International Journal of Research in Engineering, Science and Management
Volume 5, Issue 5, May 2022
https://www.ijresm.com | ISSN (Online): 2581-5792

Weight Optimization and Structural Analysis of an Electric Bus Chassis Frame

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***Abstract*: Major cities have seen an increase in motorization in recent decennium, accompanied by deteriorating/poor air quality. Electric buses shows a major obligation in this regard, as these buses have several advantages in respect of lowering noise, pollution, and fuel consumption. Additionally, the costs of keeping an electric bus are around 25% less expensive than those of maintaining a diesel bus, due to the fact that the electric engine does not require the same level of maintenance as a diesel engine. Furthermore, the negative aspect of the electric car is the battery's long-term endurance power. The more energy it takes to run a bus, the heavier it is. It is preferable and more effective to keep the weight of the vehicle elements as low as possible. Our research is focused on the chassis frame, which is an extremely important component of the bus and plays a significant role in supporting the structural safety and strength of the vehicle while also playing an important role in determining the overall weight of the vehicle, which has an impact on the vehicle's performance. This is why we chose the chassis frame as the subject of our investigation. Steel is typically used for the frame since it is sturdy, but it is also heavier and adds weight to the entire bus, diminishing operational effectiveness. The purpose of this post is to illustrate how to reduce the weight of an existing electric bus by replacing its steel components with lightweight aluminium alloys that are both safe and structurally sound while retaining the safety and structural integrity of the frame and chassis. The integrity of the structure is critical in ensuring a safe design. A structural study of the projected chassis frame model will be undertaken using the ANSYS 20.0 simulation programme, using stress and deformation as design constraints, in order to provide a more secure design.**

***Keywords*: Aluminium alloys, ANSYS, Electric bus chassis frame, Structural analysis, Weight reduction.**

1. Introduction

No one can keep up with the fast progress of transportation technology, which is occurring in both developed and developing countries. As a result of the greater movability of people in recent decades, these advancements have become vital. One of the most significant aims of the transportation industry is the creation of transportation networks that allow for the seamless, safe, quick, and cost-effective movement of people from one location to another, among other things. Transportation is such a vital component of human existence that the demand for it is rising, particularly for road transportation, which includes motorcycles, vehicles, buses, and trucks, among other forms of transportation. The need for air transportation is decreasing. Increased demand for autos can let people move more freely, but it can also have severe repercussions for the environment, such as air pollution, if the demand for automobiles increases. The vast majority of internal combustion engines are employed in modern automobiles. It is possible that the exhaust emissions from fossil-fuel driven vehicles will affect the quality of the air in the surrounding area. CO, NOx, CH4, CH4-N, SOx, and other suspended particulate matter (SPM10) are all pollutants that contribute to global warming. CO, NOx, CH4, CH4-N, SOx, and other suspended particulate matter (SPM10). They are all created by motor vehicles and all contribute to global warming in significant amounts, according to the International Energy Agency. When it comes to public transportation, the bus is a cost-effective option that is widely used and has a suitable capacity for passengers. These reasons all lead to a drop in the number of private automobiles on the road in the United States. Diesel engines, which are a type of internal combustion engine, are widely seen in buses and other commercial vehicles. NOx, CO, and other pollutants are emitted from the engine as a consequence of the lack or partial combustion, and these pollutants can pollute the surrounding environment. When diesel engines produce these gases, they also emit black smoke, which is visible when the engines are accelerated or fully loaded. It is also necessary to perform routine maintenance on them in order to keep them running. With the advent of electric buses, these downsides could be mitigated to some extent.

2. Weight Optimization

Obtained by modifying the underlying material or structure, weight optimization can be accomplished with ease. Almost all industries rely on metal for the fabrication of its chassis, which results in a heavy overall product. This forces them to look for new compounds to experiment with. Many researchers have expressed concern about the use of aluminium alloys in light-weight automobile structures [3], [4]. In this study, after looking at aluminium alloys results in ability aluminium alloys especially aluminium 6061-T6 [9], aluminium 7075-T6 [9] with excessive strength-to-weight ratio have been chosen as an alternative to the conventional metal chassis as a consequence of the outcomes in potential of aluminium alloys A description

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of those aluminium alloys is presented in the next chapter. The efficiency of machining is evaluated in terms of the willpower required to make the best choice of process adjust factors.

