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Design and Analysis of Battery Carrying Structure of an Automobile for Static and Dynamic Loading using FEA

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Abstract: In this paper, the 3D model of the battery carrying structure inside the vehicle or from existing vehicle is carried out. This structure is very important for battery, because by this structure we increases battery stability and prevent from shock jerks or load that they are transferred on the battery during vehicle is in running condition by this we increases the battery life and reduce maintenance cost. The analysis process is done in the manner of static and dynamic analysis of the battery carrying structure during the vehicle operation, and the vibration or frequency response of the battery carrying structure is simulated. In the simulation process, static analysis will be simulated during static load and we can see the relationship of the maximum principal stress of the battery carrying structure and the vibration frequency and amplitude during dynamic analysis, by this we find out the debilitated points of the battery carrying structure and optimize it.

Keywords: Battery Carrying Structure, Static & Dynamic Analysis, Vibration.

1. Introduction

1.1 Introduction

Battery is anecessary device to protect in automobile, the static and dynamic performance of the battery carrying structure is closely related to the assurance of the complete vehicle and performance of the vehicle. Therefore, it is very necessary to review the maximum principal stress and total deformation of the structure under specific practicalsituation to optimize the design of the debilitated parts of the structure's stiffness and strength.
At first, we makea3Dbody model and finite element model, and the stress state of battery carrying structure under extreme situations.In the first time, during static analysis the maximum principal stress and total deformation is carried out of the structure when engine in stop and when engine at ideal rpm.
By analyzing the modal shape characteristics and the harmonic results to vibration characteristics of the structure, the dynamic work of the battery carrying structure has been completely mastered. Definitely, based on the static and dynamic analysis output of the battery carrying structure, the debilitated points and inconsistent points are upgraded. The outcome shows that the converted model has a good enhancementresponse and has basically attain the established designqualification.
In this project , work is based on the existing battery carrying structure of automobile and we will take a dimension by existing battery carrying structure. In our battery carrying structure some variation in dimension areconsidered. This structure is made by composed of a base plate, battery clamp hold down, battery hold down rod, nut, battery cover and tray.
This battery carrying structure has made a different category of material for different parts.Aluminium Alloy is used to make battery base plate and battery clamp hold down, this material has a light weight characteristics. And Stainless Steel is used to make battery hold down rod and nut, because of its strength & resistance to corrosion. And Polyethylene is used to make tray and battery cover, because of its thermoplastic characteristics.

1.2 Literature Review

Na Yang et al 2019 [1] Dynamic and static analysis of the battery box structure of an electric vehicle.The modal calculation results of the battery boxcan enable engineers to find the defects…

Zhao, H.W., Chen. et al 2009 [2] Topology optimization of power battery packs for electric vehicles. A new methodology for the electric vehicle (EV) power battery cabin design was presented based on the topology optimization. In the modeling of topology optimization, the variable density method was used on the basis of the SIMP (solid isotropic material penalization) based interpolation function. In the topology optimization for the power battery cabin of a certain EV, taking the cabin manufacturability into account, a structure model of the optimized battery cabin was built. The optimized structure was compared with the conventional structure using the FEA to ensure the reliability of the new structure. The numerical instability in the topology optimization was avoided effectively by controlling the structure minimum size and mesh size. The battery cabin designed by the proposed topology optimization method is lighter in mass than the conventional structure at the equivalent mechanical strength. The stress distribution in the new structure appears more uniform, it is superior in realization of iso-strength design.

Wang, J. and Zhao, X. et al 2016 [3] Modal Analysis of Battery Box Based on ANSYS. At present, the development of the traditional car is more and more troubled by the high cost of environmental pollution and oil prices, many…

Li Shui, Fangyuan Chen, Akhil Garg, Xiongbin Peng et al 2018 [4] Design optimization of battery pack enclosure for electric vehicle. Lithium-ion Battery pack which is comprised of assembly of battery modules is the main source of power transmission for electric vehicles…

Hartmann, M., Roschitz. et al 2013 [5] Enhanced Battery Pack for Electric Vehicle: Noise Reduction and Increased Stiffiness. Vibration and the noise through vibration have always been major topics for the design of vehicles…

Klaus, H., Hirtz, E. et al 2013 [6] With System Integration and Lightweight Design to Highest EnergyDensities. Electric Vehicles will play an important role in future mobility….
Castano, S., Gauchia, L. et al 2012 [7] Dynamical modeling procedure of a Li-ion battery pack suitablefor real-time applications. This paper presents the modeling of a 50 A h battery pack composed of 56 cells….

1.3 Objectives
The proposed work is a part of automobile. By this project, the dynamic and static characteristics of the battery carrying structure of an automobile are analysed, and confer to the result, the structure is improved of the battery carrying structure is made. Following objectives are-

(a) To perform a static analysis under static loading condition, when engine in stop and when engine at ideal rpm.

(b) To perform a dynamic analysis under dynamic loading condition, when vehicle speed is 80, 100 and 120km/h(plane surface, uneven surface and dip or bounce) and also defining vibration characteristics.

(c) Result shows the modified model has a good characteristics than the original model.

