Transient Structural Analysis of Electric Bus Chassis Frame

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Abstract: From the few past years, usage of electric vehicles is increasing over the usage of the petrol or diesel vehicles. The main reason behind that is increasing cost of fuel and air pollution. In this vehicle chassis frame also play a major role for giving the support to the other parts acting as skeleton of the structure. During heavy load and dynamic loading conditions the structure of the chassis frame may fail and causes breakdown. It is very important to analyze the chassis frame under different loading conditions i.e., static and dynamic loading conditions. From this research paper work, the structure of the chassis frame with box section, channel section, channel section (with increased thickness) and channel section using stiffener are analyzed under static loading and transient loading (Time varying loads) in FEA Software (ANSYS 2020R2 Student Version). The material of the chassis frame is selected as Steel, Aluminum of type 6061-T6, Aluminum of type 7075-T6 and Titanium alloy. Loads and boundary conditions are applied as per the research article [1] and proper mesh is given to the geometry. From the static and transient analysis it is concluded that channel section using stiffener is having less stresses and less deformations compared to the box section, channel section and channel section with increased thickness using with different materials. Chassis frame with steel having less stresses and low deformation compared to the remaining materials. By this result, it has concluded that the channel section with stiffener using steel material gives better performance compared to the other sections.

Keywords: FEM, Static Structural Analysis, Transient Structural Analysis.

Nomenclature: \( \sigma_{yt} \) = Yield Strength, \( \rho \) = Density, \( E \) = Young’s Modulus & \( \mu \) = Poisson’s ratio.

1. Introduction:
“Chassis” a French term which means the complete automobiles without body and it includes all the systems like power plant, transmission, steering, suspension, wheels tyres, auto electric system etc. without body. There are 3 types of chassis frame sections which are shown in the Figure 1.

![Figure 1. Different type of chassis frame sections](image_url)
Note: Channel Section is good for bending; tubular section is good for twisting and box section is good for both bending and twisting.

S. Nanda Kumar [1] performed FEA on the chassis frame and calculated the stresses. He proposed that we can achieve weight reduction of 65.61% and 64.33% by using chassis frame with aluminum 6061-T6 and aluminum 7075-T6 instead of steel through which overall performance is improved. Patel Vijay Kumar V [2] performed FE analysis on chassis frame and proposed that weight of the chassis frame is reduced by 6.68% and the results are also reduced respectively 12.14%, 8.55% and 11.20%. It is clear that design is safe. Shaik Neelophar Begum [3] performed FE analysis on chassis frame and proposed that in C type Cross section, stresses and deformations are more where as I type cross section, they are less and where as they are moderate in Box type cross section and also moderate total deformation and equivalent stresses. Rohan Y Garud [4] has carried out FEA on the chassis, it can be concluded that 8 mm thick Advanced High Strength Steel chassis shows better result as compared to original 5 mm thick steel chassis. Amar R [5] has concluded that, Eicher 11.10 chassis was subjected to finite element analysis and it says that the design is safe as the Von-mises stresses are less than the permissible value. And maximum equivalent stress and total deformation are obtained through the analysis done. Vishal Francis [6] conducted FE analysis on the ladder type chassis frame of jeep and concluded shear stresses are less than the permissible value so the design is safe for all three materials. Stresses are minimum in aluminum alloy compared to the mild steel and aluminum alloy. Ramesh Kumar [7] performed design and optimization analysis on the chassis frame. Fatigue analysis is carried out on the chassis using ANSYS software to identify the weak points and the life of the chassis.

2. Problem Description
2.1 Problem Statement
To perform Transient structural analysis on the Chassis Frame using 3D FEA and to verify the design of components in strength point of view under transient loads.

2.2 Geometry
The structure of the Chassis Frame [Box and Channel Section] is designed in the ANSYS WORKBENCH 2020 R2 Student Version (Figure 2). The dimensions of the Chassis Frame are taken from the research article [1]. The isometric view of the chassis frame is shown in the below Figure. 3.

![Figure 2](image-url)

**Figure 2.** Chassis Frame (a) Box Section (b) Channel Section (c) Stiffener (d) Channel Section with Stiffener
The Dimensions of the Chassis frame is shown in Figure 4.

\[ a = 11470 \text{ mm},\ b = 2420 \text{ mm},\ t = 10 \text{ mm},\ c = 2550 \text{ mm},\ d = 3250 \text{ mm},\ e = 5735 \text{ mm} \]

Width of the Frame’s Cross-section is 300 mm, Height of the Frame’s Cross-section is 150 mm and thickness of the chassis frame is 10 mm.

