

# Design and Analysis of Tubular Space-Frame Chassis with Impact Absorbers on Sports Car Electric Vehicle

Putra Mulya Pamungkas<sup>1</sup>, Mohammad Adhitya<sup>2</sup> Danardono Agus Sumarsono<sup>3</sup>,

PG Student, Department of Mechanical Engineering, Universitas Indonesia, Kampus UI Depok, Indonesia<sup>1</sup>

Lecturer, Department of Mechanical Engineering, Universitas Indonesia, Kampus UI Depok, Indonesia<sup>2</sup>

Professor, Department of Mechanical Engineering, Universitas Indonesia, Kampus UI Depok, Indonesia<sup>3</sup>

**ABSTRACT:**Chassis is the union of all components of the vehicle also to withstand the burden that occurred. This load also includes the weight of each component and the force that occurs when the vehicle is moving (acceleration, deceleration and cornering). Chassis should also absorb energy when a collision occurs. This study was conducted to compare the Chassis of Space-Frame type without impact absorbers and filled with impact absorbers. Chassis made with weight less than 60 kg, this is to improve acceleration and mileage. Modeling was made using Solidworks and analyzed by Solidworks Simulation.

**KEYWORDS:**Space-Frame, Electric vehicle's chassis, torsional stiffness, Rigid Polyurethane Foam

## I. INTRODUCTION

The need for vehicles increases day by day. It will also increase air pollution. One technology that can resolve the problem of air pollution, especially vehicle emissions, is to create an electric vehicle. Electric cars are currently widely circulated using one or more electric motors as a driving force. In making electric car vehicles, many things are considered [1]. One important aspect of the vehicle is the Chassis. It functions to answer the maximum load for all designed operating conditions and to support components such as engine, wheel, drive train, steering, etc[2]. Chassis are considered the most significant components that can provide vehicle strength and stability under different operating conditions. The materials usually use hollow steel. Hollow steel has a high stiffness, but can't absorb energy when a collision occurs. Therefore, in this study will be discussed comparison between hollow steel without impact absorbers and filled with impact absorbers by simulation.



**Fig 1.** 3D modeling of tubular space frame

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## II. LITERATURE SURVEY

**George, A. and W. Riley**[3]. Explain that high torsional stiffness and light weight are ideal conditions for vehicle chassis. High torsional stiffness will affect the stability of vehicle handling and lightweight will impact on low fuel consumption and increase acceleration.

**Prajwal Kumar M. P, V.M., G. Madhusudhana** [4]. In this paper, a comparison of 2 materials. AISI 1018 and Chromoly 4130 steel materials were obtained to obtain a high torsional stiffness and a torsional value of Stiffness for Chromoly 4130 steel material of 2550 Nm/deg.

**Nagarjuna Reddy.Y, V.K.S** [5]. Conducting testing on FSAE Chassis. Modeling was made using CATIA V5 and analyzed by ANSYS 11.0 with 4 modes of loading, i.e. twist mode, bounce mode, pitch mode, and roll mode.

**Waterman, B.J** [6]. Explain that the best hollow section used for space frame type chassis is using square member type, with just an 11% increase in weight a 50% increase in yield strength is obtained if buckling is the failure mode. Using one or more square pipes as part of the side impact structure will make the chassis stronger. See table 2.

**Remennikov, A.M., S.Y. Kong, and B. Uy** [7]. Perform testing on hollow section added material Rigid Polyurethane Foam as absorbers. An increase in energy absorption by 14%.

**Onsalung, N., C. Thinvongpituk, and K. Pianthong** [8]. The type mass of Rigid Polyurethane Foam also influences the impact strength value. They state the value of impact strength increased by 12.8, 19, 23.9 and 31.6% for density types 100, 150, 200, and 250 kg/m<sup>3</sup>.

## III. METHOD

### Basic Design

The basic design of electric vehicle's chassis is following Caterham [9], with minor modification. Begin by drawing a sketch of the lines representing the chassis shape, then using the weldment feature (structural member) to create the desired tubular profile. The model will be analyzed as shown in Figure 1.

### Material Selection

In addition, to be able to support the vehicle load, the Chassis must also be able to absorb energy when there is a collision either from the front, side, or rear. The widely used material for Space-Frame is SAE-AISI 1018[4]. With the following properties :

**Table 1.** Material properties of SAE-AISI 1018

Properties	Value	Unit
Density	7800	Kg/m <sup>3</sup>
Modulus Young	210	GPa
Elongation	19	%
Brinell Hardness	120	
Yield Strength	360	MPa
Ultimate Strength	420	MPa
Thermal Conductivity	50	W-m/K
Thermal Expansion 20-100°C	11	µm/m-K

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**Table 2.** Round vs Square tube [6]

	Round	Square	% Difference
Cross Sectional Area (m <sup>2</sup> )	119.6318	132.7175	10.93829
Mass per Unit Length (kg/mm)	0.933128	1.035197	10.93829
Second Moment of Area (mm <sup>4</sup> )	8508.815	12688.02*	49.11618
Buckling Load for 1m Length **(N)	16795.73	25045.15	49.11618

\* The lowest value, calculated in the center axis position of the surface

\*\* Both ends use a hinge pedestal

Rigid Polyurethane Foam used is type PMDI20. This material has been tested by Wei-Yang Lu [10] and obtained material properties as in table3.