A. *Aluminum 6061- T6*

It offers yield strength equivalent to mild carbon steel and is one of the most widely used aluminium alloys available. Aluminum 6061 T6 is among the most widely used aluminium alloys available. This alloy, which belongs to the 6xxx group, is primarily made of silicon and magnesium in about the proportions necessary for the formation of magnesium silicide (Mg_2Si), which permits it to be heated to exceptionally high temperatures without melting.

The ability of this alloy to generate heat is greatly enhanced by the use of heat therapy. It is well-known for exhibiting acceptable formability, weldability, machinability, and corrosion resistance characteristics. A significant amount of the 6xxx organisation is employed in the construction industry and in other structural applications. As stated in Table 1, the chemical composition of both aluminium 6061-T6 and aluminium 7075-T6 is aluminium 6061-T6 and aluminium 7075-T6 respectively, as indicated in Table 1.

Table 1
Chemical composition

Alloy	Al	Cu	Mn	Mg	Zn	Ti	Cr	Si	Fe
Aluminum 6061-T6	97.8	0.27	0.28	0.86	0.42	0.14	0.069	0.70	0.209
Aluminum 7075-T6	89.7	1.50	0.07	2.40	5.70	0.05	0.190	0.11	0.210

B. *Aluminum 7075-T6*

Zinc is the most common alloying detail on this kind, and it can be found in concentrations ranging from one to eight percent. The combination of this compound with a reduced percentage of magnesium results in an overall strength improvement of a substantial magnitude. On the whole, the properties of 7075 Al alloy are quite appealing. Low density, ductility, toughness, and fatigue resistance are only a few of the traits that stand out the most. Various additional elements, such as copper and chromium, are only used in trace amounts in the end product on a regular basis and are not used in large quantities.Scandium is also beneficial in small amounts when used sparingly. There are seven different alloys in the 7xxx family, and each is suited for usage in a variety of applications including aircraft structures, cell equipment, and other strongly loaded components. In order to complete this project, a Sunwin SWB6121EV57 electric bus chassis frame constructed of Steel A709M grade 345W has been considered (Structural steel).The rectangular frame was chosen for modelling since it is the most appropriate alternative for big trucks.

The frame's fundamental structural characteristics are as follows:

Table 2
Frame's fundamental structural characteristics

Parameters	Values
Length	11470 mm
Width	2420 mm
Wheel Base	5940 mm
Front Overhang	2550 mm
Rear Overhang	3250 mm

The chassis body is modelled in three dimensions using the Ansys Space Claim software tool. This software programme, which estimates the mass houses of the body, can be used to determine the load on steel and aluminium alloy frames. As it is observed from the outcomes, when steel is substituted with aluminium alloys, the body weight is greatly diminished, as indicated in Table 3.

Table 3

Material	Material density (kg/m^3)	Weight of the frame (kg)	% Reduction in weight
Steel A709M grade 345 W	7850	11,504	–
Aluminum 6061-T6	2700	3957.9	65.61
Aluminum 7075-T6	2800	4103.2	64.33

3. Structural Analysis

With the following step, the goal will be to carry out a structural study of the framework. It is necessary to do structural analysis on the frame since it indicates whether or not it will be able to endure external and internal loads and stresses without cracking or deforming. The finite element method (FEM) is used in order to avoid the large cost and time commitment associated with conducting it on a model, respectively. In order to achieve this, the application Ansys 20.0 is used, which is a general-purpose finite element analysis (FEA) software package.

As shown in Figure 1, the model created using the Ansys Space Claim programme is put into Ansys Mechanical 20.0 for further processing. Following the selection of a material from the materials library, the material is assigned to the model at this point.Since the characteristics of these aluminium alloys were not previously known, they were included in the library as a result of this. This study's frame materials were selected based on their mechanical qualities, which are listed in Table 1 of this document.