1.4 Methodology
The methodology of the proposed work include –
(a) To make a finite element model of battery carrying structure.
(b) The battery carrying structure is composed of Base plate, Battery clamp hold down, Battery hold down rod, Nut, Battery cover and Tray, etc. have made a different category of material.
(c) In the modelling prepare, CREO is mostly used to construct 3d part model.
(d) After 3d body of the battery carrying structure is established in CREO, it is converted into IGES format and imported into ANSYS software for analysing.
(e) The maximum principal stress and total deformation of the structure under typical practicalsitutations are obtained by using the finite element software ANSYS.
(f) After that static analysis will be performed under static loading condition, when engine in stop and when engine at ideal rpm.
(g) Dynamic analysis is also performed under dynamic loading condition and harmonic response to vibration characteristics of the structure is also obtained.

1.5 Significance
The significance of the project is to perform analysis on static, dynamic, and impact condition for defining the stresses and total deformation of the battery carrying structure. In dynamic analysis, the vibration characteristics is defined by a harmonic response vibration in ANSYS. For this, firstly we select and solve the modal characteristics then we go to the harmonic response of the vibration, the solution of the harmonic response shows themaximum stresses appears in the battery carrying structure. By this, we easily define the dynamic characteristics of the structure. And after that we also perform impact analysis under impact loading condition on ANSYS software.
Our project focuses on the battery carrying structure of an automobile for four-wheeler. The Wagon-r car is selected, for battery carrying structure because this are the most used vehicle. The main reason for selecting this vehicle is easy to take dimension and data.

1.6 Research Design
For obtaining dimension of battery carrying structure, we disassemble the battery carrying structure part of wagon-r car and measure dimension needed for designing the battery carrying structure. Then we make a design in CREO software and put the measured dimension.

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Creo is a computer aided design software for generating solid or line diagram. By this, the mechanical arrangement is easier or faster and also easy for assembling of parts. It provide us a accurate diagram or solid geometry and easy to study.

2.Construction And Overview

2.1 Construction

In the construction of this project following parts are:-

(a) Nut

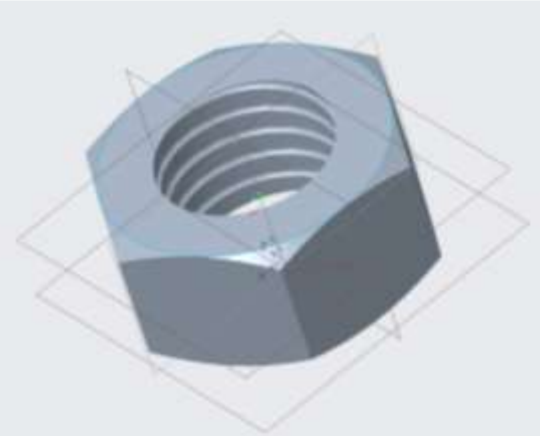

Fig. 1 : Nut designed in Creo.

(b) Battery Clamp Hold Down Rod

In this project two battery clamp hold down rod are used but in construction and designing we make a rod only one time.

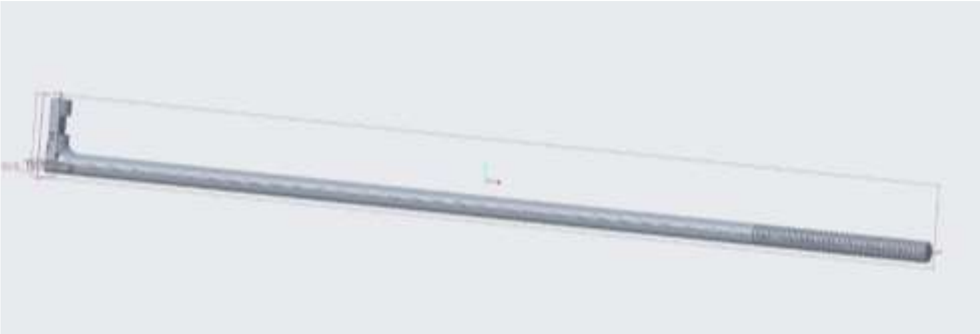

Fig. 2 :Battery clamp hold down rod designed in Creo.

(c) Battery Clamp Hold Down

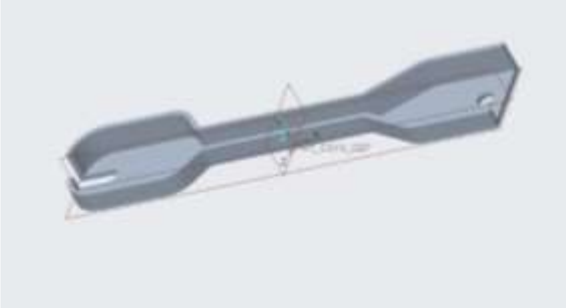

Fig. 3 :Battery clamp hold down designed in Creo.

(d) Battery Tray

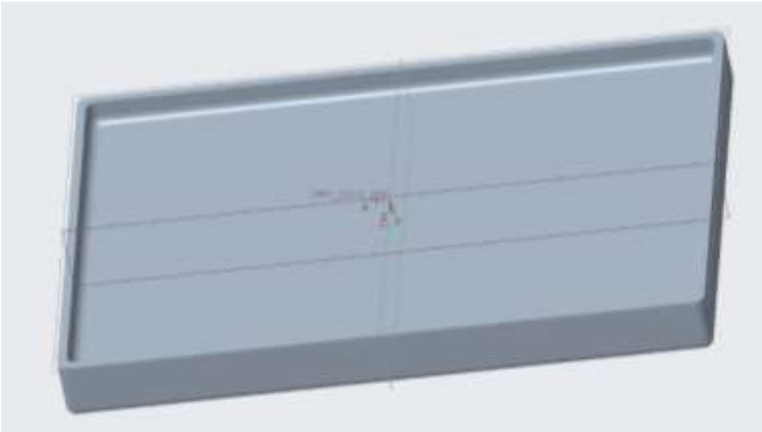

Fig. 4 : Battery tray designed in Creo.