### 2.3 Materials

In this research work, four different types of materials are used for the chassis frame i.e., Steel A709M, Aluminium 6061-T6, Aluminium Alloy 7075-T6 and Titanium Alloy. The properties of the materials are listed in the below Table 1

| Material Name                  | \( \rho \) (kg/m\(^3\)) | \( E \) (MPa) | \( \mu \) | \( \sigma_{yt} \) (MPa) |
|-------------------------------|--------------------------|---------------|---------|------------------------|
| Steel A709M Grade 345 W       | 7850                     | 200000        | 0.3     | 260                    |
| Aluminium Alloy 6061-T6       | 2700                     | 69000         | 0.33    | 275                    |
| Aluminium Alloy 7075-T6       | 2800                     | 71700         | 0.33    | 505                    |
| Titanium Alloy                | 4620                     | 96000         | 0.36    | 930                    |

### 2.4 Mesh

Meshing is the process of converting geometry entities into the finite elements. The type of element used for the chassis frame with box and channel sections is solid 186. SOLID186 is a higher order 3-D 20-node solid element that exhibits quadratic displacement behavior.

### 2.5 Loads & Boundary Conditions

The load acting on the frame is 214839 N and this particular load is acting on chassisframe mainly on two longitudinal member. So total load acting is distributed between the two members of the frame equally. Therefore the individual weight on the frame is 107419.5 N. The realistic boundary conditions are applied to the chassis frame by giving the fixed support to the horizontal channels of the frame as shown in the below figure 5.
2.5.1 Transient Load

The magnitude of the transient load which is applied on the chassis frame of the vehicle with different sections is shown in the below figure.

![Figure 5. Transient Load](image)

2.6 Connections

The realistic condition for connections (Contacts) is bolded joint connection between the frame members to from assembly frame. Here, the contacts are assumed to be bonded contacts.

2.7 Case Studies

The following case studies are studied on the chassis frame under static structural and transient structural loads. The list of case studies is described in the Table 2.
Table 2. Case Studies

| S. No | Type                                      | Thickness (mm) | Volume (mm³) |
|-------|-------------------------------------------|----------------|--------------|
| 1     | Chassis with Box Section                  | 10             | 4.373e+008   |
| 2     | Chassis with Channel Section              | 10             | 2.7578e+008  |
| 3     | Chassis with Channel Section with increased Thickness | 17             | 4.373e+008   |
| 4     | Chassis with Box Section using Stiffeners | 10             | 4.373e+008   |

3. Static Structural Analysis of Chassis Frame

Static structural analysis is performed for initial static conditions to check whether the structure is withstand the loads in strength point of view on the chassis frame with box section, channel section, channel section with increased thickness and channel section with stiffeners using different materials and the calculated results are listed in the below tables.

The static structural analysis of chassis frame with box section using Steel A709M is performed and maximum von-misses stress of the structure is shown in the below figure.

![Figure 6. Von-misses Stress of Chassis Frame with Steel A709M](image)

From the above figure, it is shown that the maximum von-misses stress of the chassis frame using steel A709M is 42.584 MPa, which is less than the material strength (260 MPa). From the above figure, it is clear that the maximum stress is located on the rear hang part of the chassis frame in bottom surface.

The static structural analysis for the chassis frame with cases [1, 2, 3 & 4] using Steel A709M Grade 345 W, Aluminium Alloy 6061-T6, Aluminium Alloy 7075-T6 and Titanium Alloy are performed and stress values are listed in the below Table 3.

Table 3. Von-misses Stress values under Static Structural Analysis

| Material          | Box Section | Channel Section | Channel Section with Increased Thickness | Channel Section with Stiffener |
|-------------------|-------------|-----------------|------------------------------------------|-------------------------------|
| Steel A709M       | 42.584      | 59.970          | 43.007                                   | 39.729                        |
| Aluminum 6061-T6  | 42.850      | 59.593          | 42.901                                   | 37.551                        |
| Aluminum 7075-T6  | 42.850      | 59.593          | 42.901                                   | 37.551                        |
| Titanium Alloy    | 43.188      | 59.071          | 42.751                                   | 37.134                        |
From the above table, it is noticed that the maximum stresses are obtained with the channel section with 10mm thickness and minimum stresses are obtained with the channel section with stiffeners. The graphical plot of the stress values of the leaf springs using different materials with different sections are plotted in the below Figure 7.