Table 4

Properties	Structural steel	Aluminum 6061-T6	Aluminum 7075-T6
Yield strength (MPa)	260	275	505
Ultimate strength (MPa)	450	310	570
Young's modulus (GPa)	200	69.0	71.7
Shear modulus (GPa)	76.9	26.6	26.9
Poisson ratio	0.30	0.33	0.33

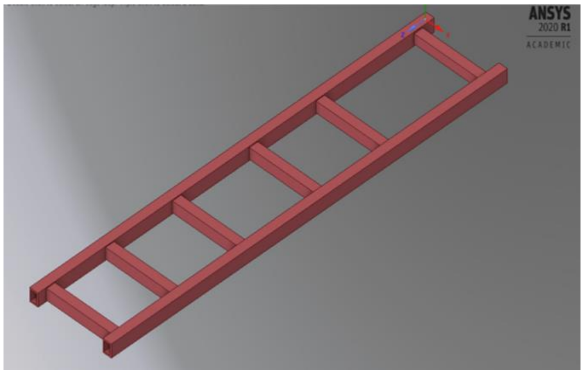

Fig. 1. CAD model of the chassis frame

A. *Meshing*

Since it dictates how the model should be broken down into finite components, mesh development is a critical stage in the modelling process. In order to create a continuous mesh, a meshing strategy was devised and implemented. The meshing was accomplished using 2D higher-order tetrahedral components, as seen in the illustration. It is advantageous to utilise this type of element in thin-walled constructions such as the ladder frame since it provides information on local stress. Figure 2 displays a mesh model of the chassis frame with a number of joints, similar to the one in Figure 1.

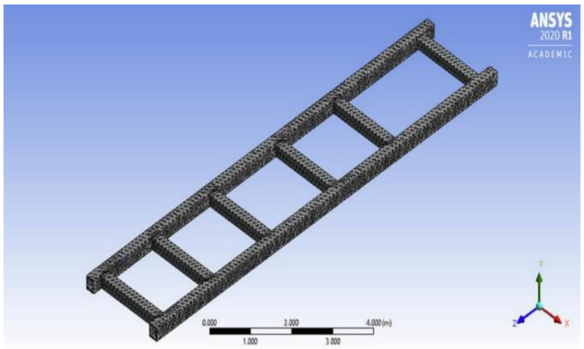

Fig. 2. Meshed model of the chassis frame

B. Loading and boundary conditions

For the purpose of simulating actual vehicle driving situations, it is critical to understand the loads and boundary conditions that will be used in the formulation of the loading parameters and testing parameters. These will be used to replicate driving circumstances including rough roads, aggressive turning, and rapid accelerations, among others. When it comes to model limitations, the structural integrity of vehicle components, as well as the specific loading scenario, are the determining factors. The following is an estimate of the load on the chassis's framework:

Gross vehicle weight (GVW) + payload = 18000 kg.

Capability of the bus = 60 passengers.

Gross weight of the passengers = (60*65) = 3900 kg.

(Assuming avg. weight as 65 kg).

Net weight acting on the frame = 18000 + 3900 = 21900 kg.

Total load acting on the frame = 21900*9.81 = 214839 N.

Those two longitudinal components of the chassis structure are subjected to the greatest amount of stress. Consequently, when a single member is employed, the single member will be subjected to a load equal to one-half (107419.5 N) of the total load operating on the frame as a whole when the frame is not used.

C. FEA results

We picked the design restrictions of stress and deformation as the primary considerations. For the chassis frame produced from three different materials, as indicated in Table 5, the results of the finite element analysis (FEA) for the chassis frame are depicted in a series of figures 3–8.

