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Fatigue analysis of electrical vehicle chassis

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Abstract
The aim of this study is to make fatigue analysis of electrical vehicle chassis which was designed previously and is to determine the fatigue damage components in advance and to find the critical life of these parts.
Then to compare the obtained data with the values taken during the road tests.To ensure smooth operation CAD model which was prepared in Solidworks is provided in .stp format and simplifications that are deemed necessary are made in the program Catia V5 R20.The prepared solid model has been transferred to the Ansys Static Structural Programmer in .stp format for finite element models. Here, static analysis is performed via on-vehicle weight. After that, fatigue analysis is performed in nCode DesignLife software with the data received from testing tracks. Within the scope of this plan, firstly static analysis will be performed with 1 driver and 2 passenger weights on the chassis, than fatigue analysis with data collected from 4 different ways during road tests will be carried out..And finally, according to the analysis results fatigue life of the parts on the model will be examined.

Keywords: Electrical vehicle; fatigue; finite element analysis;

1. Introduction

Machine elements in general is under the influence of variable loads and stresses. Loads acting on the element can be variable stresses occurring in cross-section, even though static [1–6]. The number of repeat at the elements under the influence of variable stress is important not for their maximum value [7–11]. Cyclically changing stresses cause some deterioration in the internal structure of the material. Thus breaking event occurs well below the static limit. In materials science, fatigue is the weakening of a material caused by repeatedly applied loads [12–17].

Fatigue life is the number of cycles of a specified loading that a given specimen can be subjected to before failure occurs. One of the most important points while designing a vehicle to be taken in mind is, vehicles elements should also provide the expected strength values from them [18–21]. Therefore, it is necessary to performe the strength analysis of vehicle chassis very well. Using the solution of the balance equations under the forces and moments acting is not so easy. In this case it is necessary to use different methods. Finite element analysis of these methods is due to be integrated with computer-aided design system especially easy to use and is very heavily used in the automotive industry.

With using the finite element methods in fatigue analysis, fatigue behaviours of elements can be examined without being subjected to test.. Therefore, before manufacturing, fatigue behaviours of many machine parts is determined [21, 22].

There are 3 important step in fatigue analysis. These;

- Selection of fatigue methods
- Selection of installation method
- Selection of material fatigue curve [14–16]

In this study we will use Variable Amplitude Loading Conditions Methods cause of collected data in different road conditions.

Some theories such as Soderberg, Goodman and Gerber theory are used to calculate the average stress [10, 17]. While Goodman is a good choice for brittle

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materials Gerber is a good choice for ductile material[23]. And Soderberg is useful for low ductile materials[24]. In this study we will use brittle material (St37). Therefore Goodman approach will be used. Again in this study for using Life Stress method,S-N curves for material will be create.

2. Material and Methods

2.1.Static Analysis

2.1.1. CAD Model Creation

CAD model is designed as shown in the Figure 1. By making arrangements, some parts which arent necessary for analysis have been removed, such as powertrain, suspension fittings, steel sheets. Pipe profiles constitute a part of the chassis model. There are gaps,shears and telescoping parts at the connection of the tube profile arising from the design parameters. For a healthy solution, solid model must exist in geometric errors and also closest to the actual model. so some arrangements have been made in connection of the chassis models. It was also found that, connection of the perforated sheet model which was designed for transporting the Pb-Acit battery on the chassis is too weak.. When this is done the weak link shape with fatigue analysis, the analysis is expected to occur in the breaking of the perforated sheet metal seams. Fatigue damage in other regions can not be seen as the true value for the break to occur somewhere on model. Therefore, it recommended that the support profiles 40*40 placed under the perforated sheet metal and seat carrier profile and these support profiles have been added to the embodiment was prepared for analysis. Of the amendment made, embodiments of ready to create an analysis model is as shown below in Figure 2.

2.1.2. Creating a mesh model

The prepared solid model has been transferred to the Ansys Static Structural Programmer in .stp format for finite element models with some arangements. Static analysis will be done by applying the necessary boundary conditions. The mesh structure is created to chassis as shown in Figure 3. Mesh structure consists of a total of 96,978 hekzahedron,and tetrahedron elements and 294,979 nodes.

2.1.3. Definition of Material Information

Mechanical properties of St37 steel was used for the chassis model. The mechanical properties of steel St 37 are as follows:.

