Design of a light chassis for an urban electric vehicle

AHMED TALAL SELEM
Automotive department, Military Technical College, Cairo, Egypt, ahmeddabbour53@gmail.com
Supervisor: Hisham M. Eltaher*, Professor*
Military Technical College, Cairo, Egypt, hisham.kamel@mtc.edu.eg

Abstract- There is a global trend in electrifying ground transportation. For reasons such as reducing greenhouse emissions, maintenance costs and running costs. However, without government subsidies and tax reductions, the initial cost of an electric vehicle is comparatively higher than an ICE one. Moreover, the need for a dedicated infrastructure demands a high capital investment. Therefore, it is more efficient and economically viable to design a light weight electric vehicle. In addition, this vehicle can be used for urban mobility only, given that most individual daily commute is within a 60 to 100 km.

In this paper, we propose the design of a small lightweight electric vehicle that can seat two persons. The focus in this paper is on designing the chassis frame. To construct a vehicle chassis there is some parameters to take into consideration to judge that the constructed chassis is optimum one to be used in such vehicle also there are some main missions the constructed chassis must achieve all of them efficiently to be ready for service.

We also must say that the material you will use as well as the type of chassis must be chosen carefully according to some specified parameters, we will discuss them in details.

Keywords- chassis, electric vehicle, vehicle design, environment friendly, stress analysis

I. Introduction

The current events in the world affected many principals all over the world starting from the global warming and the diseases from the pollution of the air that leaded to killing of many innocents all over the world ending to the wars between countries that leaded to shortage of all raw materials and sources of energy also the economic crises that affected the world without exception.

As a result, the governments made many restriction and laws to seize air pollution sources that the transportation and exhaust from vehicles' tailpipes took a great section from it

Table 1 the percentage of sources participating in air pollution [1]

Transportation	58%
Electricity generation	16%
Industrial	13%
Residential	9%
Commercial	4%

One from that solutions is the electric vehicle which consider as a magical solution to the pollution, economic crises as well as shortage of energy sources it is required to make the vehicle as light as we can by this way, we decrease the emissions from vehicle and the cost of whole vehicle and to make it light we must take a look to the chassis and how to decrease its weight to get a light electric vehicle.

How to choose the chassis that optimize your decision is important thing and, in that paper, we will show how to make this easily from the point of view of material and the type of chassis.

Types of materials:
1- Steel
2- Al alloy

Types of chassis:
1- Ladder frame
2- Twin tube or multi tube frame
3- Backbone structure
4- Triangulated tube structure
5- Roll cage
6- Perimeter space frame or 'birdcage' frame
7- Punt or platform structure
8- Pure monocoque
9- Integral or unitary body structure

II. Design goals

The chassis is not only designed to bear the loads from the vehicle it also used to make some other missions:
1- Strength to bear the load of the vehicle at static mode
2- deformable in order be able to absorb the crash energy
3- torsional stiffness to be able to resist torsions
4- high strength specially in high temperature in order not to lose its properties at high operating temperature
5- low cost
6- low weight as can as possible
7- durability
8- reliability
9- as simple as possible
10- low volume
11- maintain the shape of the vehicle

III. Models in SolidWorks

An experiment using Solidworks shows two models one of them is steel while the other is Al alloy we will show the photos of the two chassis we have made. In figure 1

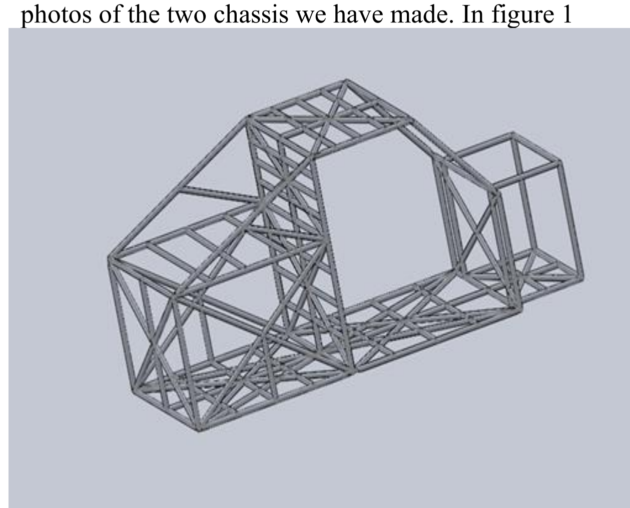


Fig. 1 Spaceframe chassis made from Al2024

We will show the model from steel.

