluation of the currency and the import sometimes of materials, a study divides the costs in materials and manufacturing, and in terms of materials one meter of pipe had a price of $3236 and 43 meters were required for a cost of $999148 in 2015 [6]. Universities have been incorporating research and development programs for Formula SAE, as is the case of the Julio Garavito School, where a group of students of mechanical engineering, electronics, industrial and management want to create innovative designs for the industry [7]. The Colombia Racing Team is the first Colombian team to participate in the competition and belongs to the Technological University of Pereira [8].

In this research a technical-economic study for the manufacture of a chassis for the Formula Student, with the raw material of 4130 steel and 25 mm x 2.5 mm, 25 mm x 1.65 mm and *25 mm x 1.2 mm, as* well as carbon fiber, which will allow to know if a project of construction of a chassis for the formula Student can be viable from the perspective of university students.

II. METHOLOGY

The cost of manufacturing the chassis for a Formula SAE vehicle is a definitive factor when entering this competition. Each of the participating teams evaluates which is the best structure that offers excellent performance in terms of weight and stiffness, with a cost reduction in both raw material and manufacturing process. For the above mentioned. A comparison of manufacturing costs has been made between the tubular steel structure and the carbon fiber monocoque to determine the best option at the time of manufacturing the vehicle chassis. Tubes of 25 mm x 2.5 mm, 25 mm x 1.65 mm and *25 mm x 1.2 mm* will be used.

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Raw Material Costs Tubular Chassis Steel 4130

To calculate the total cost of the required material, we have started by determining the total length of each of the profiles used that make up the chassis structure. For the 25 mm x 2.5 mm tubes, this is shown in Table 1.

Table 1. Number and initial required length of 25 mm x 2.54 mm tubes

Quantity	**Length [mm] Length [mm**
2	350
2	315
2	585
2	320
3	370
2	150
2	120
2	230.65
2	80
1	290
2	177.26
2	500
2	525
2	228.59
2	120
2	734.37
2	85
2	154.46
1	78.36
2	589.22
2	193.33
2	152
1	404.62
Total	13102.74

For the 25 mm x 1.65 mm tubes, see table 2.

Table 2. Number and initial required length of 25 mm x 1.65 mm tubes

Quantity	**Length [mm] Length [mm**
2	967.17
2	209.69
2	458.6
2	787.86
2	709.75
2	622.13
2	267.1
2	913.85
Total	9872.3

For the 25 mm x 1.2 tubes, see table 3.

Table 3. Quantity and initial length of 25 mm x 1.2 mm tubing needed

Quantity	**Length [mm] Length [mm**
2	684.33
2	678.59
2	307.16
2	366.4
2	598.35
2	677.2
2	350
2	300
2	578.98
2	370
2	107.13
2	50
1	352.49
Total	10488.77

Considering the above, the total price of the structure is shown in Table 4.

Table 4. Length and total cost of raw material for the manufacture of the tubular chassis

Profile	Total length [m].	Unit price [COP/m].	Total price [COP].
25 mm x 2.5 mm	13.5	135550	1829925
25 mm x 1.6 mm	10	72830	728300
25 mm x 1.2 mm	11	88790	976690
Total	34.5		3534915

Source: *[9]*

Raw material costs Carbon fiber single-seater chassis

The estimated cost of raw material for the carbon fiber **single-seater** was made by quoting the materials needed to manufacture the structure, these are: Carbon fiber panels, Honeycomb core, epoxy resin, resin hardener and a carbon fiber tape which allows to secure certain areas of the chassis. Table 5 shows the price of each material with its corresponding vendor.