(e) Battery Cover

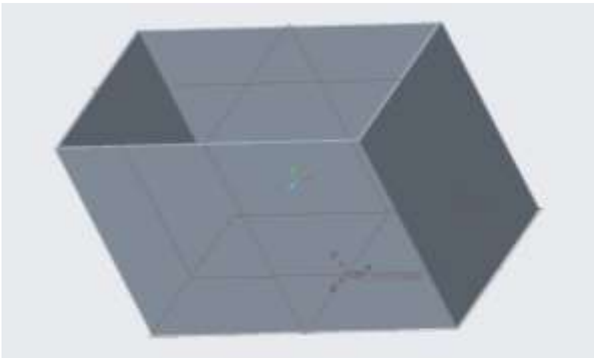

Fig. 5 : Battery cover designed in Creo.

(f) Battery Base

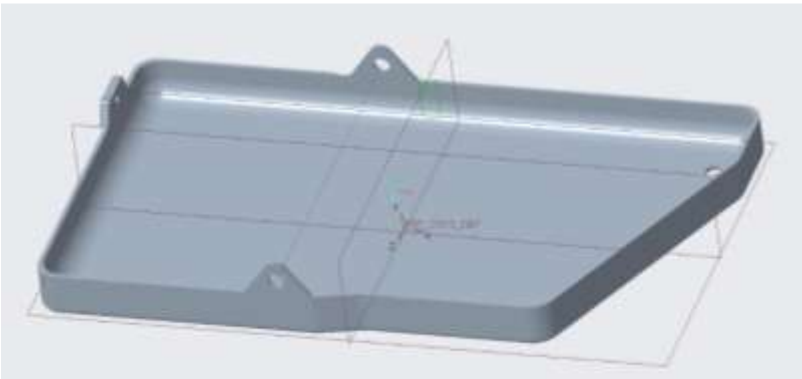

Fig. 6 : Battery base designed in Creo.

2.2 Experimental Setup

In this project, construction and designing of parts are done one by one in CREO software and after the all parts are making then assembling of parts are done again in CREO software. After the assembly work our final design of battery carrying structure are made.

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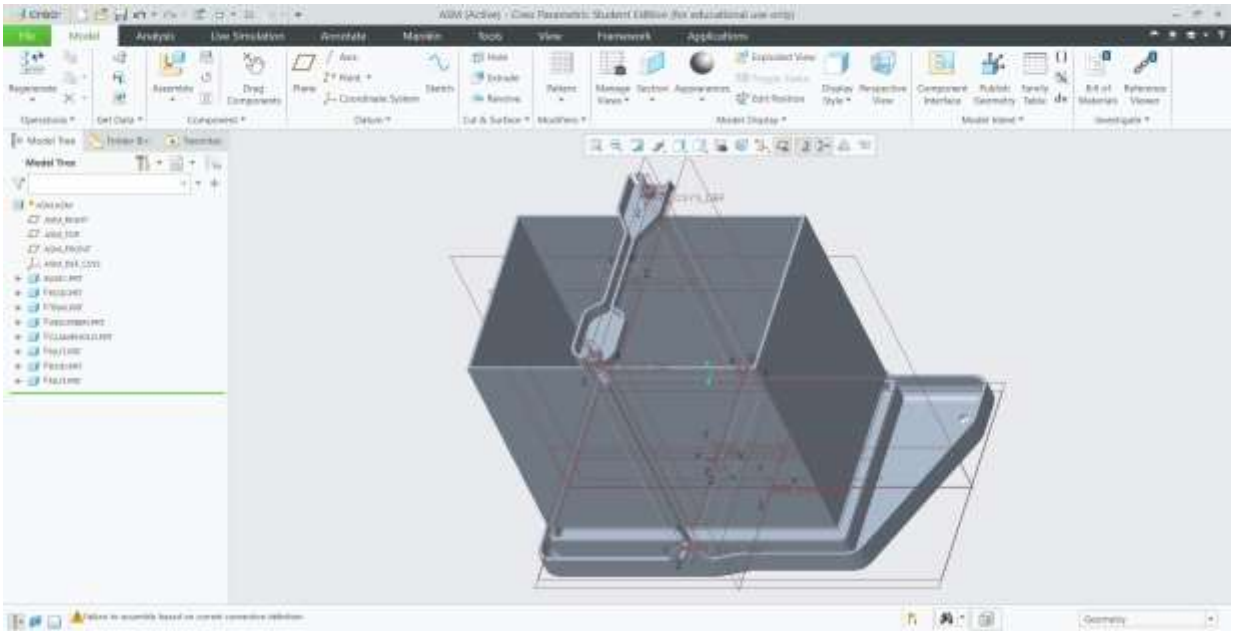

Fig. 7 : Battery carrying structure designed in Creo.

3.Static Analysis

Static condition will be performed on two conditions like-

3.1 When engine in stop.

3.2 When engine at ideal rpm.

3.1 When Engine in Stop.

In this condition the rpm of the engine will be zero, frequency will be zero, in this case only the gravity force will be apply on the battery carrying structure, the force will be 11kg-force or 107.87N.