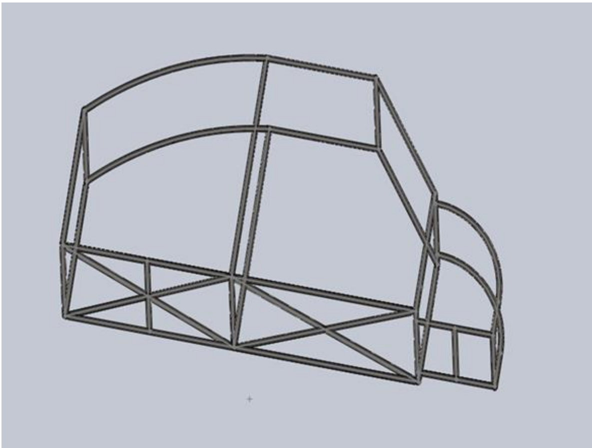


Fig. 2

We then will show the results that is displayed as a result of applying the forces, weights and reactions

The model from Al 2024:

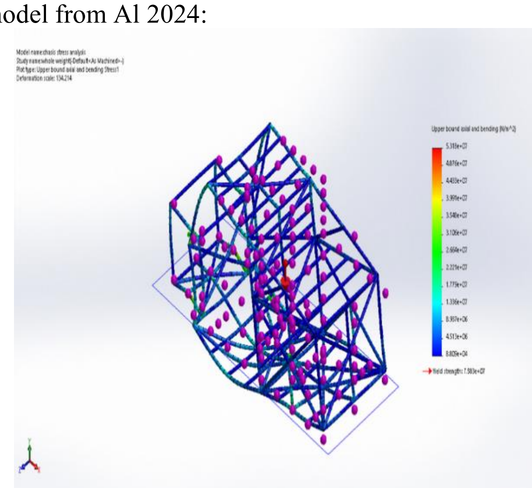


Fig. 3

Name	Type	Min	Max
Stress1	Upper bound axial and bending	0.000e+00 N/m^2 Element: 1538	5.318e+07 N/m^2 Element: 1267

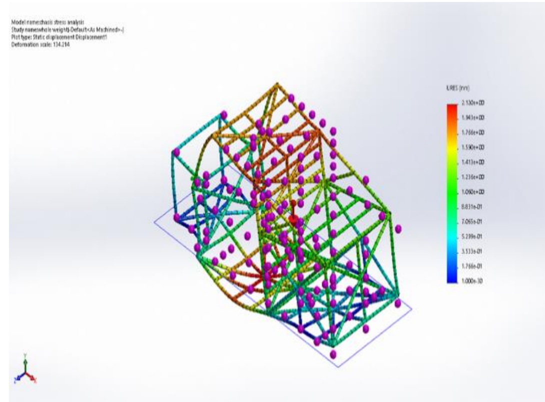


Fig. 4

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000e+00 mm Node: 99	2.120e+00 mm Node: 967
Name	Type	Min	Max
Factor of Safety1	Automatic	1.426e+00 Node: 735	7.423e+02 Node: 801

Secondly the model from steel:

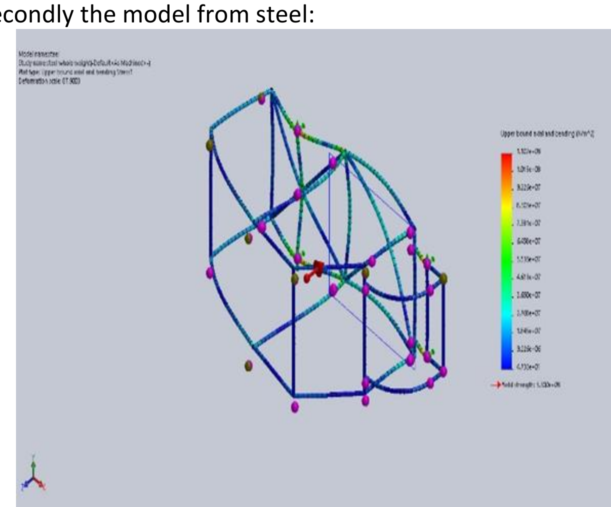


Fig. 5

Name	Type	Min	Max
Stress1	Upper bound axial and bending	0.000e+00 N/m^2 Element: 698	1.107e+08 N/m^2 Element: 669

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000e+00 mm Node: 35	3.243e+00 mm Node: 299

Name	Type	Min	Max
Factor of Safety1	Automatic	4.787e+00 Node: 416	1.120e+07 Node: 312

We then made the torsional stiffness test which can be applied by applying force to only one side of axle and fix the others and now we will show the results of that test for both models:
The Al2024 model

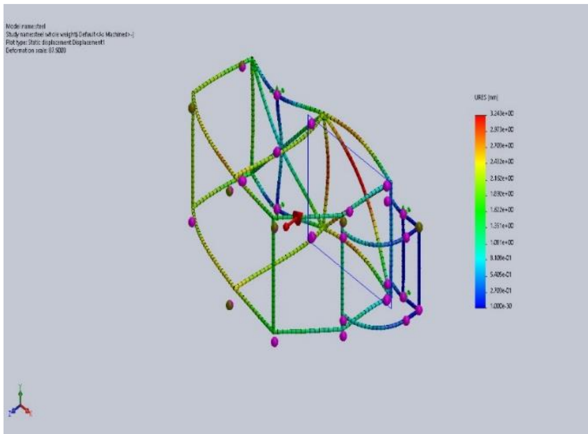


Fig. 6

Displacement 1	**URES: Resultant Displacement**	**0.000e+00 mm Node: 58**	**7.086e+00 mm Node: 411**

Name	Type	Min	Max
Stress1	Upper bound axial and bending	0.000e+00 N/m^2 Element: 1537	5.038e+07 N/m^2 Element: 33

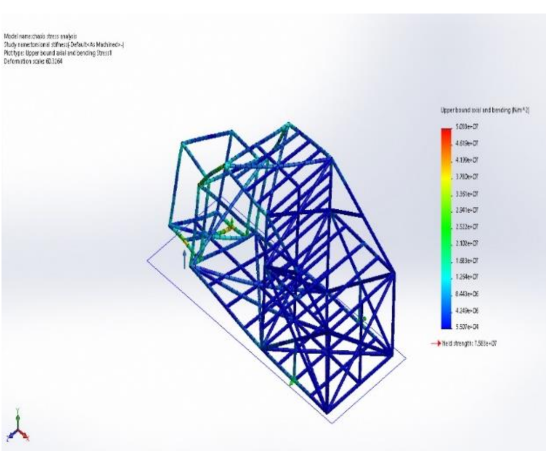


Fig. 7

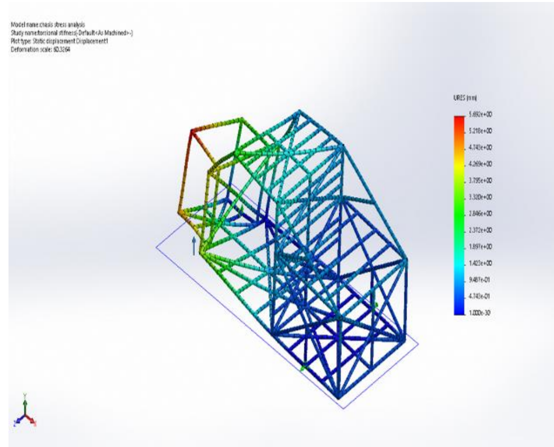


Fig. 8

Name	Type	Min	Max
Displacement 1	URES: Resultant Displacement	0.000e+00 mm Node: 36	5.692e+00 mm Node: 253

