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Design, Analysis and Validation of Torsional Stiffness of Chassis for Formula Student Car

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Abstract

This paper describes the analysis and validation of torsional stiffness of chassis of a formula student vehicle. Chassis being a major component of a vehicle it determines the dynamic performance of the car. Design of major systems such as Suspension, Steering and Wheel Assembly are affected due to torsional stiffness of the chassis. In this paper experimental determination of torsional stiffness of single seat tubular chassis for comparison with Finite Element Analysis (FEA) models.

Keywords: *Chassis, Analysis, torsional stiffness, formula student, validation*

1. Introduction

The torsional stiffness of formula student racing car chassis plays a very important role in its handling characteristics. These handling characteristics can be improved by altering the roll stiffness of front and the rear suspension (for e.g. understeer and oversteer). The load distribution is affected due to adjustment of these parameters which affects high speed cornering stability. Forces generated during high speed corner are high enough to deform the chassis which has adverse effects on suspension geometry thus hindering the handling characteristics of the vehicle. To avoid this chassis needs to be stiff.

2. Methodology And Experiment

For conducting the experiment one beam was used. In this the rear bulkhead was fixed from its hardpoints. While the front axle was attached to a beam which could rotate about longitudinal axis of the frame. To one end of this beam we apply a known amount of force which inturn acts like a torque on the frame. Due to this torque the frame twists along its longitudinal axis. The angle of twist was measured with the help of an inclinometer place at the front end of the frame. Thus the ratio of torque applied to the angle of twist gives the torsional stiffness of the frame

Torsional stiffness of chassis is usually measured in units of Nm/deg and is denoted by 'k'.

Hence,

$$K=T/\theta$$

Where,

T = torque applies on the front beam in Nm
Θ = angle of twist on degrees

$$T= F.\, r$$

Where,

F is the force caused by the applied mass and r is the distance from the point of the force to the point of the rotation.

Also,

$$F=m.g$$

Where,

m = mass of the applied weight
g =acceleration due to gravity which is 9.8 m/s²

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2.1 SETUP

A. The rig is designed for validating the torsional stiffness of various chassis. Further making some changes which can be done in no time within the test rig will make it suitable to test different chassis. But for now it is made to test our current years FS vehicle chassis.

B. Following are the images for setup of the test rig:

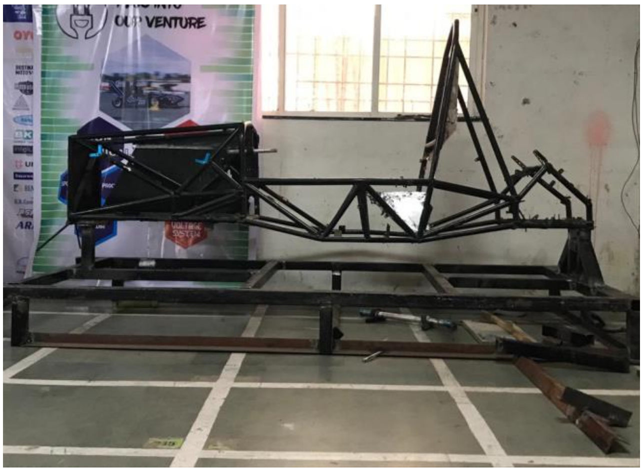

Figure1: Side view of the test rig and chassis mounted for the validation.

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Figure 2: Rear bulk head mounting on the test rig

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Figure3: Front bulk head mounted on the beam for allowable rolling moment about longitudinal axis

The chassis can also be tested with suspension geometry as well but in that case the test rig has to be designed and developed with very high precision which can cost time as well as money. Also that test rig can be used for a particular design of the chassis. For the same we decided to test the chassis without suspension geometry which makes the test rig simple and easy to construct in small budget.

C. Design of Chassis:

The design of chassis begins with the final design of suspension geometry. Both the trackwidth and wheelbase are determined by the suspension department. Then position of all the hard points are determined and from these positions the design of chassis begins. Design of a Formula Student Vehicle is based on a rule book and everyone must follow it. As a result chassis design is also based on set of rules mentioned in the rule book. For a tubular chassis the OD(outer diameter) and thickness of the tubes used also have certain limits.Following is the table describing the rules for tubular members used in construction of chassis.Title must be in 24 pt Regular font. Author name must be in 11 pt Regular font. Author affiliation must be in 10 pt Italic. Email address must be in 9 pt Courier Regular font.

TABLE I

MINIMUM MATERIAL REQUIREMENTS

Item or application	**Minimum wall thickness**	**Minimum cross sectional area**	**Minimum aera moment of inertia**
Main and front hoops, shoulder harness mounting bar	2 mm	175 mm^2	11320 mm^4

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Side impact structure, front bulkhead, roll hoop bracing, driver's restraint harness attachment	1.2 mm	119 mm²	8509 mm⁴
Front bulkhead support, main hoop bracing supports	1.2 mm	91 mm²	6695 mm⁴

Non-welded strength for continuous material calculations:

- Young's Modulus (E)= 200GPa
- Yield Strength (Sy)= 305MPa
- Ultimate Strength (Su)= 365MPa

Welded strength for discontinuous material such as joint calculations:

- Yield Strength (Sy)= 180MPa
- Ultimate Strength (Su)= 300MPa

Considering all the rules and design constraints of all departments (steering, drivetrain, powertrain, wheel assembly) the chassis design was finalised. Following is the design of our chassis for the upcoming season.