For this condition, the operation will be perform on the ANSYS software we get a two result in terms of equivalent stress and total deformation. By this we get maximum value of stress and maximum value of deformation applying on the structure.

In this condition analysis will not be done on a complete structure. It will be done in two parts like-

(i) Battery Carrying Structure without Tray & Battery Cover.

(ii) Only Tray & Battery Cover.

(i) Battery Carrying Structure without Tray & Battery Cover.

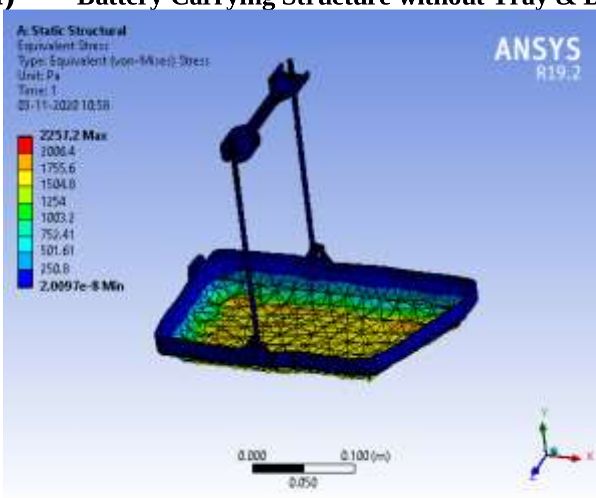

Fig. 8 :Equivalent Stress.

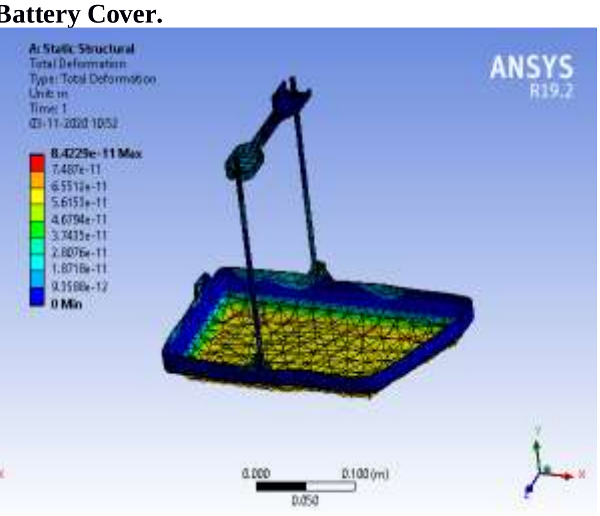

Fig. 9 : Total deformation.

In the above figure we can see a Maximum Stress is 2257.2 Pa and Total Deformation is 8.4229e-11 m.

(ii) Only Tray & Battery Cover.

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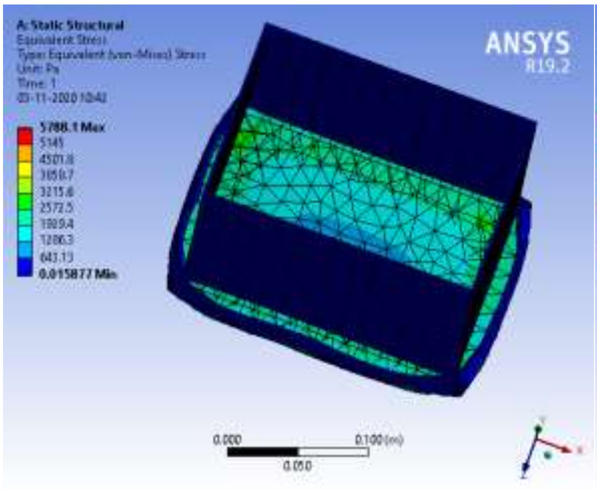
In this case the operation will perform on only tray and battery cover because we want to know how the force and other parameter will be applying on this both bodies.



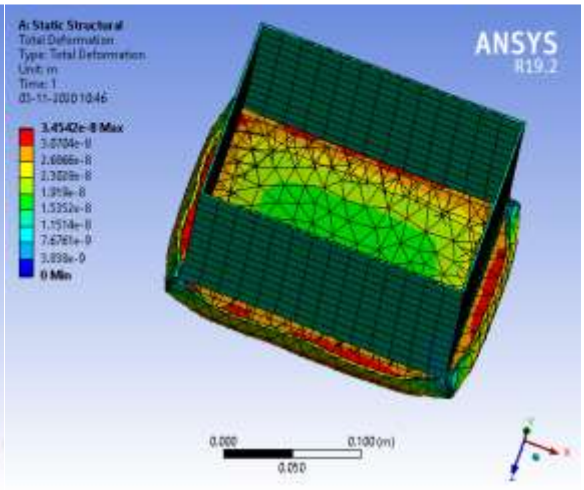


Fig. 10 :Equivalent Stress.Fig. 11 : Total Deformation.

In the above figure we can see a Maximum Stress is 5788.1 Pa and Total Deformation is 3.4542e-8 m.

3.2 When engine at ideal rpm.

In this condition the rpm of the engine will be 850rpm, frequency will be 14.167Hz, the gravity force will also apply on the battery carrying structure, the force will be 11kg-force or 107.87N.

In this condition analysis will not be done on a complete structure. It will be done in two parts like-

(i) Battery Carrying Structure without Tray & Battery Cover.

(ii) Only Tray & Battery Cover.