**Figure 7.** Von-misses Stresses of the Chassis Frame under Static Loads

From the above figure it is shown that, channel section with 10mm thickness has maximum stress values, channel section with stiffener has minimum stress values. The box section and channel section with increased thickness has similar value of stresses for every material. Steel A709M having higher stresses and Titanium has less stress values.

### 4. Transient Structural Analysis of Chassis Frame

The chassis frame is subjected to Transient structural analysis with box section with Steel A709M and maximum von-misses stress over the time is calculated using FEA software and it is shown in the below Figure 8.

**Figure 8.** Maximum Von-misses stress of the chassis frame with box section
From the above figure, it is shown that the maximum von-misses stress of the chassis frame using steel A709M over the time range of 1 sec to 10 sec is 214.05 MPa, which is less than the material strength (260 MPa). From the above figure, it is clear that the maximum stress is located on the rear hang part of the chassis frame in bottom surface where constrains are given. The minimum von-misses stress is located on the extreme end of the rear hang part of the chassis frame. The minimum, maximum and average stress values of the chassis frame with box section using steel A709M material is listed in the below Table 3.

Table 4. Stress values of the Chassis Frame using Steel A709M

| Time (Sec) | Maximum Stress (MPa) | Time (Sec) | Maximum Stress (MPa) |
|------------|----------------------|------------|----------------------|
| 1          | 85.53                | 6          | 128.36               |
| 2          | 128.5                | 7          | 171.12               |
| 3          | 171.04               | 8          | 128.37               |
| 4          | 214.05               | 9          | 85.507               |
| 5          | 171.1                | 10         | 42.804               |

It is noted that the maximum stress value of the chassis frame using Steel A709M over the time range of the 1 sec to 10 sec of transient load are 214.05 MPa which is takes place at 4th second of the transient load. The maximum von-misses stresses of the chassis frame [case 1, 2, 3 & 4] using different materials at time of 4 sec are shown in the below Figure 9.

Figure 9. Von-misses Stress of the Chassis Frame under Transient Load
From the above figure, it is shown that the maximum stresses of the chassis frame using different materials at 4 sec of transient time are obtained with the channel section. Minimum value of stress values are obtained with the channel section with the stiffeners.

The total deformation of the chassis frame with box section using Steel A709M for transient load range of 1 sec to 10 sec is shown in the below Figure 10.

**Figure 10.** Total Deformation of the chassis frame with box section using Steel A709M

From the above figure, it is shown that the maximum total deformation of the chassis frame is 16.925 mm. The maximum total deformation is located on the extreme rear hang part of the chassis frame. The minimum total deformations are located at the fixed support locations of the chassis frame with box section. The total deformations of the chassis frame [case 1, 2, 3 & 4] using different materials are plotted in the below Figure 11.

**Figure 11.** Total Deformations of the Chassis Frame under Transient Load

From the above figure, it is observed that the maximum deformations are obtained with the channel section with 10mm thickness and minimum deformations are obtained with the channel section with increased thickness.
5. Conclusions

The chassis frame of the electric bus is analysed under static and transient loads and list of conclusions are drawn from the work.

1. Von-misses stresses of the chassis frame with box section, channel section, channel section with increased thickness and channel section with stiffener are within the limits of the material strengths. That indicates that the structure withstands the static and transient loads.
2. The von-misses stresses of the chassis frame with channel section with 10mm thickness posses higher values due to the less cross sectional area of the section compared to the other sections.
3. The total deformations of the chassis frame with channel section with 10mm thickness posses’s higher values due to the less cross sectional area of the section compared to the other sections.
4. The von-misses stresses of the chassis frame with channel section using stiffeners posses less values compared to the other sections.
5. The total deformations of the chassis frame with channel section using increased thickness posses less values compared to the other sections.
6. Structure using Steel A709M showing better results in stresses and deformations compared to the other materials.
7. The structure of the chassis frame with channel section using stiffener has low weight and higher strength.
8. It is recommended to study the structure under other dynamic conditions using super alloys.

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