



## Finite Element Simulation for Electric-Car Chassis Development from Scratch

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### ABSTRACT

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*electric car chassis, development from scratch, finite element simulation, torsional stiffness, stress analysis*

Indonesian engineers need to design and build their electric car chassis from scratch. These cars need to possess high torsional stiffness and maximum Von Mises Stress value. Therefore, this determines the value of Torsional Stiffness and Von Mises Stress from an electric car scratch chassis using Finite element simulation. A twist load was placed in front, with back support used to determine the torsional stiffness. The stress was analyzed using three types of loading, namely; vertical, lateral, and braking. Meanwhile, the JIS G 3141 galvanized plate with a thickness of 1 mm and 1.2 mm from Indonesia's marketplace was the chassis material used. The simulation results showed that the maximum Von Mises Stress value with a thickness of 1.2 mm produces safe strength, with a torsional stiffness of 11735 Nm/deg. In conclusion, the rigidity and strength of the chassis with a plate thickness of 1.2 mm is in a proper category. Furthermore, this chassis can be used for the development from scratch of an electric car.

## 1. INTRODUCTION

The design and development of more environmentally-friendly electric cars is a primary concern of several countries, including Indonesia. This car, which uses energy stored in rechargeable batteries, is becoming popular and acts as an alternative to gasoline vehicles. Some famous automotive companies such as Mini, Audi, Volkswagen, Peugeot, Hyundai, BMW, Honda, Kia, Nissan, and Chevrolet already have electric cars [1, 2]. Tesla, which is one of the new automotive companies specializing in electric vehicles, is currently dominating the worldwide sale of the product [3, 4].

Electric cars are also needed in Indonesia to reduce pollution and the amount of fuel yearly imported. Unfortunately, the intense domination of Japanese brands has limited the research and development of electric vehicles [5-8]. Irrespective of this fact, Indonesian engineers need to design and build their electric cars from scratch. However, this alternative means of transportation cannot imitate conventional cars.

Chassis is the main component of a car. Most fuel tanks located at the rear of the chassis, strapped up tightly to the gasoline vehicle's undercarriage. Meanwhile, most electric car batteries are situated under the car beneath along the middle of the chassis. Therefore, engineers need to pay special attention to the area under the seat where the battery is placed [9, 10]. This ensures that batteries with large densities are assigned adequate space in the car to keep the chassis safe with sufficient weight, thereby enabling it to travel long distances. Besides, it also needs to be stiff in its compartment to achieve

maximum performance while driving.

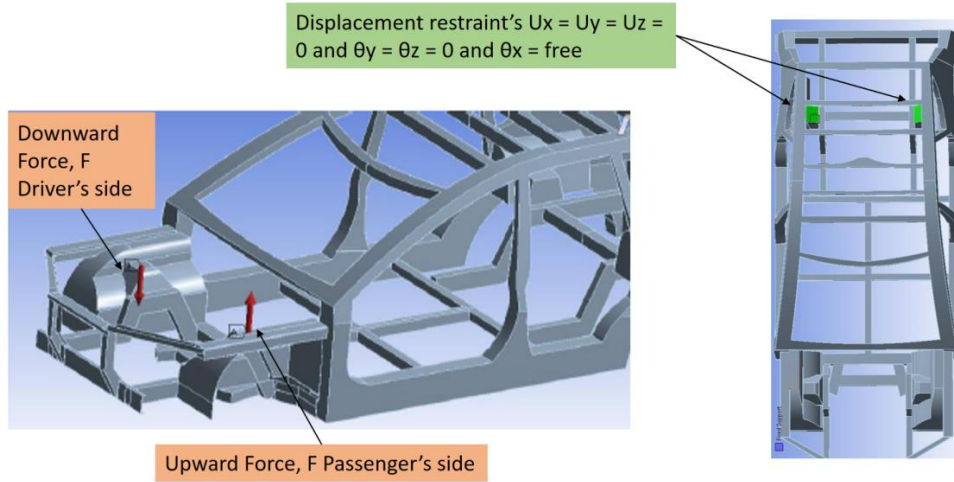
Therefore, based on these reasons, the main parameters that need to be fulfilled by the chassis are high torsional stiffness with the ability to achieve maximum Von Mises stress values [11-14]. Torsional stiffness is obtained by placing a twist on the front and back support [13], while the vertical, lateral, and braking load are used to determine the stress analysis [11].

Chassis are built using steel, aluminum, or magnesium materials with varying thicknesses plates [15-17]. In Indonesia, car materials are generally steel, provided by state-owned enterprises such as Krakatau-steel company [18]. Therefore, in this article, the scratch chassis material is the JIS G 3141 galvanized plate with thickness options of 1 mm and 1.2 mm.