**Table 3.** Material properties of PMDI20

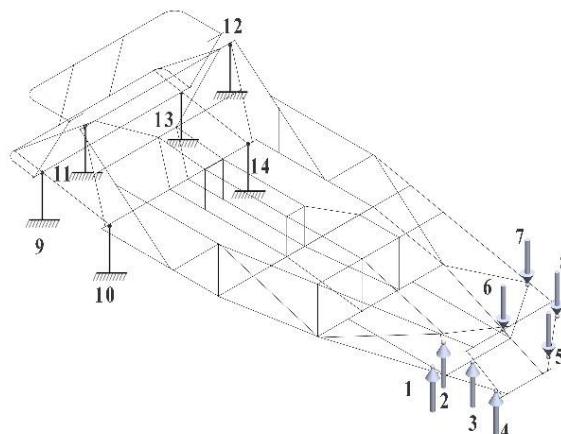
Properties	Value	Unit
Density	290	Kg/m <sup>3</sup>
Modulus Young	220	MPa
Elongation	35	%
Yield Strength	6	MPa
Ultimate Strength	55	MPa

### Torsional Stiffness Analysis

Torsional stiffness (K) in units of N/m can be formulated [11] as follows:

$$K = M_T / \theta \quad (1)$$

The simulation process uses Solidworks Simulation. The force (800 N) is applied to 8 points on the front of the chassis to produce torque (point 1,2,3,4 upward force and point 5,6,7,8 downward force), and at the rear of the chassis is given 6 fix points as shown in figure 2. Then the torsional stiffness value will be obtained.



**Fig 2.** Torsional stiffness model testing

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The rear chassis is made rigid, then torque moment is given on the front of chassis. The torque moment is made by increasing the force (F) at node 1-8. The stiffness value of the simulation result will be stated.

### Tensile Test

To ensure that the material matches the data in table 1, it is necessary to first test the tensile test with ASTM E8 standard [12], using a universal tensile testing machine. tensile test specimen using square tube type hollow section to be formed with dimensions as in figure 3.

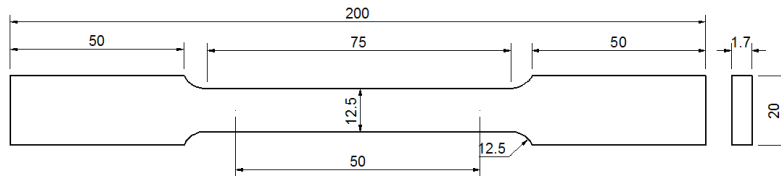


Fig 3. Dimension for tensile test

## IV. RESULTS AND DISCUSSIONS

From the result of mild steel that has been done obtained results as shown in table 4.

Table 4. Tensile test result of mild steel

Sample Code	Area (mm <sup>2</sup> )	Size dimension (mm)	Gauge length (mm)	Tensile Stress (Kg/mm <sup>2</sup> )	Yield Stress (Kg/mm <sup>2</sup> )	Elongation (%)
Mild Steel	19.30	t= 1.35 w= 14.30	50	44	40	13.88

Torsional stiffness (K) required is more than 1350 Nm/deg [11], and weighing is less than 60 kg. By comparing the torsional stiffness and impact strength value on the chassis filled with impact absorbers and without impact absorbers, it can be seen in table 5. The weight of the chassis reaches 52.15 kg (without impact absorbers) and 57.94 kg (filled with impact absorbers). Lightweight of the chassis will help electric car has more energy efficient and increase the top speed.

