



Salwa Cars Structure Testing Standards Regulation Formula Society of Automotive Engineers

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Abstract

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This research was to find out the results of the bending and torsional stiffness testing of the SALWA car according to Formula SAE 2021 regulations. The research method was by designing through Solidworks 2014 software. Testing of test specimens referred to Formula SAE 2021 regulations. The front impact test results produced max Von Mises 1046.921 MPa with a displacement of 8,540 mm; the rear impact test resulted in a max Von Mises of 222,529 MPa with a max displacement of 6.85 mm; and the side impact test resulted in max Von Mises Stress of 104.15 MPa with a max displacement of 9,116 mm. In the front torsional test, the max Von Mises Stress reached 135,266 MPa with a total max displacement of 4,844 mm. The rear torsional test had a max Von Mises Stress value of 147,144 MPa with a displacement of 5.51 mm. The feasibility test still found connection and construction placement errors, and there was a low Factor of Safety value. In conclusion, the construction of the SALWA Electric Car prototype frame is not in accordance with Formula SAE regulations.

Keywords: Frame, Solidworks, Stress, Displacement, Torsional rigidity

Abstrak

Penelitian ini untuk mengetahui hasil pengujian bending dan torsional stiffness mobil SALWA disesuaikan dengan regulasi Formula SAE 2021. Metode penelitian dengan membuat desain melalui software Solidworks 2014. Pengujian spesimen uji mengacu pada regulasi Formula SAE 2021. Uji front impact menghasilkan max Von Mises 1046.921 MPa dengan displacement 8.540 mm. Uji rear impact menghasilkan max Von Mises 222.529 MPa dengan max displacement 6.85 mm. Uji side impact max menghasilkan Von Mises Stress 104.15 MPa dengan max displacement 9.116 mm. Hasil uji front torsional mencapai max Von Mises Stress 135.266 MPa dengan total max displacement 4.844 mm, sedangkan hasil uji rear torsional memiliki nilai max Von Mises Stress 147.144 MPa dengan displacement mencapai 5.51 mm. Pada uji kelayakan masih ditemukan kesalahan sambungan dan kesalahan penempatan konstruksi serta terdapat nilai Factor of Safety yang rendah. Kesimpulannya, konstruksi rangka purwarupa mobil SALWA Electric Car belum sesuai dengan regulasi Formula SAE.

Kata-kata kunci: Rangka, Solidworks, Stress, Displacement, Torsional rigidity



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1. Introduction

Formula SAE, often called Formula Student, is an international competition for students in the automotive field. Formula SAE presents student-level car racing styled like a Formula 1 car. It consists of static events and dynamic events. Static events include design report, cost report, and business plan presentation [1]. Meanwhile, dynamic events include acceleration test, skip pad, autocross, endurance, and efficiency. In 2020, the Automotive Engineering Education Study Program at the University of Muhammadiyah Purworejo sparked the idea of making an electric power-based car called SALWA. SALWA Electric Car is a prototype of today's electric car designs that adopt the form of a single-seater car. The car-making started with doing observations in several school institutions, continued by making and assembling the frame construction [2]. The frame is a very substantial and crucial part in the manufacturing process.

The vehicle frame (automobile frame) is a structure that supports all essential components in the car [3]. In another sense, the vehicle frame is a support for the vehicle. In addition, being able to withstand the load and protect the driver is a must.

Several types of frames are in use today. Three frames are based on cross-section, namely tubular, hollow/box, and channel. Meanwhile, in terms of construction, the frame is divided into four types, namely ladder frame, monocoque frame, backbone frame, and space frame. The type of frame chosen to be applied to the SALWA car prototype is the space frame [4].

The manufacture of the space frame on the prototype SALWA car does not yet have a standardized design and design drawing, and basic tests such as bending and torsion have not been carried out [5]. Besides, the feasibility of the frame on the SALWA car prototype is not yet known.

Based on the description of the background stated, the formulation of the problem is as follows:

- a. What is the procedure for drawing the construction of the SALWA car prototype?
- b. What are the results of the bending and torsional stiffness simulation tests on the prototype frame?
- c. What is the feasibility of the 2020 SALWA prototype construction?

