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DESIGN AND ANALYSIS OF THE TORSIONAL STIFFNESS OF THE CHASSIS OF A COMPETITION PROPOTYPE FORMULA SAE USING THE FINITE ELEMENT METHOD

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Abstract. The torsional stiffness of the chassis of a competition prototype is one of the main factors to be analyzed in structural design. Regarding the vehicle dynamics, the chassis design must have enough torsional stiffness so that the suspension work does not influence the structure behavior. On the other hand, the chassis should not have excessive weight, since it is a high performance prototype. In this context, the structural design of the chassis should take into consideration the balance of the functional aspect (torsional stiffness) and its performance (weight factor). The purpose of the present work is to design and analyze the torsional stiffness of the chassis of a Formula SAE Prototype of competition, when subject to the efforts arising from the suspension as a function of vehicle dynamics during a competition. The finite element study aims to replace the bench test, which in most cases demands excessive time and high cost. Simulations performed with SolidWorks software will serve to validate and verify the compatibility of the results found. The results obtained will be presented through the main torsional stiffness indicator and the other indicators related to the stress and strain variables.

Keywords: Chassis, Formula SAE, MEF, torsional stiffness.

1 Introduction

From the beginning of the automobile's history to the present day, engineers have been constantly looking for better performance and efficiency in automobiles in order to improve parameters such as: power, torque, consumption, curve dynamics, resistance and safety.

One of the main parameters correlated with the car's performance is torsional stiffness and will be the subject of study in this work. Generally car chassis are complex to be treated analytically and are usually analyzed with computational tools, and in this work the finite element method will be used.

This work aims at the design and development of the tubular chassis of a Formula SAE prototype, subject to the efforts arising from the suspension dynamics during the competition. And after obtaining the data, make a performance comparison with the previous models.

2 THEORETICAL FUNDAMENTALS

2.1 Structural Frame Concept

Ideally, the purpose of an automobile chassis is to connect all four wheels to a structure that is rigid in flexion and torsion. It must be able to support all components and occupants, in addition to absorbing all introduced loads without transmitting them incorrectly [2].

The term Chassis can be used referring to all systems that are attached to the structure, for example, suspension and steering system, power and transmission system, among others, in the present work the chassis will be analyzed only as a structural component [3].

In motor sports cars the chassis must be rigid and light enough to improve the response and performance of the suspension and powertrain system, in addition to complying with competition regulations.

The chassis is the link between the other subsystems and its main function is to provide adequate safety for the driver. As a result, the chassis must follow some strict rules in its design and dimensioning [4].

The chassis can be divided into 5 categories: tubular, cruciform, ladders, monocoque and hybrid [6]. In this Project, the tubular chassis was used, as it has a high torsional rigidity, ease of construction and low cost when compared to other models.

2.2 Torsional rigidity

Torsional stiffness is the amount of torque required to deform a mechanical system or structure by 1 ° degree (on a given axis of rotation). The torsional (or angular) deformation of a chassis refers to the rotation around the length of the car (longitudinal axis put figure). In practice, a chassis will be subjected to torsion when a tire is under high load and the opposite tire under low load and this happens in curves due to lateral force or when there is some discontinuity in the track [5][7].

Increasing a race car's torsional stiffness improves handling by allowing suspension components to control a greater percentage of the vehicle's kinematics [1].

3 METHODOLOGY

The methodology of this work consists of projecting the geometry of the prototype in solidworks, choosing the material for analysis of finite elements, application of loads and supports in the simulation environment (cosmoworks) of solidworks, mesh generation, display and analysis of the results.

3.1 The prototype

In the proposed chassis, the efforts employed were aimed at a longitudinal reduction in the structure in order to improve the agility of the prototype, and consequently also resulted in a reduction in weight. In relation to the previous model, a longitudinal reduction of 91 mm was obtained, and a reduction of approximately 3 kg in the structure (Figure 2).

In the construction of the prototype several sections of tube were used, in the points subject to Flexion, tubes of square section were adopted to result in less deflection when compared to circular tubes with the same weight per linear meter [8].

The project was conceived entirely with the Solidworks 2016 software (Figure 1). The Chassis was designed primarily to accommodate the suspension geometry, therefore, achieving the desired performance in the tires, while aiming to maximize the torsional stiffness / weight ratio.