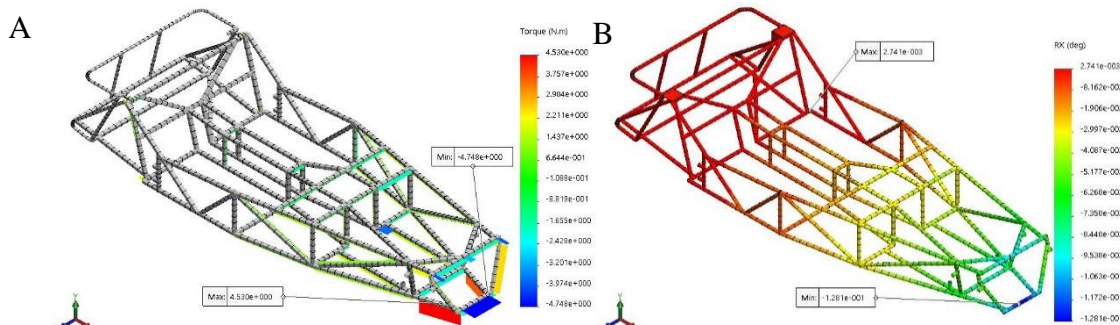


Fig 4. Torsional test chassis without RPF a) Torque Value b) Rotation occurs

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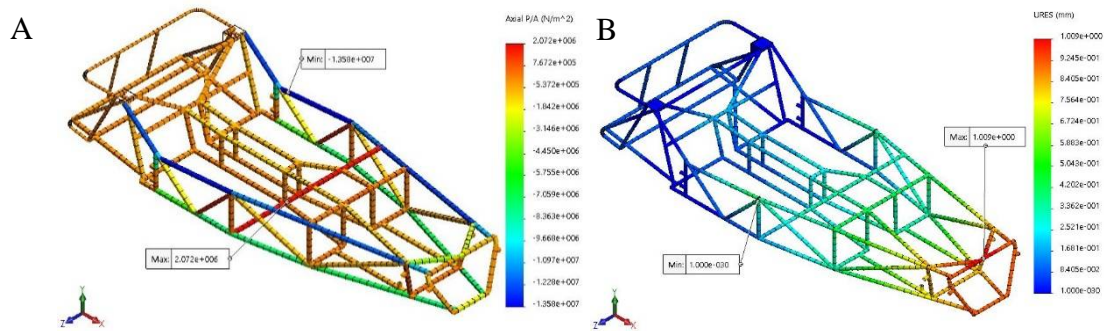


Fig 5. Crash test chassis without RPF a) Stress b) Deformation

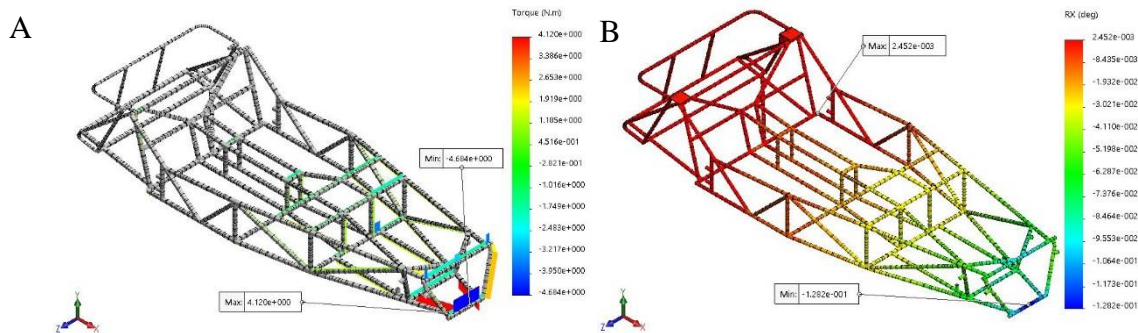


Fig 6. Torsional test chassis filled with RPF a) Torque Value b) Rotation occurs

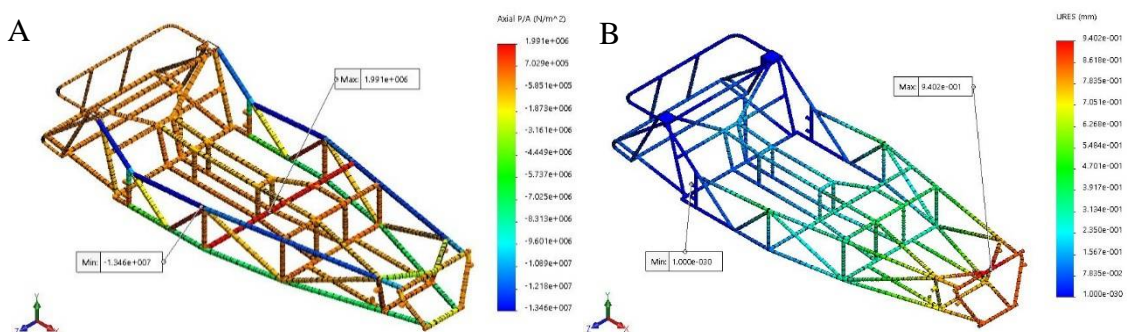


Fig 7. Crash test chassis filled with RPF a) Stress b) Deformation

Table 5. Simulation for torsional stiffness

Item	Without RPF	Filled With RPF	% Difference
Torque (Nm)	4.53	4.12	9.95
Rotation (deg)	0.002741	0.002452	11.79
Torsional Stiffness (Nm/deg)	1652.68	1680.26	1.64

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**Table 6.** Simulation for Crash Test

Item	Without RPF	Filled With RPF	% Difference
Stress-Von misses (MPa)	2.072	1.991	4.07
Deformation (mm)	1.009	0.9402	7.32

## V. CONCLUSION

From the simulation results, as shown in Table 5 and Table 6, it can be concluded that with the use of impact absorbers material on the inside of the hollow section can increase the torsional stiffness value by 1.64% and decrease the crash test value by 4.07%. On the other hand, the chassis design meets the minimal value of torsional stiffness, which is 1652 Nm/deg for chassis without Rigid Polyurethane Foam and 1680 Nm/deg for chassis filled with Rigid Polyurethane Foam.

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