Therefore, the objectives of this research are:

- a. To know the procedure for making construction drawings of the SALWA prototype frame.
- b. To find out the results of bending and torsional simulations.

- c. To determine the feasibility of constructing the SALWA prototype based on the SAE Formula regulation.

From the research conducted, the researcher hopes that the research will provide the following benefits:

- a. As a reference for further development research.
- b. Fostering student interest in studying the SAE Formula competition.
- c. Improving students' abilities in the field of mechanical engineering.
- d. Can introduce SALWA prototypes to students through courses related to standardization, automotive design, basic formation, vehicle motion mechanics, and engineering drawings [6].

2. Method

The research was carried out for two months at the Automotive Engineering Education Laboratory and Workshop belonging to the Automotive Engineering Education Study Program [7]. It was carried out in several stages, starting with determining which products had been validated, followed by reviewing the updated literature with a maximum age of 5 years before the research was made, and followed by testing limited trial by comparing the existing data on the SALWA prototype with the standard parameters of the 2021 SAE Formula regulation. More extensive trials were carried out with static simulations on the frame. The validation employed the standard benchmark of the 2021 Formula SAE regulation.

- a. Measurement Stage

Before the drawing process was carried out, measurements were made with standard regulations for the Formula SAE competition, both in terms of frame construction and size. The results of the measurement process are in Table 1.

Table 1. Observation table first sheet

Variabel	Aspek yang diamati	Indikator	Sub Indikator	Ada	Tidak
Rangka SALWA 2020	Rancangan	Bentuk Kontruksi	Bulkhead	V	
			Front Hoop Braces	V	
			Front Hoop	V	
			Main Roll Hoop	V	
			Main Roll Braces	V	
			Side Impact Structure	V	
			Driver Template		V
			Pedal Template		V
			Power Unit Template	V	
			Suspension Template	Suspensi depan	
	Material	Material Yang dipilih	Steel Tube		
			Aluminium		
			Komposit		
			Bahan lain	Stainless Steel 304	
			Diameter luar: 25 mm		
			Ketebalan: 1,65 mm		
Pembebanan	Trangulasi	Titik Triangulasi	V		

Table 2. Observation table second sheet

Variabel	Aspek yang diamati	Indikator	Sub Indikator	Ukuran	
Rangka SALWA 2020	Dimensi	Ukuran Konstruksi	Bulkhead	Panjang	545 mm
				Labar	305 mm
				Tinggi	225 mm
				Material	A151 304
			Front Hoop Braces	Panjang	380 mm
				Labar	305 mm
				Tinggi	345 mm
				Material	A151 304
			Front Hoop	Panjang	295 mm
				Labar	305 mm
				Tinggi	405 mm
				Material	A151 304
			Main Roll Hoop	Panjang	525 mm
				Labar	605 mm
				Tinggi	1085 mm
				Material	A151 304
			Main Roll Braces	Panjang	1020 mm
				Sudut main hoop	35°
Side Impact Structure	Tinggi dari alas	225 mm			
	Panjang	1300 mm			
	Labar	205 mm			

b. Design Stage

The design stage begins with doing working drawings by drawing activities on an ISO standard A3-size drawing book. The drawing includes the form of construction, working drawings of construction joints, and the size of the frame construction according to the data obtained. Construction drawings made are illustrated as follows.