Name	Type	Min	Max
Factor of Safety1	Automatic	1.505e+00 Node: 36	1.067e+03 Node: 666

Steel model

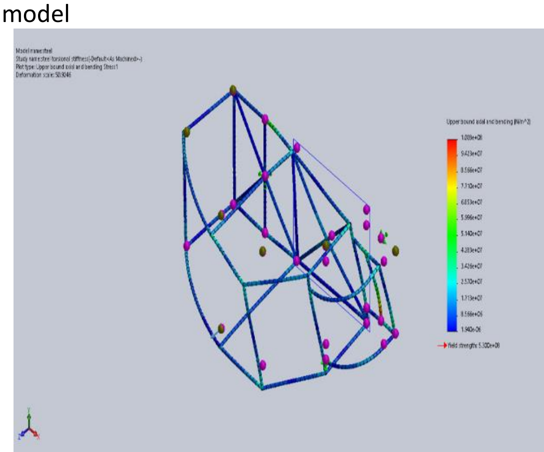


Figure 9

Name	Type	Min	Max
Stress1	Upper bound axial and bending	0.000e+00 N/m^2 Element: 699	1.028e+08 N/m^2 Element: 135

Properties of steel [2]	
Name:	2024 Alloy
Model type:	Linear Elastic Isotropic
Default failure criterion:	Max von Mises Stress
Yield strength:	7.58291e+07 N/m^2
Tensile strength:	1.86126e+08 N/m^2
Elastic modulus:	7.3e+10 N/m^2
Poisson's ratio:	0.33
Mass density:	2800 kg/m^3
Shear modulus:	2.8e+10 N/m^2
Thermal expansion coefficient:	2.3e-05 /Kelvin

Name	Type	Min	Max
Factor of Safety1	Automatic	5.156e+00 Node: 139	2.732e+14 Node: 633

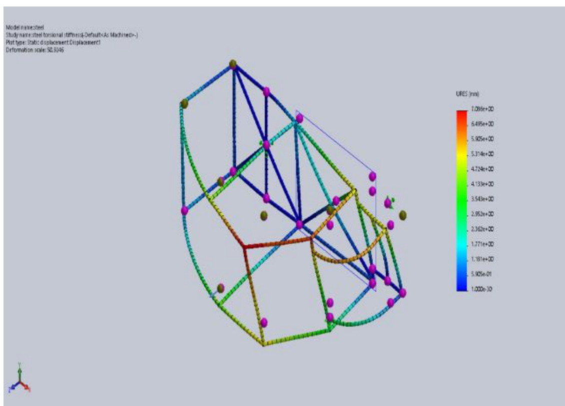


Fig. 10

Now we will show the mass properties for each model and the location of the centre of gravity knowing that the we applied at each model the weight of the batteries which equals 270 Kg, the weights for passengers in addition to accessories and body weight which equals 250 Kg and the weights of systems and luggage which equals 70 Kg with total added weights of 590 Kg.

Al2024 model:

- Mass = 681.27 kg
- Volume = 0.03 m^3
- Surface Area = 16.54 m^2
- Center of mass: (m): X = 0.33, Y = 0.55, Z = 0.37
- Structure mass: (m): 91.27 Kg

Secondly to steel model:

- Mass = 688.30 kg
- Volume = 0.01 m^3
- Surface Area = 6.31 m^2
- Center of mass: (m): X = 0.18, Y = 0.55, Z = 0.05
- Structure mass: (m): 98.3 Kg

IV. Comments on the Results from Solidworks which Helps in Choosing the Optimum Chassis

undoubtedly that the material parameters play an important role in the choice process like strength, ductility, availability, cost, density, melting temperature, machinability, weldability in addition to another parameters like stress analysis, factor of safety, torsional stiffness, ease of manufacture, simplicity, center of gravity height.

All of these parameters should be optimized to reach the most fitting choice with lowest cost and weight and simple enough to be easy manufactured with common machines.

Here we will show the properties of both material and start our comments.