Modulus of Elasticity : 210 GPa
Density : 7850 kg/m^3
Yield Stress: 250 MPa
Tensile Stress: 460 MPa
Poisson's Ratio: 0.3

2.1.4. Determination of Loading Conditions

Location and weight information of the batteries constituting the majority of the weight which acts on the chassis model was determined as shown in Figure 4. The average weight of 130 kg load generated by onboard equipment in addition to other values was effected from the estimated vehicle center of gravity.

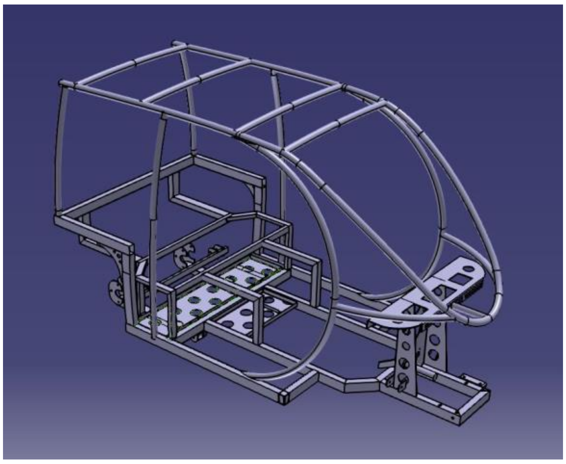

Figure 1. General view of electric vehicle chassis.

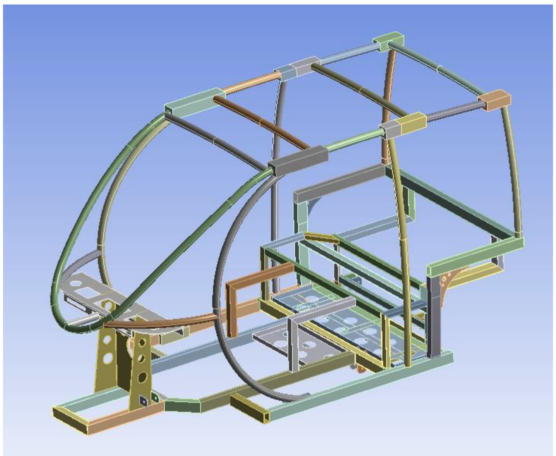

Figure 2. Purified chassis view.

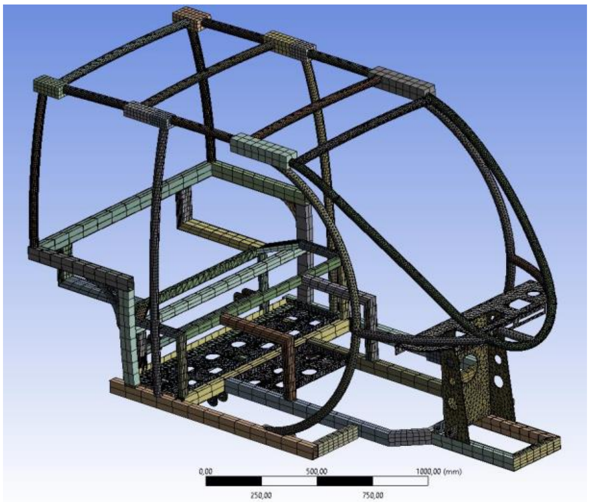

Figure 3. Mesh structure of chassis model

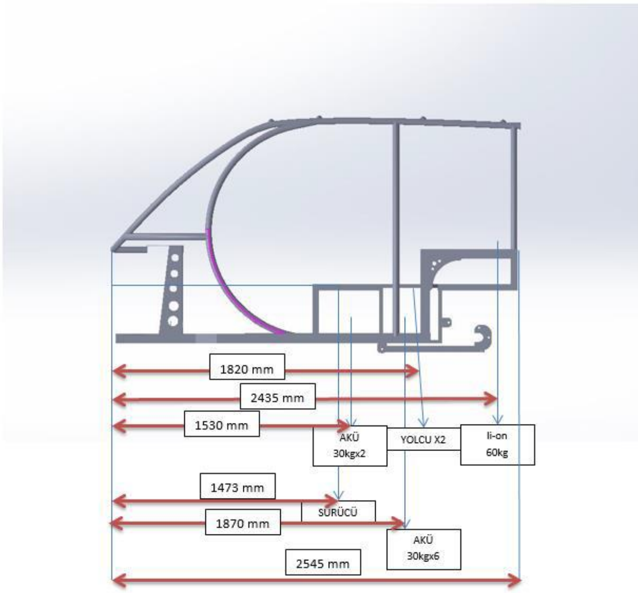

Figure 4. Weight information impact on the chassis.