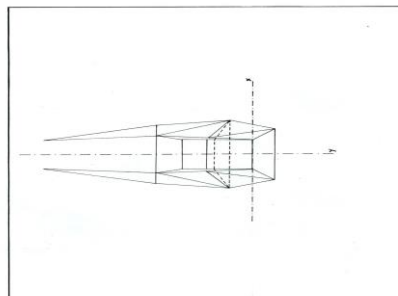


Figure 1. Front view

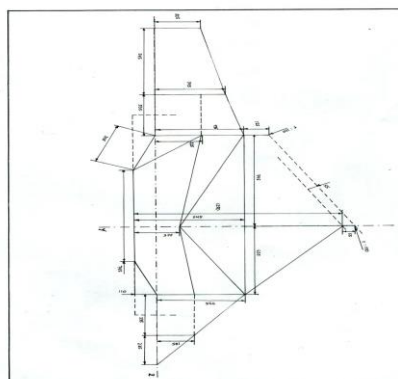


Figure 2. Side view

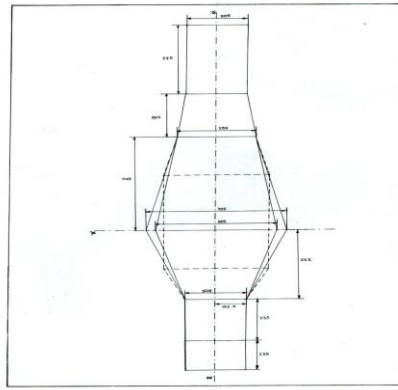


Figure 3. Top view

c. Design Creation

At this design stage, Solidworks software was used to create a 3-dimensional design. The entire design drawing was made in a 3-dimensional model and was given an additional weldment profile using Alloy Steel material [8]. The change in the use of this material was due to the fact that during the observation process, the researchers had difficulty finding the type of iron used because in the cost report for making the SALWA prototype, the material used was written as a steel stamp.

This replacement was carried out when the test was about to be carried out because the weight of the alloy steel material was the same as the weight of the prototype car frame, which was 28.302 Kg, different from the AISI 304 material that weighs 32 Kg. The results of the design are depicted in Figures 4 and Figure 5.

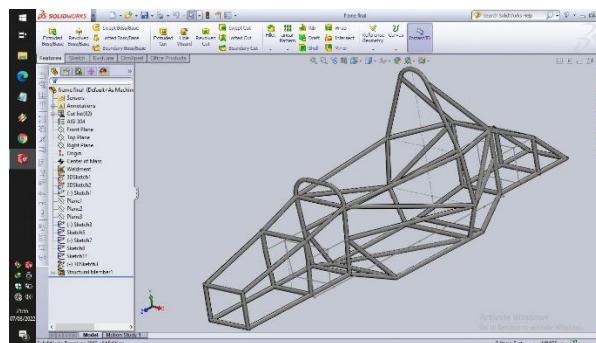


Figure 4. 3D Solidworks modelling

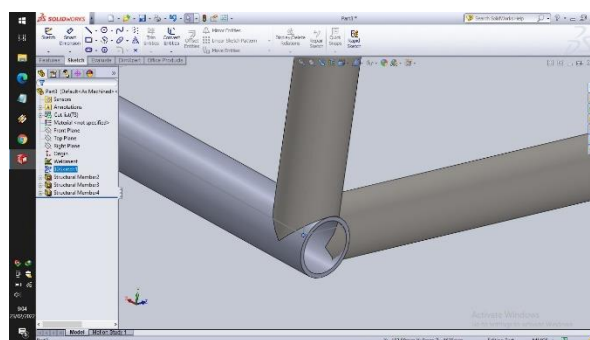


Figure 5. Connection of frame construction

d. Frame Testing Stage

After the modeling stage was complete, the following process was the testing. The tests carried out were static tests on the frame for bending tests, including testing simulations of loading front impact, side impact, and rear impact [9]. Then, the torsional testing used front torsional and rear torsional simulation tests.

1) Preparation

On the Solidworks simulations menu, the first thing is to determine the number of connections that you want to include in the test. Then, select the connection point that will be the fixture geometry, followed by selecting the connection that will be subjected to the force along with the force direction. The following is the pictures of the condition of the force loading on the frame.