Table 5. Total raw material cost carbon fiber **single-seater**

Material	Dimension	Quantity	Unit Cost [USD].	Total Cost [USD].	Supplier
Carbon Fiber Sheeting	48" x 48" x .0098"	20	45	900	Fiberglast
Honeycomb Core	48" x 48" x 1"	2	345	690	ACP Composites/Hexcel
Carbon fiber tape	6" x 1Yd x 0.12"	1	22	22	ACP Composites
Epoxy Resin	1 gallon (3.7 Liters)	1	129	129	Fiberglast
Resin Hardener	1 room	1	50	50	Fiberglast
Total				1791	

As can be seen in Table 5 and 4 the raw material needed for a tubular structure is cheaper than for the development of the carbon fibre monocoque, this being a key factor in determining the most suitable chassis that satisfies all the requirements in terms of stiffness, weight and cost.

III. RESULTS

This section will define the manufacturing process and corresponding costs for the proposed final chassis, with the aim of achieving a structure as close as possible to the C.A.D. design, since a bad manufacturing will directly diminish the performance of the vehicle.

Pipe bending

The tube bending process is performed by applying a mechanical force on the walls of the material, forcing it to take a bend with a specific radius. In this process, the inner wall is compressed and the inner wall is stretched. This stress condition causes a thinning and elongation of the outer wall, and thickening and reduction of the inner wall [10], so that, if the process is not performed properly, the tube deforms excessively forming bending folds. The objective of this step is to avoid the occurrence of both a bending fold and the rupture of the tube and thus form a uniform bend. It is of utmost importance to take into account the pipe diameter, thickness, material and bending radius in order to determine the most

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appropriate method to be used when performing the bending process [10].

The roll bows are the longest structural members in the chassis, as specified in section 2, each of these consists of a continuous circular tube without cuts or perforations. The most effective procedure for bending each arch is rotary roller bending, which consists of bending the tube over a bending form or roller, clamping it with a clamp and applying a radial load through a pressure bar, as shown in Figure 1.

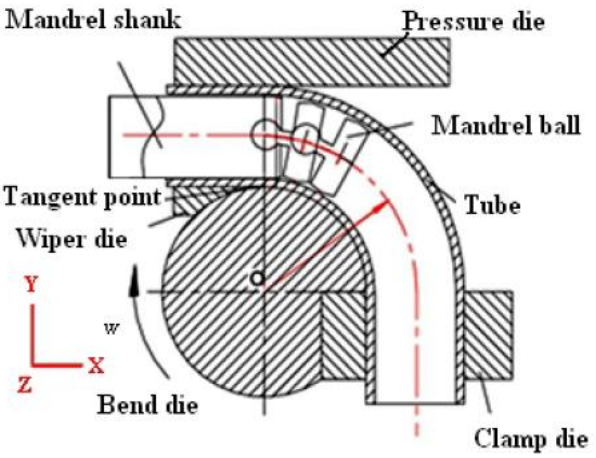

Fig. 1. Working principle of the rotary bending method. ***Source:*** *[11]*

Pipe Marking and Cutting

To ensure that the cutting process of each structural member is carried out in a proper way, a series of templates have been designed with the help of SolidWorks software, as shown in Figure 2. For this, the type of coupling or cut to be made is the commonly called fishmouth, which facilitates the welding process of the structure and avoids excessive material input.

The guide template is generated by extending the tube profile, which generates a sheet. This should be printed in 1:1 scale and used on the pipe when cutting. An example of the process is shown below.

Fig. 2. Example of template guides for the cutting process of each structural member. **Source:** UPS Racing Team

Once the previous step has been completed, the cutting process must be carried out. For this there are several processes that offer excellent results, such as laser cutting which performs the cut in a clean and precise way, the radial or band saw cutting which is an economical process, but if not done properly could generate burrs, hindering the final assembly of the chassis. If the latter is used, the thickness of the saw to be used must be taken into account, so it is recommended that the length of the tube to be cut is slightly longer than the element in the plan, allowing to guarantee the dimensions of each structural member.

Assembly

In the chassis fabrication process, one of the biggest problems is defining the correct way to secure and support each structural member during the welding phase. For this, the teams participating in Formula SAE use a structure called *Jigs* or *Fixtures (*Figure 3). Jigs are designed taking as a matrix the geometry of the tubular chassis and manufactured in thin steel or wood sheets. An example of this support structure used by Formula SAE teams is shown in Figure #.