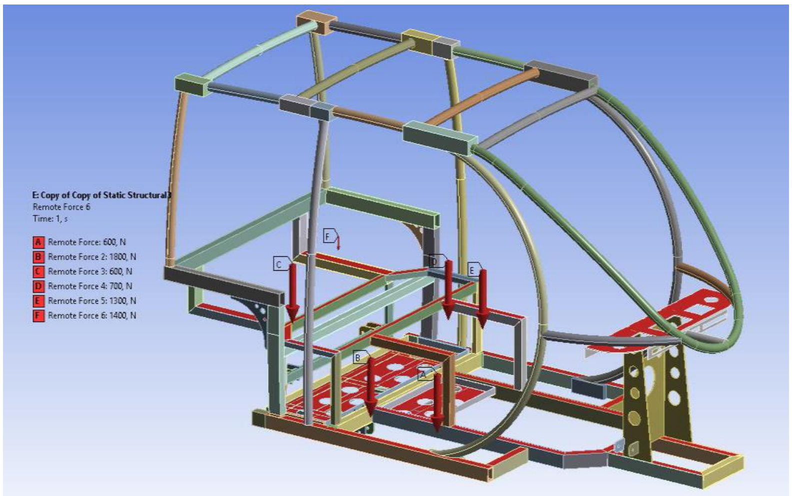

Figure 5. The forces on the chassis.

All the weight acting on the model, was applied from the estimated centre of gravity as remote force as shown in the Figure 5. Here A indicates the weight of Pb-Acit battery which is 60 kg, B indicates the weight of Pb-Acit battery which is 180 kg, C indicates the weight of Li-on battery which is 60 kg, D indicates driver weight which is 70 kg, E indicates other vehicle equipments and F indicates two passenger weight which is 140 kg. After defining the loads acting on the chassis, 6 degree of freedom in direction has been reset from the suspension connection area.

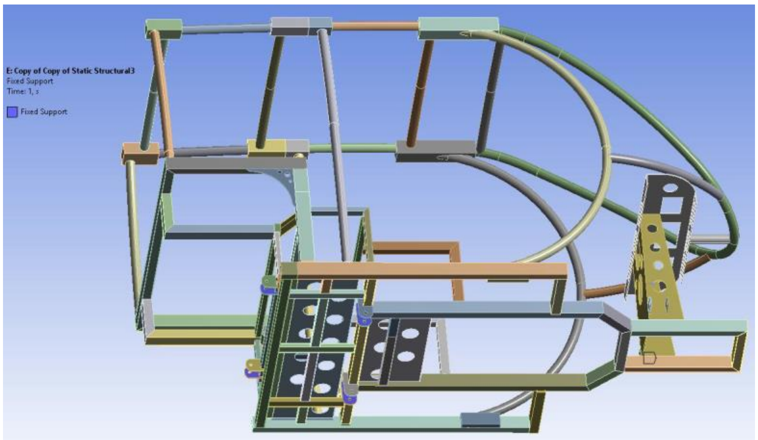

Figure 6. Chassis model fixed surfaces.

Fixing surface of the chassis was entered. Şasinin sabitleme yüzeyleride girildikten sonra During tests on paving way, 18m/s² acceleration value collected from suspension is added to the analysis model in the vertical direction. After entering all necessary data for static analysis, finite element model was created and solution built on this model.

2.2. Fatigue Analysis

2.2.1. Selection Method

We want to calculate the average lifetime value of each part assuming that no cracks or breakage on the chassis. Therefore we used Life Stress method for fatigue analysis carried out for the vehicle chassis.

2.2.2. Determining the Installation Status

In the electrical vehicle test drives, data were taken with the speed and energy consumption from 4 different test tracks. In this study, the fatigue characteristics of the chassis model to be examined analysis will be done with the suspension over acceleration data. These data are the acceleration values obtained from four different test tracks on the 3 km long. These collected acceleration datas after some arrengements are provided in the gravitational acceleration format (g; m/s^2) as shown in Figure 7.

2.2.3. Material S-N Curve

Numbers which form the fatigue curve on the materials are calculated with the relevant calculation method and S-N curve of St37 steel was formed as shown in Figure 8.

2.2.4 Fatigue Analysis Flowchart

After the selection criteria and the method steps, fatigue analysis solution diagram was formed in nCode DesignLife programme as shown in Figure 9.