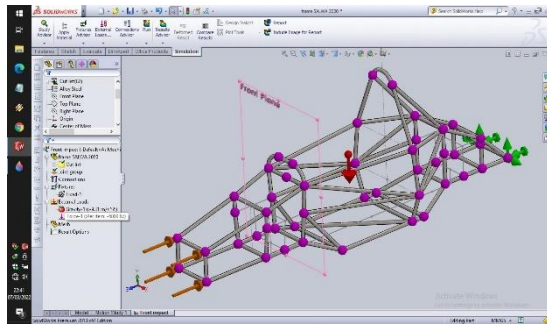


Figure 6. Front impact loading conditions

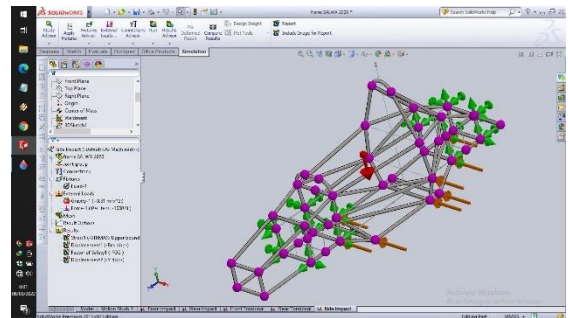


Figure 7. Side impact loading conditions

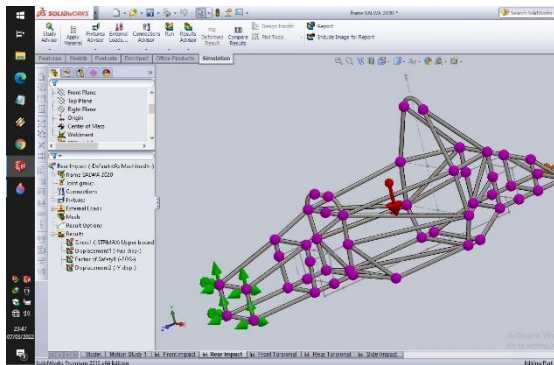


Figure 8. Rear impact loading conditions

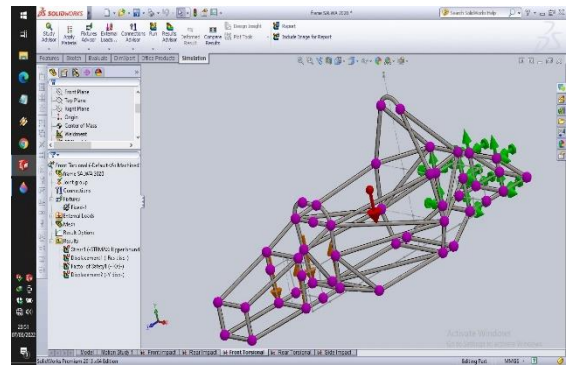


Figure 9. Torsional front loading conditions

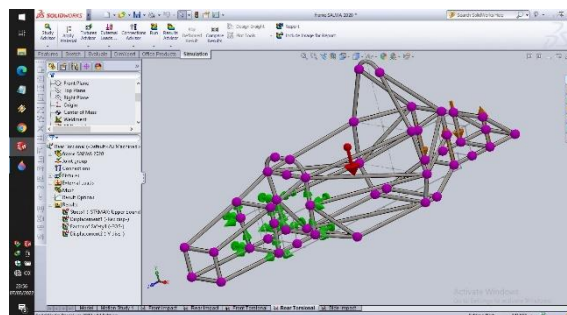


Figure 10. Torsional rear loading conditions

2) Test Implementation

The test was carried out by adding a load of 6000 N of force to the bending test and 1000 N to the torsional test, coupled with a constant gravitational force of 9.81 m/s². The simulation started automatically by pressing the meshing button.

3. Results and Discussion

The body of the SALWA frame was made for a prototype gasoline engine motor vehicle, a series of research in the final project. In this prototype, the frame and body of the automobile are similar to that of Formula 1 [10]. The parts of the frame as well as the separate body so that the work of focus can be and is used. For this reason, after the body frame was finished, it needed to be tested so it is comfortable and safe to use [11]:

a. Bending simulation results

Bending simulation aims to determine the maximum stress value occurring at the connection point subjected to the force. By doing a bending simulation, the deflection value of the material of which connection is subjected to a force in the form of displacement is obtained. The results of the Solidworks simulation are demonstrated in the images below.