Properties of Al2024 [2]	
Name:	AISI 1045 Steel, cold drawn
Model type:	Linear Elastic Isotropic
Default failure criterion:	Max von Mises Stress
Yield strength:	5.3e+08 N/m^2
Tensile strength:	6.25e+08 N/m^2
Elastic modulus:	2.05e+11 N/m^2
Poisson's ratio:	0.29
Mass density:	7850 kg/m^3
Shear modulus:	8e+10 N/m^2
Thermal expansion coefficient:	1.15e-05 /Kelvin

To talk from the point of view of cost we will find that the steel cheaper than Al2024 which from the price the ton for Al2024 is for 62400L.E [4].

If we talk from point of view of availability steel is more available in the market and doesn't need special workers or machines to be produced.

In the point of view of strength, the steel is stronger which is clear from the properties we showed above.

To talk about weldability, we will find that the aluminum alloys are characterized by low melting point range, high thermal conductivity, and high rate of thermal expansion this means that much high welding speeds are required, greater care to avoid distortion, and for arc resistance welding much higher current densities are required. [5]

It also not quenches harden-able. However, weld cracking may result from excessive shrinkage stresses due to high rate of thermal expansion. [5]

It is very clear from the above that aluminum alloys require much more skilled workers and special machines to deal with it which increase cost and these requirement not available in all workshops which make the machinability for Al alloys harder also the ease of manufacture is for steel which give high recommendation for using steel.

For the point of view of simplicity, it is clearly found that steel model is much simpler than Al alloy one knowing that the two models passed the tests with acceptable results with higher safety factor for steel.

If we talk about C.G height the steel model has lower C.G which give more stability to vehicles.

V. The stages that the aluminum chassis passed by till reaching the final shape

The first trial

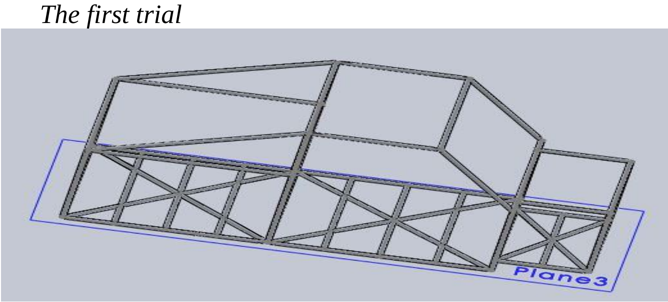


Fig. 11

Factor of safety	Max. deformation	mass
0.87	6.588 mm	48.82 Kg

Second trial

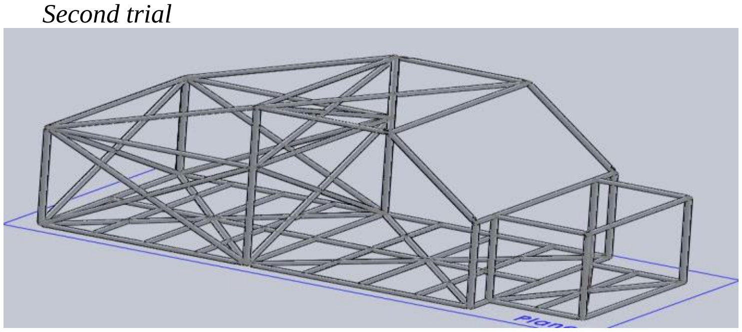


Fig. 12

Factor of safety	Max. deformation	mass
1.006	5.164 mm	66.66 Kg

Third trial

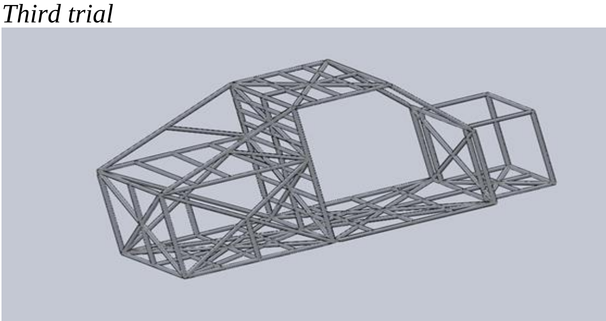


Fig. 13

Factor of safety	Max. deformation	mass
1.426	2.12 mm	91.27 Kg

VI. Relation between vehicle performance and load distribution

And know we will talk in our case it is an electric vehicle which requires a portion to but batteries which take high part of cost and weight of the vehicle and we choose the space frame so let's see the vehicle after loading it and then talk about important parameter in the vehicle performance which is subjected to our choice to chassis which is steering state