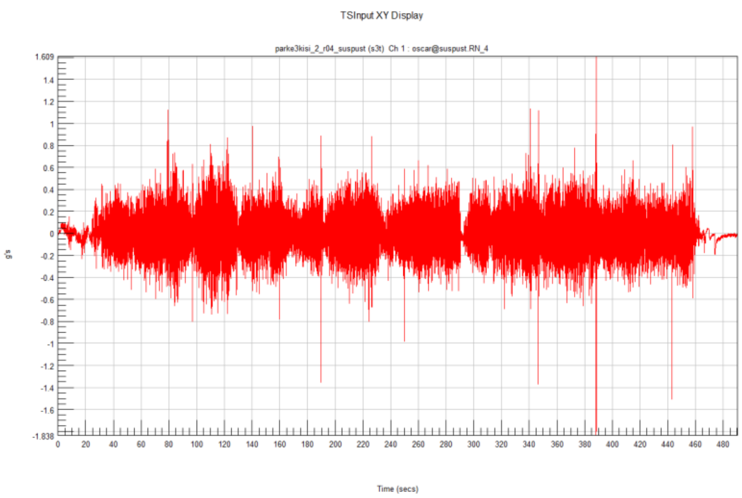

Figure 7. Suspension over acceleration data receievd frm paving the way.

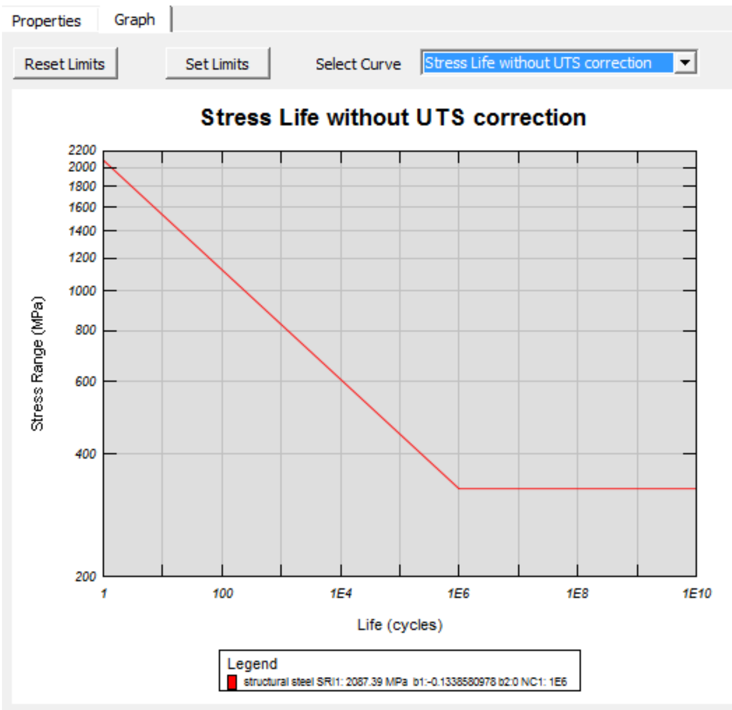

Figure 8. S- N curve of material used in the chassis model.

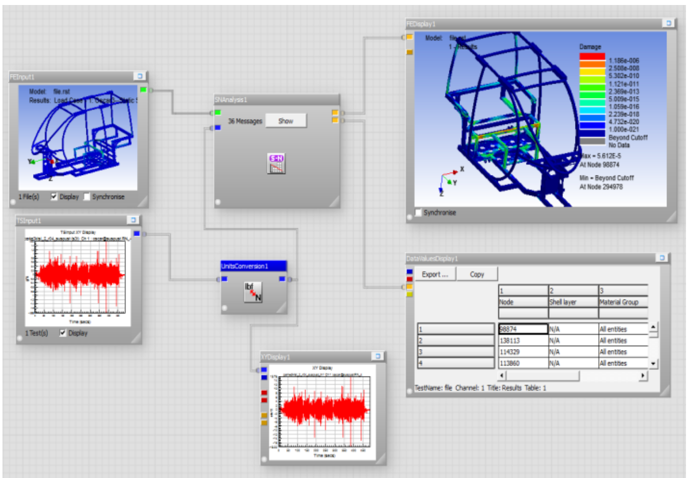

Figure 9. DesignLife Fatigue Analysis Flowchart

3. Results

3.1. Static Analysis Results

As a result of static analysis, the equivalent stress distribution is obtained as shown in Figure 10.