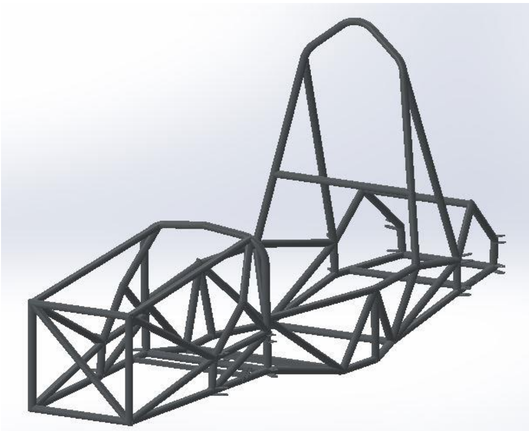

Fig.4 CAD of chassis for our upcoming season

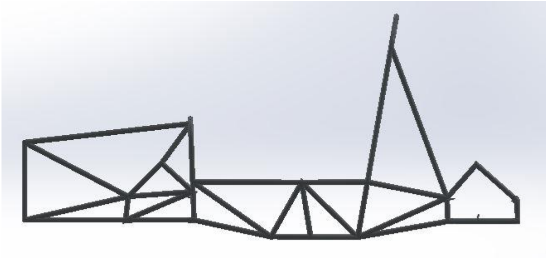

Fig 5 Side view of chassis

Analysis:

After the design, analysis for the above chassis design was carried out. FEA (Finite Element Analysis)technique was used to analyse the chassis. Till previous year we were just analysing the design and were not validating it. This gave rise to many questions during design presentations at various FS competitions to which we couldn't answer satisfactorily. So this year we decided to analyse as well as validate the design so not only for the design event but how correct our design and analysis is could also be checked.

III Result:

Torsional stiffness analysis where we get the total deformation. The below result is carried out for the maximum G-force that could be experienced by the chassis i.e. 4.5G

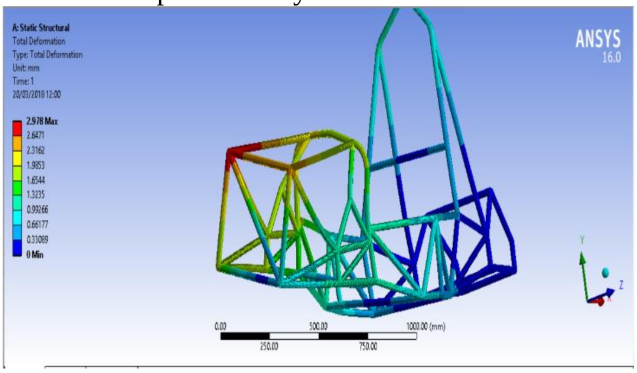

Fig 6 Torsional stiffness analysis (4.5G)

While below is the result of the maximum stress that can be induced at the damper hard point (point where actual force acts) at 4.5G

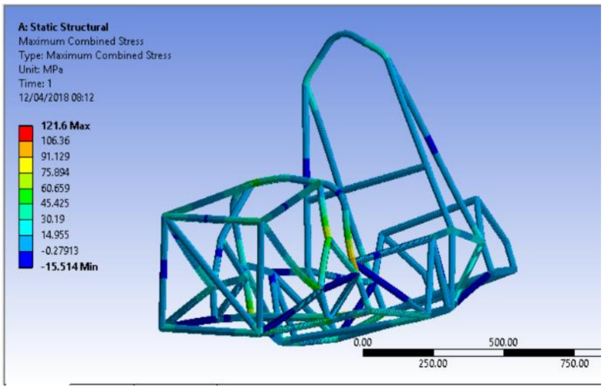

Fig 7 Maximum stress induced.

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During the analysis we found the torsional stiffness of the chassis came out **be 1800 Nm/deg**. And during the actual validation the torsional stiffness came out to be **1720 Nm/deg**. This is not exactly same as there can be some errors during the manufacturing period as well as the welding strength may also differ as the chassis was welded by two different members of our team.

IV Conclusions

The purpose of this paper is to describe one of the few methods to validate the torsional stiffness of the chassis of a FS vehicle. Also the design constraints are described in this paper which will make it easy for designing an error proof chassis. The method described in this paper for torsional stiffness validation is one of the easiest method that can be used which is not very complex as well as not very costly. This test rig can also be modified further as per new chassis design with some minor changes which again will not be costly. Many other changes can be done in the structure of the test rig which will make it highly flexible but will need some high investment in the uture.

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