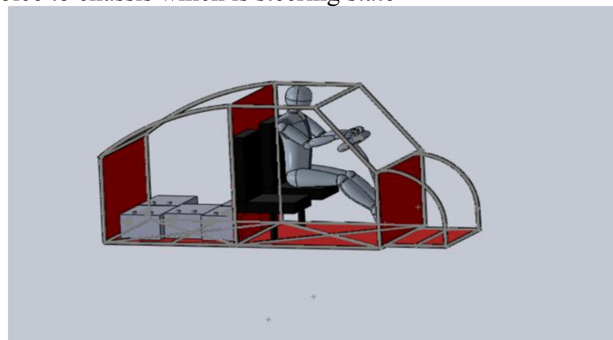


Fig. 14

From the above photo we see that all batteries are concentrated in the back portion of vehicle which affects load distribution to the axle of vehicle which is calculated to be 35% on the front axle and 65% on the rear axle which will result in the vehicle to be over steered.

So, I recommend that the chassis type to be ladder frame with batteries to be distributed on the floor of vehicle to avoid oversteering problem as shown in fig.15. Or there's another solution is to redistribute batteries on front and rear axle to achieve appropriate load distribution to avoid the problem of over steering as shown in the following photo

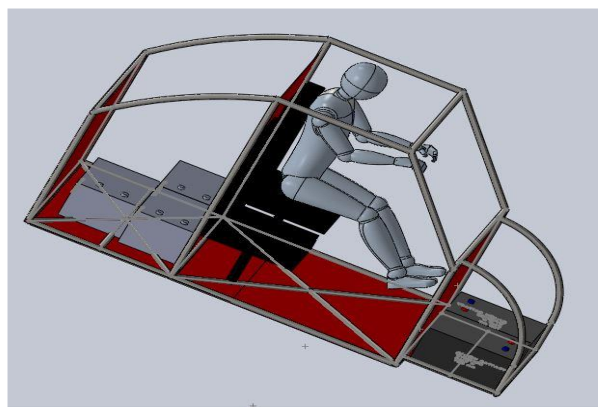
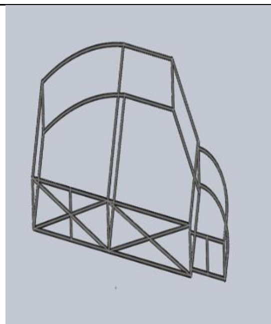
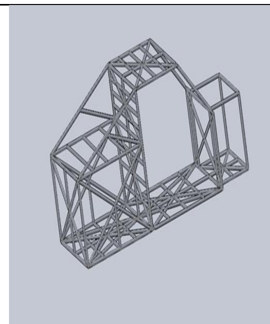


Fig. 15

VII. Conclusion

The main objective from that paper is to show how to choose the right chassis type, material and the main missions that the chassis must achieve to be ready for service and how to optimize the parameters to reach the fit chassis to your case with an experiment using Solidworks and giving opinion to the case we discussed.

And now we will show a complete comparison between the two chassis we made as shown in the following table:

Points of comparison	Steel model	Al model
shape		
Safety factor	4.787	1.426
Max. deformation	3.243 mm	2.12 mm
mass	98.3 Kg	91.27 Kg
Max. deformation at torsional stiffness test	7.086	5.692
Safety factor at torsional stiffness test	5.156	1.505

VI. References

[1] MMV 510 environment friendly vehicles lecture notes MTC Automotive engineering department

[2] Library of Solidworks

[3] Brown. (2001). Motor Vehicle Structures. Lieu de publication, Butterworth-Heinemann.

[4] MMV 506 Repair of vehicles lecture notes MTC Maj.Gen\ Metwally Moussa