D. Structural steel frame

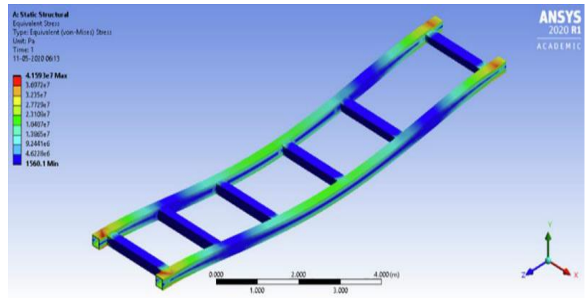

Fig. 3. Equivalent stress of steel frame

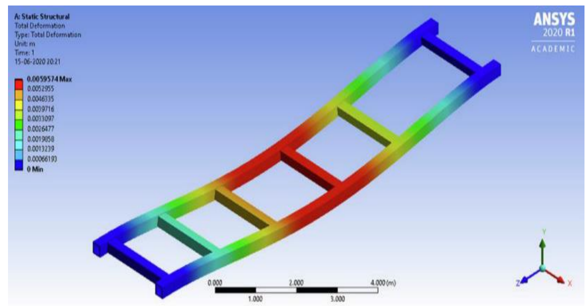

Fig. 4. Total deformation of steel frame

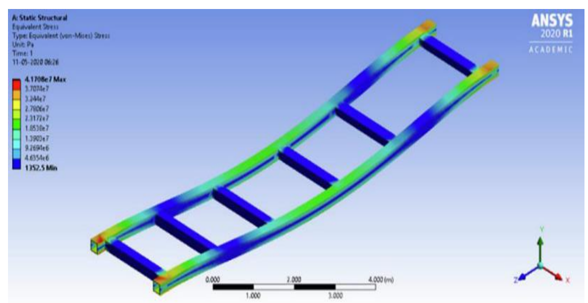

Fig. 5. Equivalent Stress of Alminium 6061-T6 frame

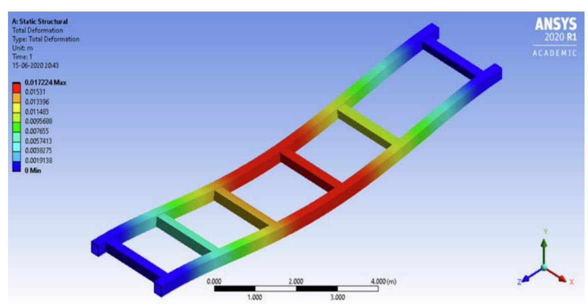

Fig. 6. Total deformation of Aluminium 6061-T6 frame

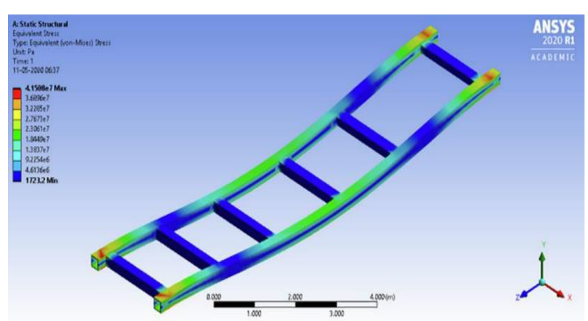

Fig. 7. Equivalent stress of Alminium 7075-T6 frame

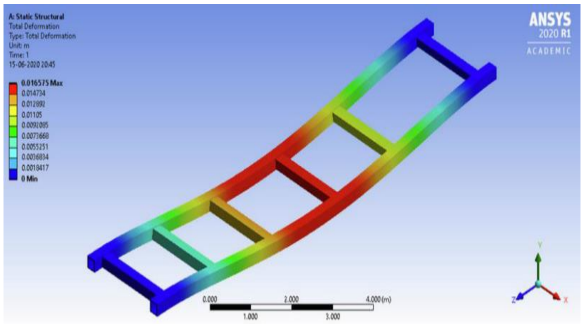

Fig. 8. Total deformation of Alminium 7075-T6

Table 5
Details of the materials

Material	Equivalent Stress (Mpa)	Total Deformation (mm)
Structural Steel	40.56	5.92
Alminium 6061-T6	40.68	17.18
Alminium 7075-T6	40.48	16.52

4. Conclusion

It is possible to lower the weight of the chassis frame by 65.61 % and 64.33 %, correspondingly, by substituting aluminium 6061-T6 and aluminium 7075-T6 for the steel component. The bus's overall performance is significantly improved as a result of the weight reduction achieved. In order to identify safe stress limits for the frame, a finite element analysis was done using finite element software. Upon reviewing the results of the finite element analysis, it was revealed that all three frames were not subjected to stress that exceeded their respective ultimate tensile strengths, proving that the design is safe.

After being subjected to rigorous testing, the aluminium 7075-T6 frame revealed less stress and deformation than its aluminium counterpart, demonstrating that it is a suitable material for the chassis frame, as indicated by the test results.

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