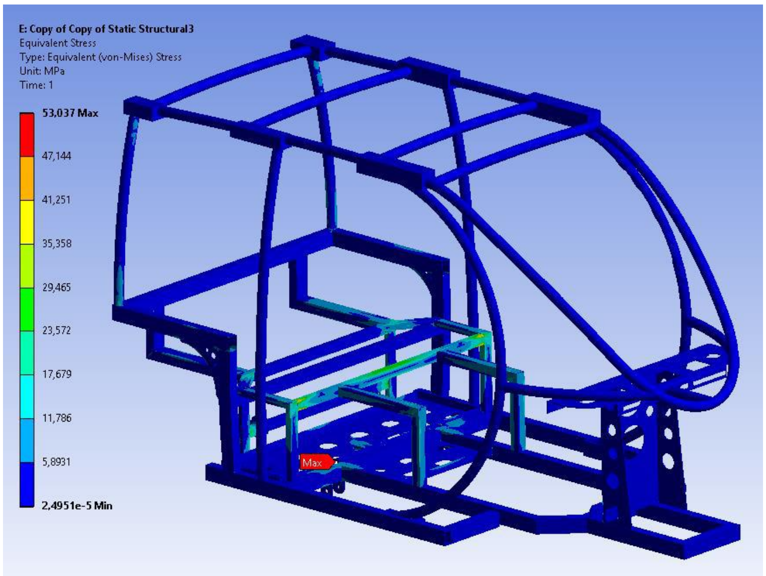

Figure 10 Equivalent stress distribution

And as a result of static analysis, the elastic deformation on model is obtained as shown in Figure 11. Here maximum stress value is 53,037 MPa as shown in the Figure and these values occur in rear axle swing profile connection area.. As can be seen the value of this stress on the model, there is no problem in terms of static load on the chassis and safety structure in terms of static coefficient is approximately 4.71.

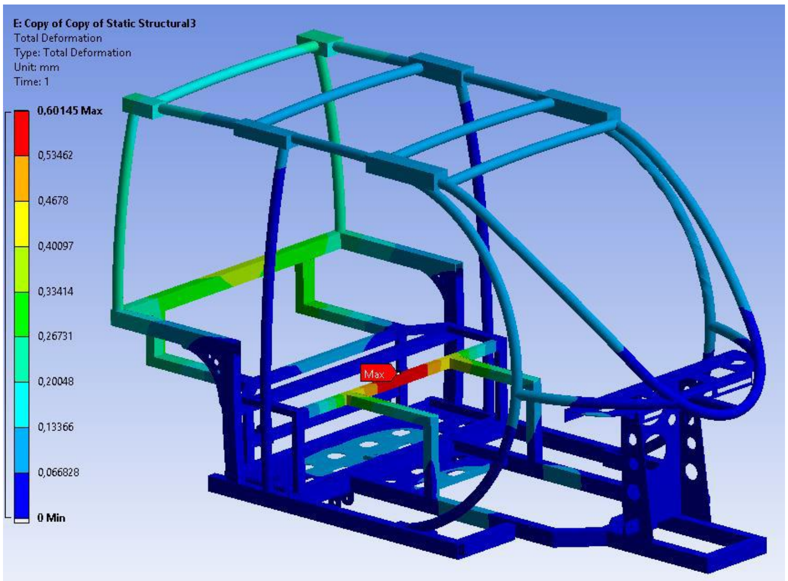

Figure 11 Elastic deformation on model

3.2. Fatigue Analysis Results

Upon entering the three basic parameters required for fatigue analysis, analysis models for each four different tracks were solved. As a result of analysis, the life and damage values on the chassis model were obtained for four different tracks as shown in Table 1.

Tablo 1: Fatigue life and damage results for four different test tracks

	Asphalt Road	Downgrade	Parker road	Unpaved Road
Life	$4,156x10^4$	$1,058x10^5$	9789	6765
Damage	$2,406x10^{-5}$	$9,453 x10^{-6}$	$1,022x10^{-4}$	$1,478x10^{-4}$

The most critical results for fatigue life and damage were obtained from unpaved road testing datas. Fatigue life value from the analysis results is the value of re-loading data., We can find estimated kilometers value with multiplying this value by the length. İf we want to calculate the estimated fatigue lifetime value with data from analysis on unpaved road; 6765*3=20295 km.

The meaning of the values here, the permanent deformation due to fatigue after an average of 20 295 km on the unpaved road may occur on the chassis. As a result of the analysis made by unpaved road data, fatigue lifetime distribution on the chassis model is as shown in Figure 12.