Furthermore, engineering analysis is needed to choose the material and thickness suitable for an electric car chassis. Besides experimentation, a more comfortable and cheaper way used to design and develop electric cars is through finite element simulation [19-24].

Therefore, this article aims to determine the value of Torsional Stiffness and Von Mises Stress from an electric car scratch chassis using Finite element simulation. These simulation results are the design of the electric car with high Torsional stiffness value and safe stress analysis.

This research is structured as follows: The introduction contains the background of the study, the current state of the art of electric cars, explanations of the finite element simulation method, results and discussion of the simulation, and the chassis development process. It finally ends with a conclusion.



**Figure 1.** Boundary conditions to twist chassis models: applied torque in the front part and restraints at the rear

## 2. METHOD

Before the simulation, the chassis needs to be drawn using Computer Aided Drawing (CAD), with the basic size adjusted to fit the designer team's description. Meanwhile, the thickness of the plates used are 1 mm and 1.2 mm. The chassis image obtained from CAD is exported to the Computer-Aided Engineering (CAE) software for finite element simulation uses the JIS G 3141 SPCD sheet metal produced by Krakatau Steel.

**Table 1.** Material properties of JIS G 3141

Physical properties	Metric
Density	7.872 g/cc
Hardness, Brinell	95
Tensile Strength, Ultimate	340 MPa
Tensile Strength, Yield	285 MPa
Modulus of Elasticity	200 GPa
Bulk Modulus	160 GPa
Poissons Ratio	0.29

Table 1 shows that the properties material of JIS G 3141 is similar to AISI 1008 Steel, with  $S_y$  value of 285 MPa [25]. Meanwhile, the used meshing is the tetrahedron element with 83661 nodes and 42481 elements.

The vertical load needs to be given to the chassis' front and back to obtain the right torsional stiffness, as shown in Figure 1. The vertical deformation value is obtained from performed simulations and entered into Eqns. (1) - (3) to get the right Torsional Stiffness, as shown in Figure 2. The vertical load is also compared to the Torsional Stiffness of the cars in the marketplace. Therefore, the suitable plate thickness used as a chassis to build electric cars from scratch is determined as follows:

Equations and assumptions, from [13].

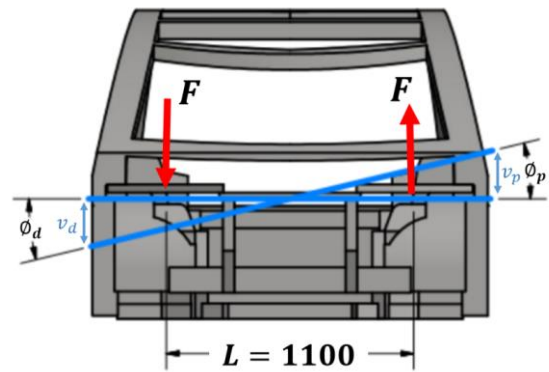
$$K = \frac{Torsion}{Twist\ angle} = \frac{F \cdot L}{0.5 \cdot (\phi_d + \phi_p)} \quad (1)$$

$$\phi_d = \tan^{-1} \left( \frac{v_d}{L/2} \right) \quad (2)$$

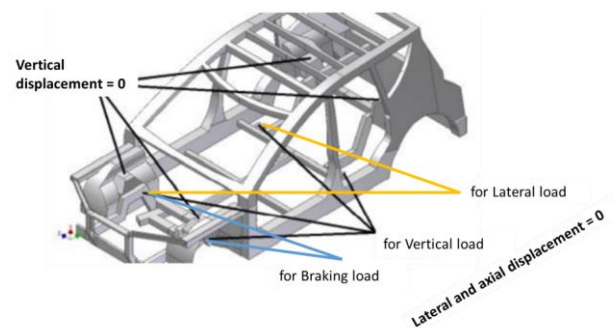
$$\phi_p = \tan^{-1} \left( \frac{v_p}{L/2} \right) \quad (3)$$

where,  $F$ : Vertical forces on the frame rails at a point in the vicinity of the front suspension pick-up points on the driver's and the passenger's side;  $L$ : Lateral distance between the driver and the passenger's load application points;  $\phi_d$ : Twist angle calculated from the vertical deflection of the frame rail on the driver's side;  $\phi_p$ : Twist angle calculated from the vertical deflection of the frame rail on the passenger's side.

The vertical, lateral, and braking loadings are used to determine the chassis strength [26]. The vertical displacement suspension point for all types of loading is zero. Conversely, on lateral and axial displacement, arm points values are dependent on the type of loading, as shown in Figure 3.