(i) Battery Carrying Structure without Tray & Battery Cover.

For this condition we perform a analysis part on the harmonic response criteria by this we get total deformation and maximum principal stress because this condition have a rpm, frequency and force parameter.

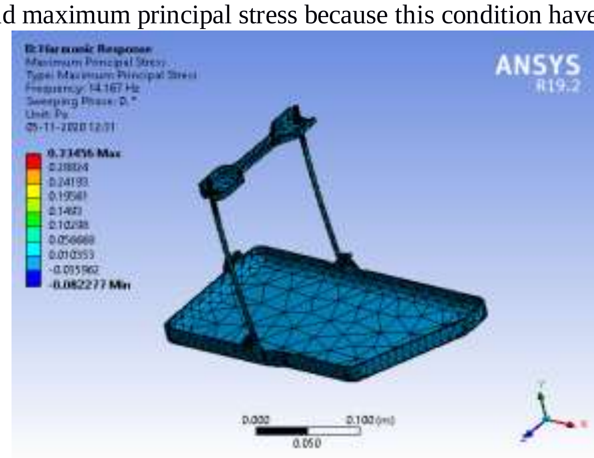


Fig. 12 :Maximum principal stress

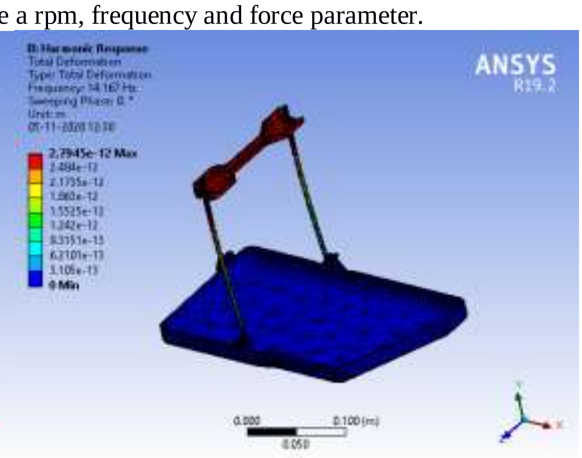


Fig. 13 : Total deformation

In the above figures we can see maximum principal stress is 0.33456Pa at maximum& total deformation is 2.7945e-12 m at maximum during harmonic response.

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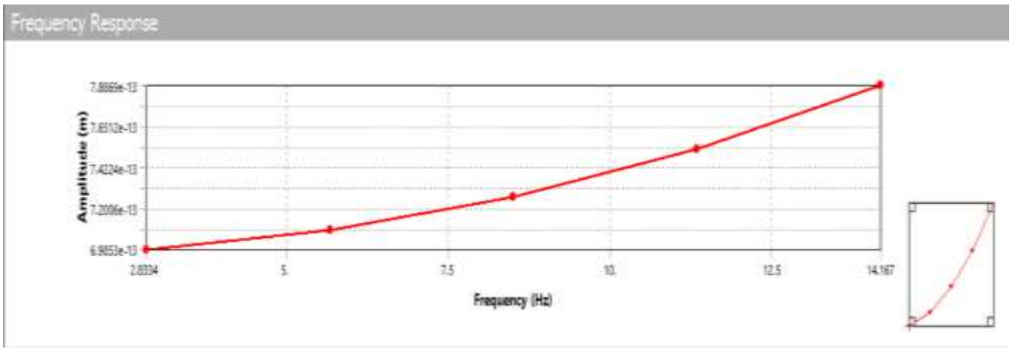
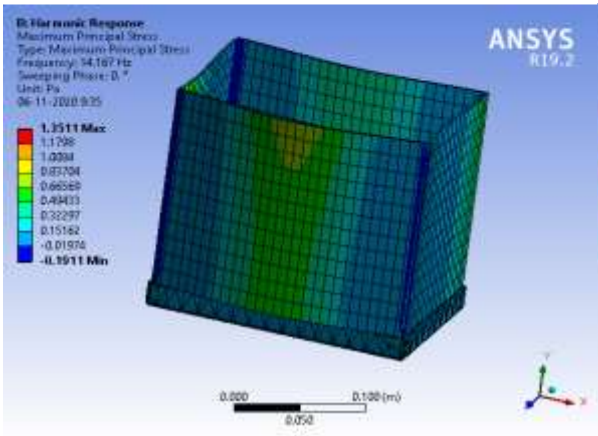


Fig. 14 : Frequency response between Amplitude v/s Frequency without tray and cover during ideal rpm.

(ii) Only Tray & Battery Cover.

In this case the operation will perform on only tray and battery cover, for this condition the engine rpm, frequency & force will be considered same as above condition.



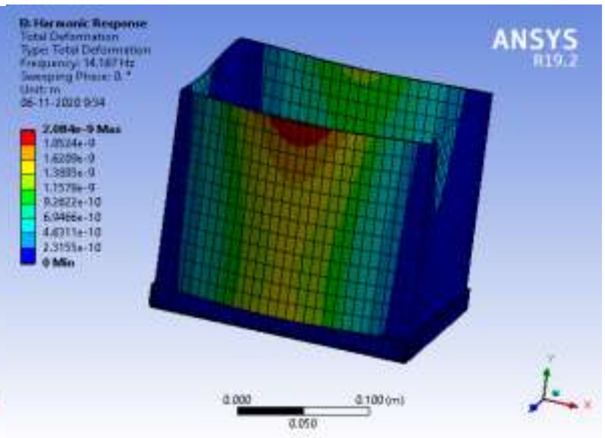


Fig. 15 : Maximum principal stress Fig. 16 : Total deformation

In the above figures we can see maximum principal stress is 1.3511Pa at maximum & total deformation is 2.084e-9 m at maximum during harmonic response.