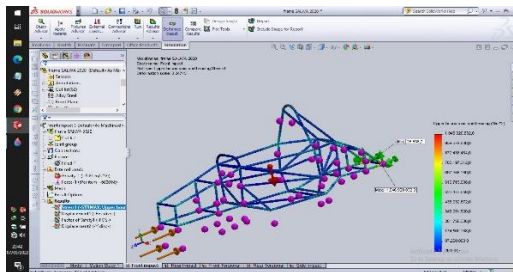


Figure 11. Von Mises front impact

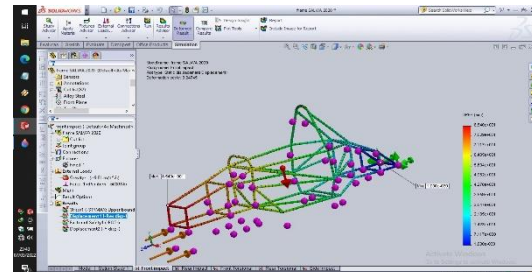


Figure 12. Displacement simulation front impact

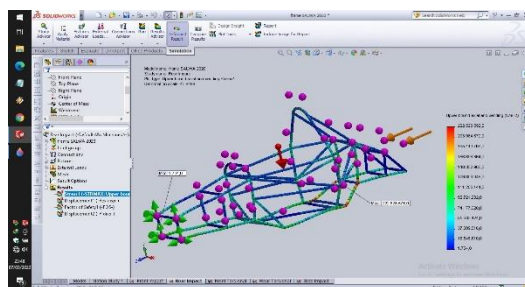


Figure 13. Von Mises rear impact

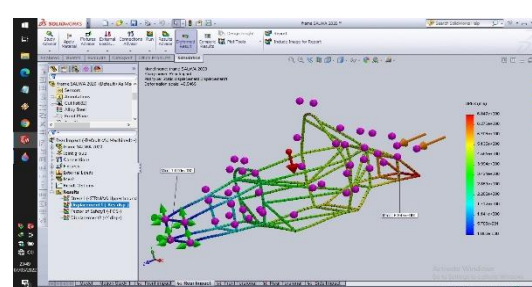


Figure 14. Displacement simulation rear impact

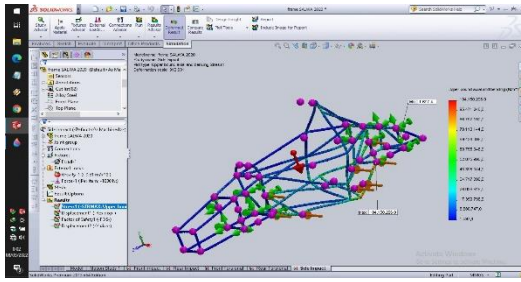


Figure 15. Von Mises side impact

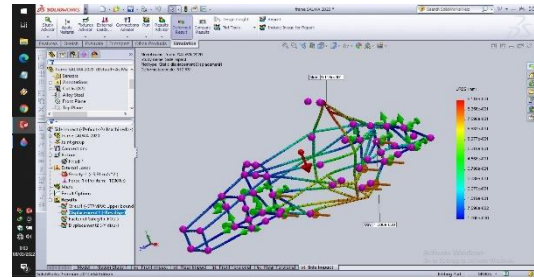


Figure 16. Displacement simulation side impact

The pictures above illustrate the front impact simulation resulting in a max Von Mises Stress value of 1046.921 MPa, a max displacement of 8.54 mm, and a min FOS value of 0.59. The rear impact simulation produces a max Von Mises Stress value of 222,529 MPa and a max displacement of 6.85 mm with a min FOS value of 2.79. Meanwhile, the side impact simulation results have a max Von Mises Stress of 104.15 MPa with a displacement of 9,116 mm for the maximum and a min FOS value of 5.96.

b. Torsional simulation results

The torsional simulation aims to measure the stiffness and connection of the material. The loading of the force in the torsional simulation is carried out in two ways, namely, loading the front and the rear. The following are the pictures of the results of the two torsional simulations.