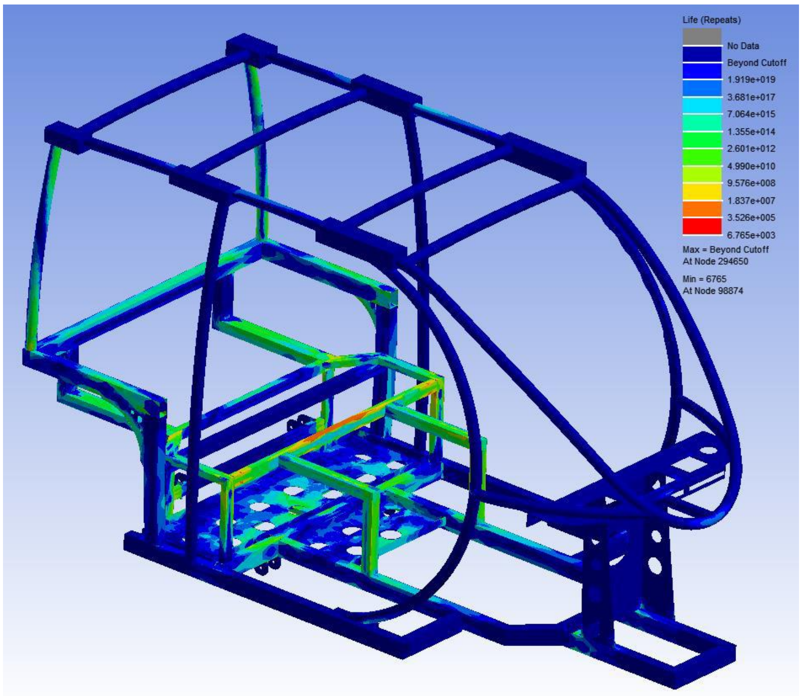

Figure 12 Lİfetime distribution on chassis model

4. Conclusion and outlook

The most critical regions of the fatigue life on the chassis are profiles carrying the driver and passenger seats and perforated sheets carrying the Pb-acit battery. Amount of damage formed on the vehicle as a result of the analysis made by unpaved road data is as shown in Figure 13. The maximum amount of damage is likely to be 0.0001478.. This value is proportional value of the damage on the chassis. It means max. 0.01478 percent of damage occurs on the seat carrier profiles when the car used 3 km on unpaved road. When used in 20 295 km will be one hundred percent and the amount of damage that will create a permanent deformation in the critical areas on the chassis.

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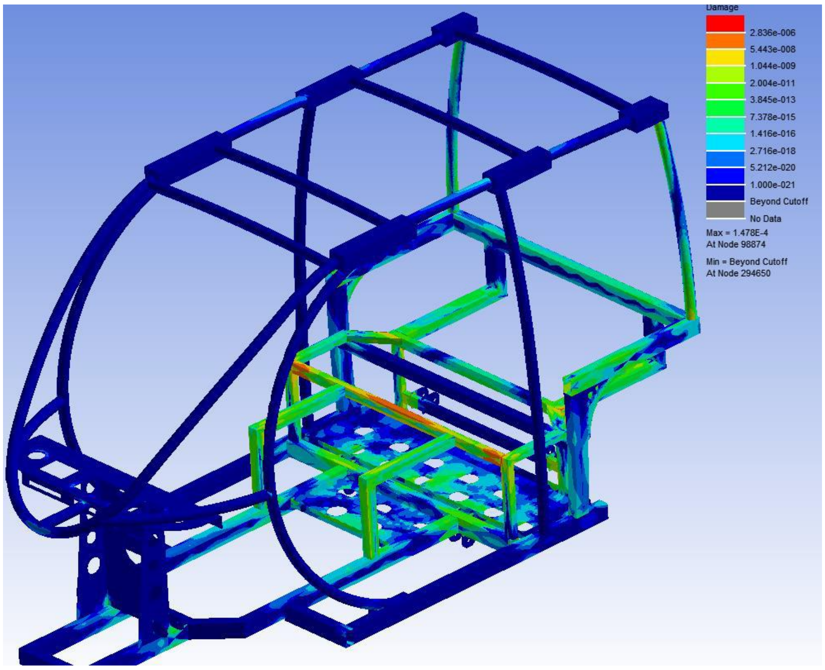

Figure 13 Damage distribution on chassis model

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