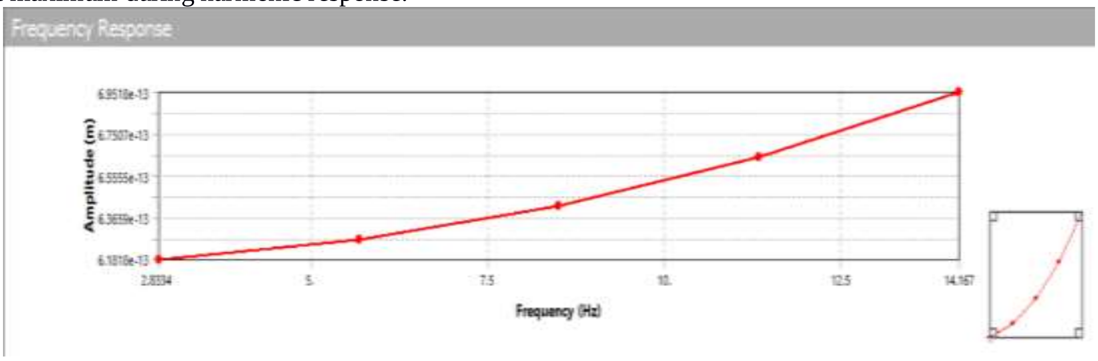


Fig. 17 : Frequency response between Amplitude v/s Frequency only with tray and cover during ideal rpm .

4.Dynamic Analysis

In this chapter we perform a dynamic analysis under dynamic loading condition, when vehicle speed is 80,100and 120km/h(plane surface, uneven surface and dip or bounce) and also defining vibration characteristics.

The following conditions are :-

4.1 Vehicle speed is 80,100 and 120km/h on plane surface.

4.2 Vehicle speed is 80,100 and 120km/h on uneven surface.

4.3 Vehicle speed is 80,100 and 120km/h on dip or bounce surface.

4.1 Vehicle speed is 80,100 and 120km/h on plane surface.

For dynamic analysis, in this condition we have only speed parameter by the calculation we get rpm and frequency datas. For data the following table are –

Speed(km/h)	RPM	Frequency(Hz)

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80km/h	1500	25Hz
100km/h	2000	33.333Hz
120km/h	2500	41.667Hz

Table 1 : For speed, rpm, and frequency on plane surface.

In this condition analysis will not be done on a complete structure. It will be done in two parts like-

(i) Battery Carrying Structure without Tray & Battery Cover.
(ii) Only Tray & Battery Cover.

(i) Battery Carrying Structure without Tray & Battery Cover.

For this condition we perform a analysis part on the harmonic response criteria by this we get total deformation and maximum principal stress because this condition have a speed, rpm, frequency parameter and it will be done on the plane surface during various speed have different frequency.

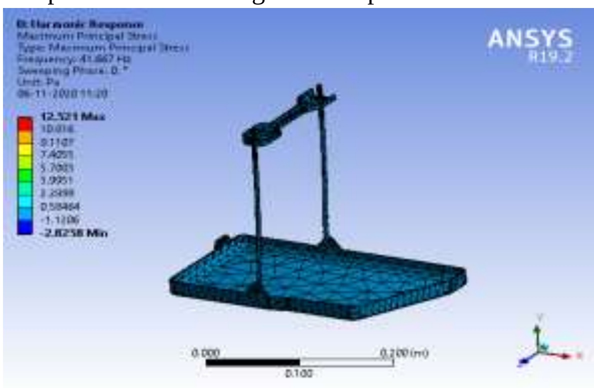

Fig. 18 : Maximum principal stress

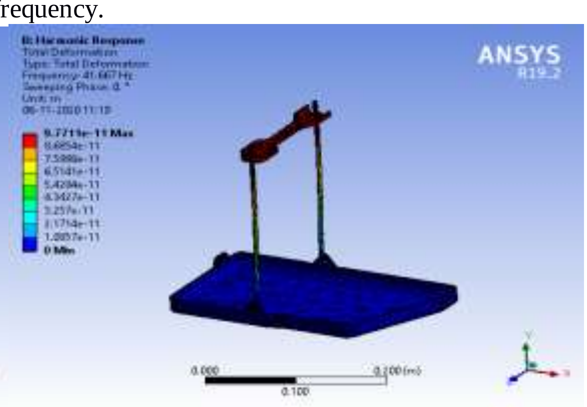

Fig. 19 : Total deformation

In the above figures we can see maximum principal stress is 12.521Pa & total deformation is 9.7711e-11 m at maximum frequency 41.667Hz during harmonic response.