**Figure 2.** Position of vertical force and twist angle in chassis used to determine torsional stiffness

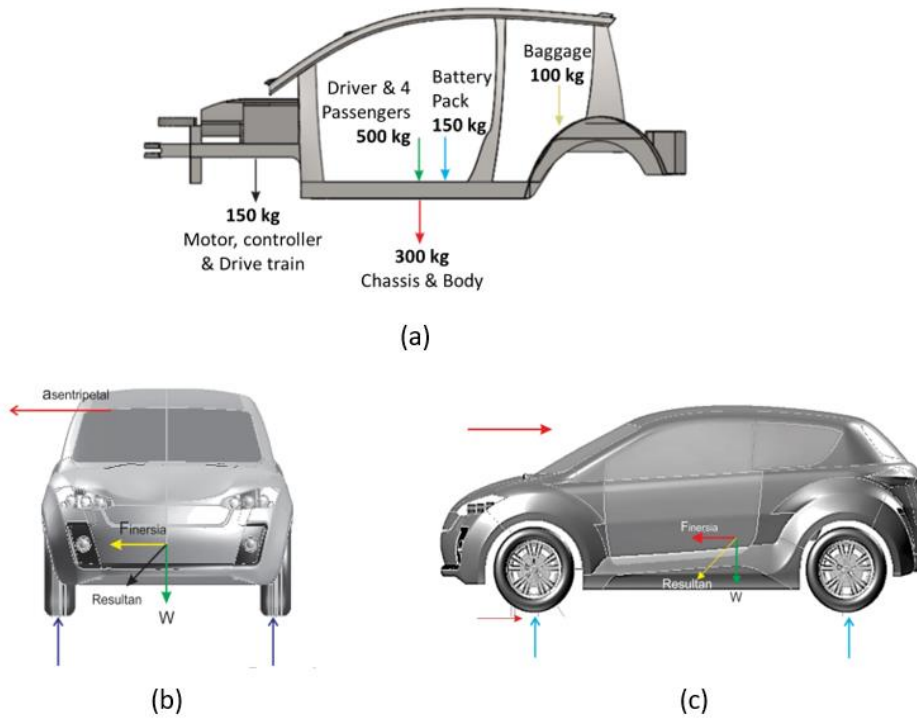


**Figure 3.** Boundary conditions of displacement for the three types of loading conditions

Figure 4 shows the loading conditions. In Figure 4 (a) the vertical load is derived from each component in the chassis that works on the weight point. While Figure 4 (b) shows the lateral load when turning at a speed of  $V = 30$  km/h and a radius of  $R = 4.5$  meters, with the emersion of centrifugal force and vertical load. Lastly, braking load is given when the car experiences a slowdown process of  $a = 9.6$  m/s<sup>2</sup>; therefore,

each component produces inertial force and a vertical load, as shown in Figure 4 (c).

The Von Mises stress analysis is used to determine the loading and sheet thickness of the simulation produced. Furthermore, the design is declared safe when the value of Von Mises stressed compared to the yield force is above 1.3.



**Figure 4.** Loading conditions for (a) vertical load, (b) lateral load, (c) braking load

### 3. RESULTS

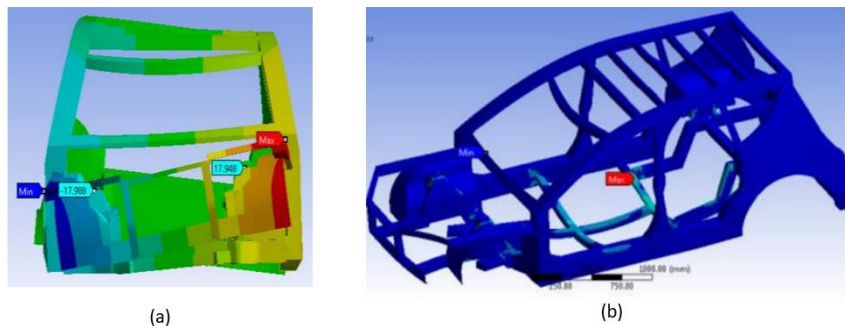
The results of finite element simulation are shown in Figure 5 (a), with the vertical deflection due to twist load. Figure 5 (b) shows the maximum value of Von Mises Stress due to lateral load of sheet thickness of 1.2 mm, with the most critical position occurring in the battery compartment.

The vertical deflection is grouped, as shown in Table 2, until the twist angle value is obtained using Eq. (2) and (3). The chassis torsional stiffness ( $K$ ) is the ratio of the change in the chassis' torsion to change the twist angle. Knowing the geometrical quantities and the value of the applied load can estimate the torsion. By using the twist angle in Table 2, we

can calculate the chassis' torsional stiffness.

The torsion and twist angle values are inserted into Eq. (1) and plotted on the chart to obtain the torsional stiffness, as shown in Figure 6. The torsional stiffness of the chassis with a thickness 1.2 mm is more rigid compared to 1 mm. Stiff chassis feels more responsive in transient cornering, while a compliant chassis feels laggy. Also, a stiff chassis allows for the suspension to be turned more effectively.