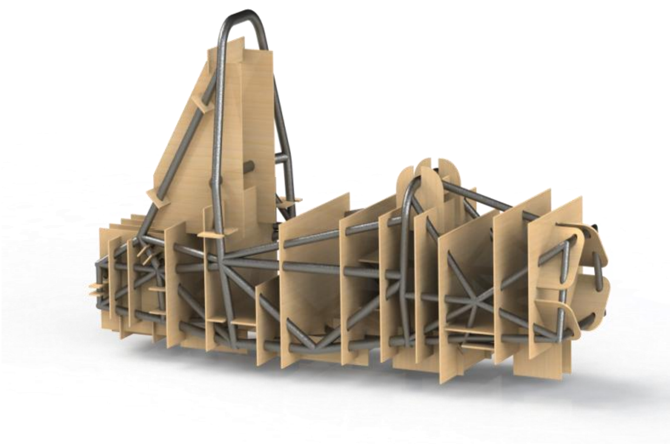

Fig. 3. Example of Jigs or Fixtures Structure. **Source.** Peen Electric Racing Team, 2014

The cutting of each sheet of the Jigs structure must be of high precision so the use of CNC machines is recommended.

Welding

At the moment of welding the chassis structure, there are several methods which allow to obtain excellent results, the most recommended and implemented by the Formula SAE teams are the T.I.G. welding and the M.I.G. welding. Next, each method will be explained in detail, emphasizing the advantages and disadvantages of each one.

- **T.I.G. Welding**

The arc welding under shielding gas with non-consumable electrode T.I.G (Tungsten Inert Gas), uses as energy source the electric arc that is established between a non-consumable Tungsten electrode and the piece to be welded, while an inert gas, usually argon, protects the fusion process [12], [13].

Final manufacturing costs

For the final manufacturing costs, the cost of raw material, and labor for each of the manufacturing processes and machinery to be used have been taken into account. Table 6 and 7, shows the final cost of the proposed Formula SAE chassis.

Table 6. Raw Material Costs

Raw Material Costs					
Description	Material	Total Quantity [m]	Unit Price [USD].	Total Price	Total Price [COP].
1 "x 0.095" Round Pipe	AISI 4130 steel	20	$43.74	$874.8	$2699501.6
1 "x 0.065" Round Pipe	AISI 4130 steel	14.5	$23.5	$340.75	$1051503.4
Square Pipe 1" x 0.083"	AISI 4130 steel	2	$56.91	$113.82	$351231.4
M.I.G./T.I.G. electrode.	Copper coated mild steel	5 lb	$6.28	$31.4	$96869.00
Total					$4199105.4

Source: *[9]*

Table 7. Manufacturing Processes Costs Final Chassis

Manufacturing Process Costs				
Manufacturing Process	Quantity	Labor	Machinery	Total
Tube Bending	22 folds	$20000 COP	$2600000 COP	$3040000 COP
Pipe cutting	1 Chassis Formula SAE.	$1280628 COP		$1280628 COP
M.I. G welding	1 Chassis Formula SAE.	$120000 x 8hr Daily for 3 Days		$2880000 COP
Total				$7200028

The cost of the proposed final chassis is $11.400.000 COP, which is distributed in the purchase of the raw material and the realization of each one of the manufacturing processes. This value is well below the established by the regulation which determines that the maximum price for the manufacture of the chassis is $25,000 USD, which is equivalent to $ 77,000,000 COP. So the development of the proposed structure is low cost.

IV. CONCLUSION

The technical-economic study to design, analyze and build a car for the Student formula has focused on materials, which have an affordable price, but present an obstacle at the time of construction by the few resources that can be available to university students in South America. But at the same time presents an opportunity to create and build efficient designs that allow the region of Norte de Santander in Colombia to distinguish itself as a growth area in the automotive area, generating job opportunities for recent graduates. The option of carbon fiber chassis is not discarded in its entirety since good results were also obtained in its analysis, even though the construction of the vehicle with this material is much higher than the steel structure.

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