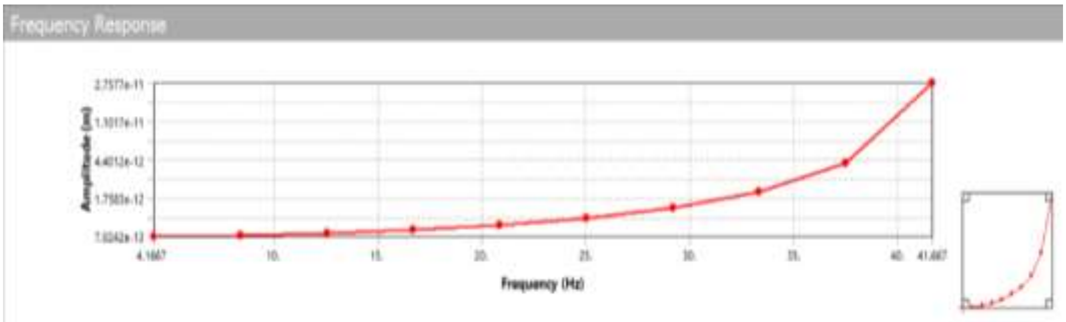

Fig. 20 : Frequency response between Amplitude v/s Frequency without tray and cover on plane surface.

Frequency(Hz)	Amplitude(m)
25Hz	1.1019e-012
33.334Hz	2.0218e-012
41.667Hz	2.7577e-011

Table 2 :Frequency, amplitude on plane surface

(ii) Only Tray & Battery Cover.

In this case the operation will perform on only tray and battery cover, for this condition the engine rpm, frequency & force will be considered same as above condition.

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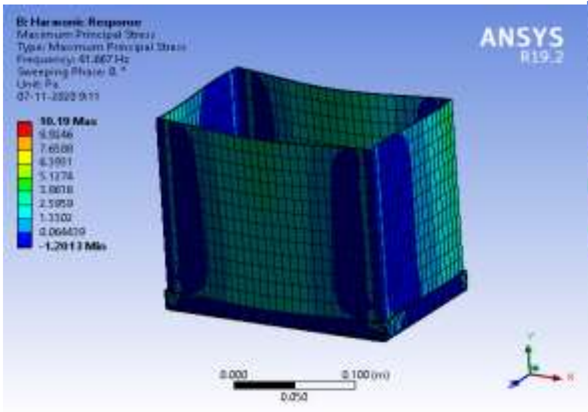

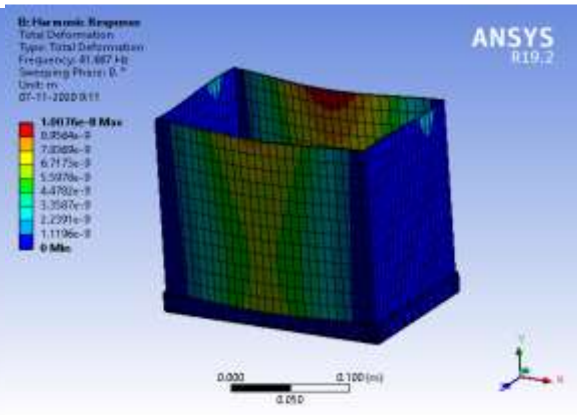

Fig. 21 : Maximum principal stress

Fig. 22 : Total deformation

In the above figures we can see maximum principal stress is 10.19Pa & total deformation is 1.0076e-8 m at maximum frequency 41.667Hz during harmonic response.

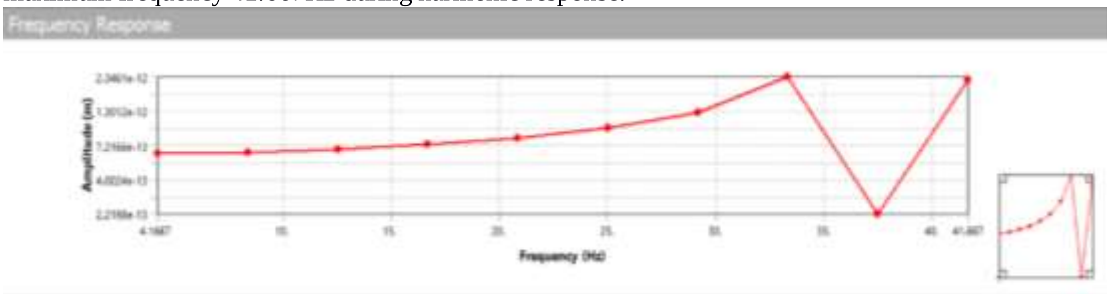

Fig. 23 : Frequency response between Amplitude v/s Frequency only with tray and cover on plane surface .

Frequency(Hz)	Amplitude(m)
25Hz	9.7373e-013
33.334Hz	2.3461e-012
41.667Hz	2.2223e-012

Table 3 :Frequency, amplitude on plane surface.

4.2Vehicle speed is 80,100 and 120km/h on uneven surface.

For dynamic analysis, in this condition we have only speed parameter by the calculation we get rpm and frequency datas. For data the following table are –

Speed(km/h)	RPM	Frequency(Hz)
80km/h	1500	45Hz
100km/h	2000	53.333Hz
120km/h	2500	61.667Hz

Table 4 : For speed, rpm, and frequency on uneven surface.

In this condition analysis will not be done on a complete structure. It will be done in two parts like-

(i) Battery Carrying Structure without Tray & Battery Cover.

(ii) Only Tray & Battery Cover.

(i) Battery Carrying Structure without Tray & Battery Cover.

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For this condition we perform a analysis part on the harmonic response criteria by this we get total deformation and maximum principal stress because this condition have a speed, rpm, frequency parameter and it will be done on the uneven surface during various speed have different frequency.