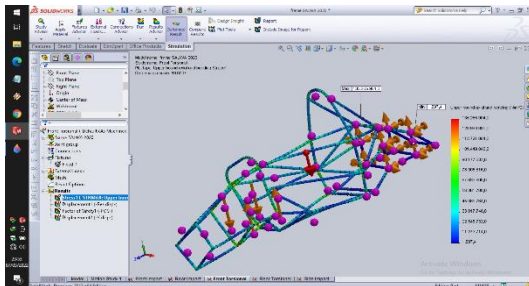


Figure 17. Von mises front torsional

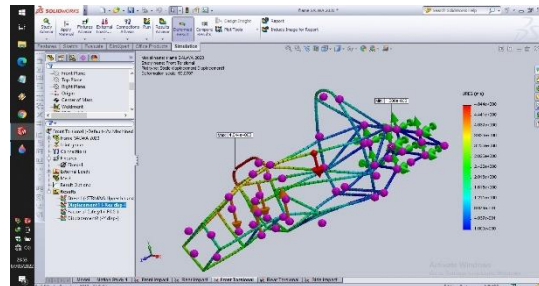


Figure 18. Max displacement front torsional

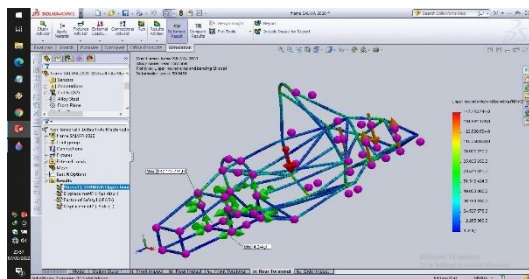


Figure 19. Von mises max rear torsional test

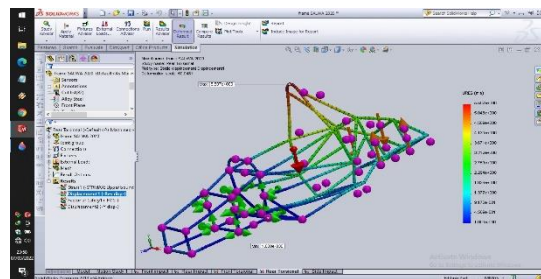


Figure 20. Displacement max rear torsional

The reading from the torsional front simulation results shows that the max Von Mises Stress is 135,266 MPa with a max displacement value of 4.844 mm and a min FOS value of 4.59. Then, the meshing results from the rear torsional simulation bring a max Von Mises Stress value of 147,144 MPa, and a max displacement of 5.51 mm with a min FOS value of 5.96.

The results stated in accordance with what is written in the meshing results of the front impact simulation shows that the factor of safety is still below number two. Number two is the minimum number for safety standards in the test simulation. This phenomenon can happen because:

- 1) The connection point is not in a triangulation point.

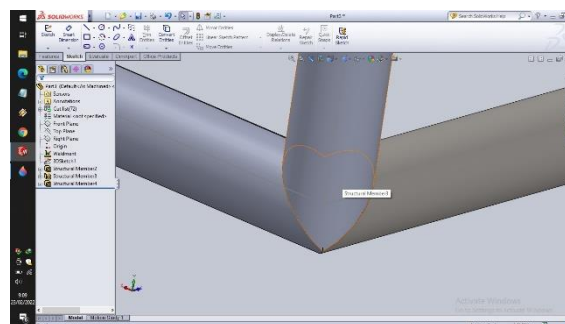


Figure 21. Triangulation weldment point

- 2) The absence of a triangular design node in the construction.

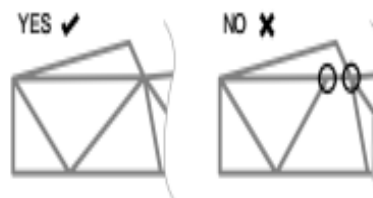


Figure 22. Node triangulation

- 3) The material for making the frame is not appropriate when referring to the regulatory standards for the Formula SAE competition, in which the material chosen is alloy steel [12].

Based on the three aforementioned points, the frame of the SALWA electric car prototype is not yet worthy of the SAE Formula regulation standards.

4. Conclusion

Based on the previous results and discussions, it can be concluded that the SALWA electric car prototype frame is still not in accordance with the standards in the SAE Formula regulation.

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