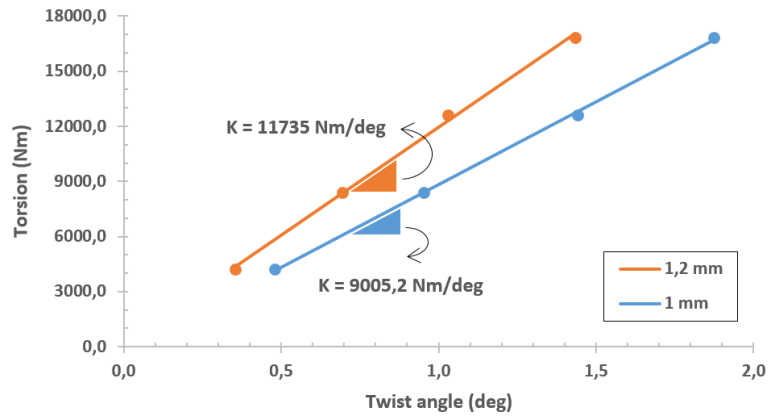
The value of torsional stiffness for passenger cars in this study is in the range of 5000 - 20000 Nm/deg [22, 27-29]. This shows that JIS G 3141 material with a thickness of 1.2 mm produces a good torsional stiffness for chassis development from scratch design at 11735 Nm/deg.



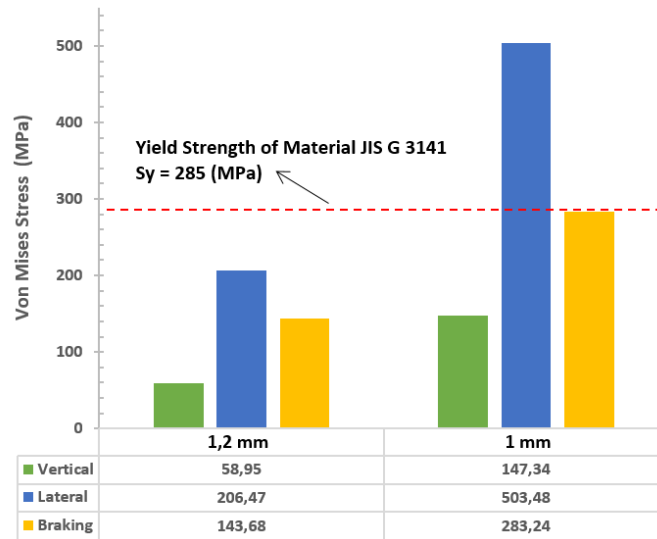
**Figure 5.** Simulation results for sheet thickness 1.2 mm, (a) Vertical deflection with vertical load 15288 N, (b) maximum Von Mises stress of lateral load

**Table 2.** Vertical deflection and twist angle from finite element simulation

	Vertical Force (N)	Torsion (N-m)	$V_p$ (m)	$V_d$ (m)	Twist angle (deg)
1,2 mm	3822	4204.2	0.003378	0.003428	0.354653
	7644	8408.4	0.006560	0.006746	0.693417
	11466	12612.6	0.009759	0.009990	1.029174
	15288	16816.8	0.013726	0.013798	1.434372
1 mm	3822	4204.2	0.004610	0.004609	0.480434
	7644	8408.4	0.009140	0.009124	0.951801
	11466	12612.6	0.013670	0.013970	1.440417
	15288	16816.8	0.017948	0.017988	1.872750



**Figure 6.** Torsional stiffness of electric car chassis from finite element simulation



**Figure 7.** Summary Von Mises Stress of electric car chassis from finite element simulation



**Figure 8.** Chassis of electric-car, (a) fabrication process, (b) final prototype

Furthermore, the maximum Von Mises Stress simulation results are graphed with various loading conditions and sheet thickness. Figure 7 showed that the maximum value of Von Mises Stress under lateral conditions exceeds the material's yield strength at a thickness of 1 mm. Therefore, it is dangerous to be used in building an electric car chassis from scratch.

According to previous studies, the plate with a thickness of 1.2 mm also has a high value of Torsional Stiffness. Therefore, the results can be the basis for continuing the development of the chassis using JIS G 3141 with a thickness value of 1.2 mm. Figure 8 showed the development process of electric car chassis from scratch to final.

#### 4. CONCLUSIONS

In conclusion, this research analyzes the steps used by the finite element simulations to build an electric car chassis from scratch using the JIS G 3141 material. The simulation results showed that the torsional stiffness value with a thickness of 1.2 mm produces safe strength, with a maximum Torsional stiffness of 11735 Nm/deg. This finite element simulation provides a solid basis for continuing the development of the electric car chassis from scratch for the next research platform.

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