Figure 1. Proposed Formula UFPB prototype
Source: Elaborated by the author

Chassis Geometry

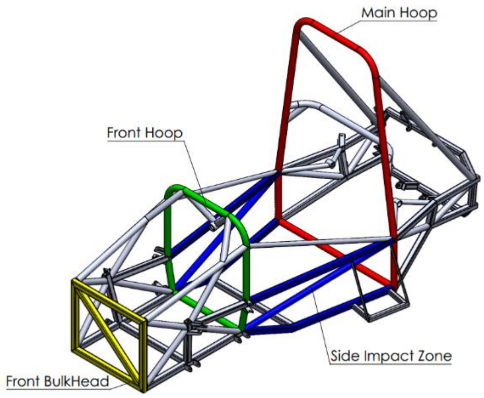

Figure 2. Chassis components
Source: Elaborated by the author

3.2 Boundary Conditions

3.2.1 Supports, Loads and Mesh

For the study, the rear suspension attachment points were considered fixed, the fixed brackets are indicated in green in the figure 3. The loads imposed by the suspension are shown in the figure below and have a modulus equivalent to 1833 N and 1029.42 mm apart (Figure 4). The mesh type chosen was beam type because the model behaves well with this type of element (Figure 5) [9].

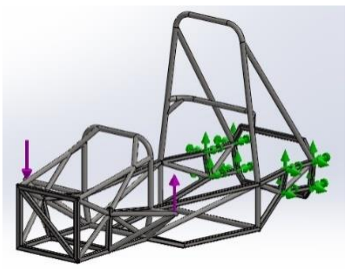

Figure 3. Position of loads and supports

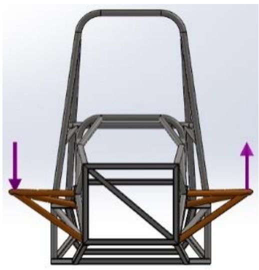

Figure 4. load directions

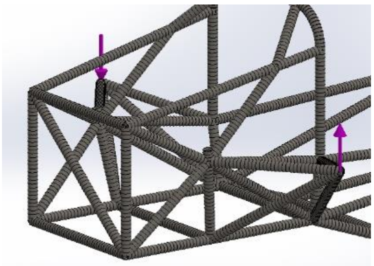

Figura 5. Mesh

Source: Elaborated by the author

4 RESULTS

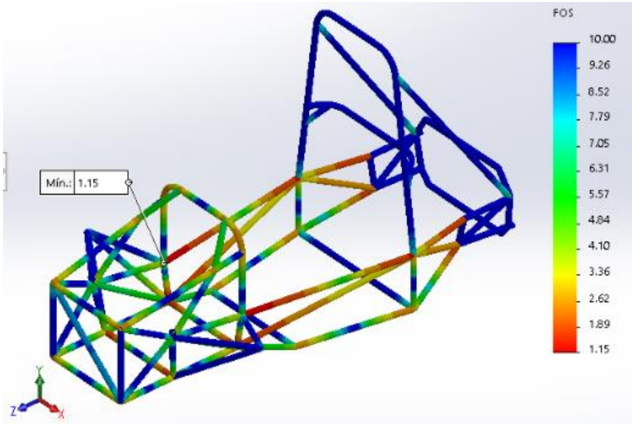

Figure 6. Safety Coefficient min 1.15
Source: Elaborated by the author

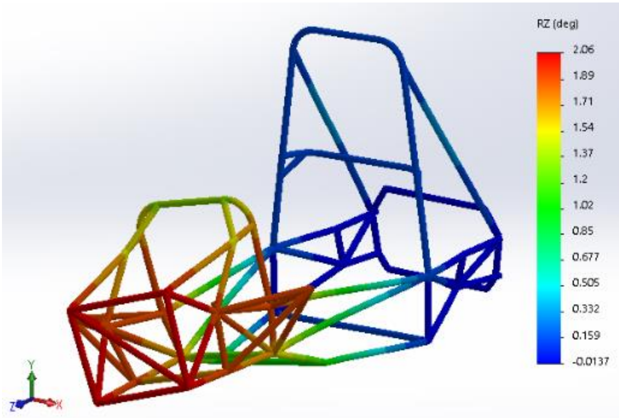

Figure 7. Angular displacement, max 2.06 degrees
Source: Elaborated by the author

5 CONCLUSIONS

A torsional stiffness of 935 Nm/degree against 836 Nm/degree of the previous frame was obtained while maintaining the same mesh conditions of the old frame an improvement of approximately 12%, the result was already expected because according to the angular deformation equation the shorter a body the smaller the deformation the same goes for multiple cross sections as is the case with the chassis. With the longitudinal reduction it was also possible to obtain a mass reduction of approximately 3kg compared to the previous chassis, in fact fewer tubes were used to build the frame. The Longitudinal Length was achieved a 90mm decrease in longitudinal length by repositioning the pilot in riding condition which provided a better allocation of components such as pedals, fuel tank and the pilot seat resulting in a better positioning of components and faster suspension response on turns.

Below is the table showing comparatively the chassis evolution of the last 3 project Designs.

Table 1. Frame parameters comparison

Year	Torsional Stiffness	Weight	Longitudinal Length
2013	--	55 Kg	2400 mm
2015	836 Nm/grau	43 Kg	1994 mm
2017	915 Nm/grau	40Kg	1903 mm

Source: Elaborated by the author

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