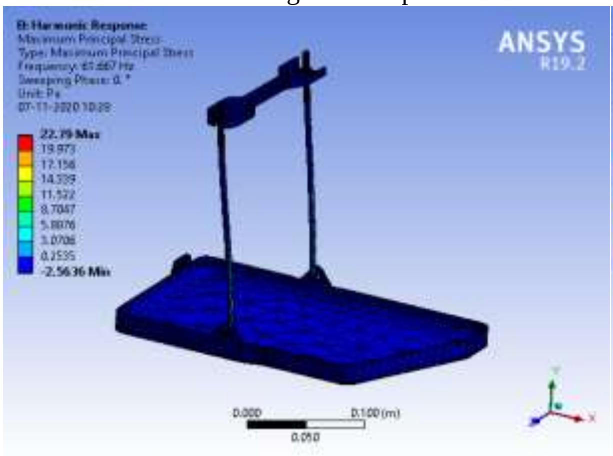

Fig. 24 : Maximum principal stress

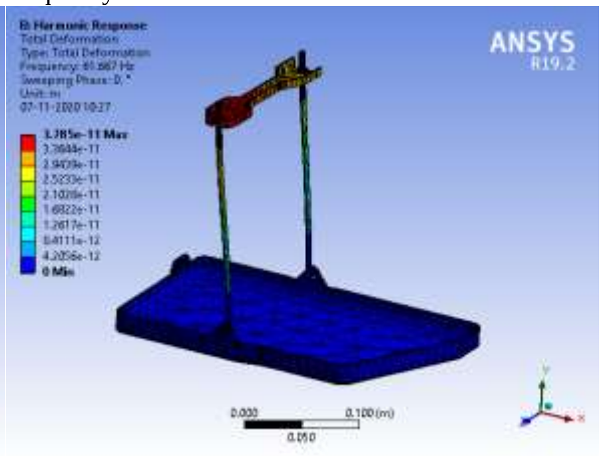

Fig. 25 : Total deformation

In the above figures we can see maximum principal stress is 22.79Pa & total deformation is 3.785e-11 m at maximum frequency 61.667Hz during harmonic response.

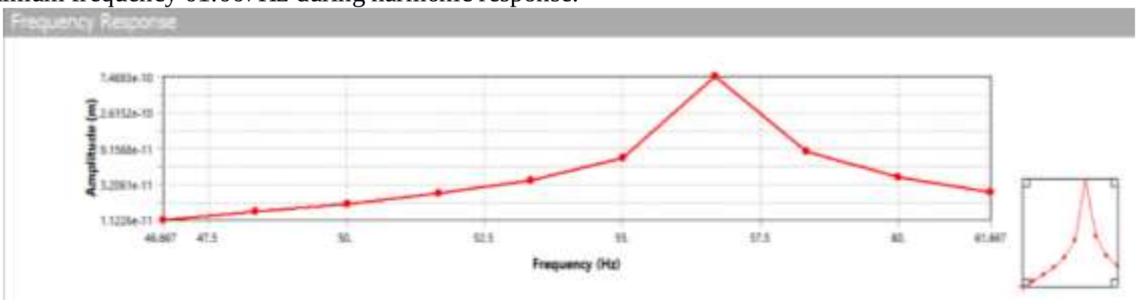

Fig. 26 : Frequency response between Amplitude v/s Frequency.

Frequency(Hz)	Amplitude(m)
45Hz	8.374e-012
53.334Hz	3.6235e-011
61.667Hz	2.5683e-011

Table 5 :Frequency, amplitude on uneven surface

(ii) Only Tray & Battery Cover.

In this case the operation will perform on only tray and battery cover, for this condition the engine rpm, frequency & force will be considered same as above condition.

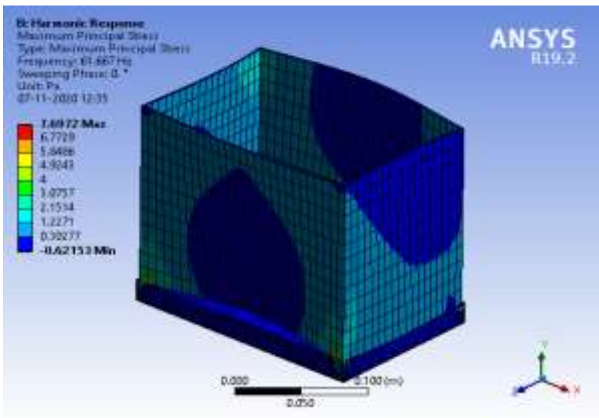

Fig. 27 : Maximum principal stress

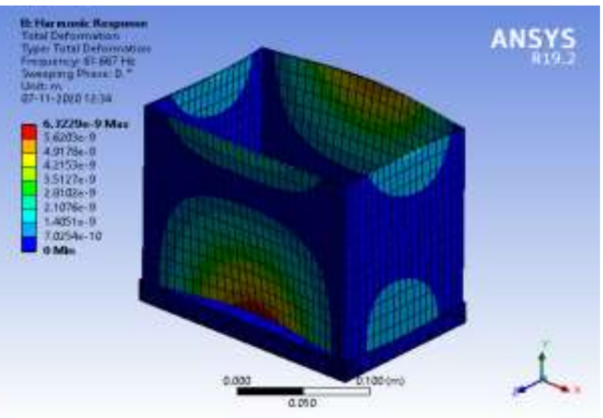

Fig. 28 : Total deformation

In the above figures we can see maximum principal stress is 7.6972Pa & total deformation is 6.3229e-9 m at maximum frequency 61.667Hz during harmonic response.

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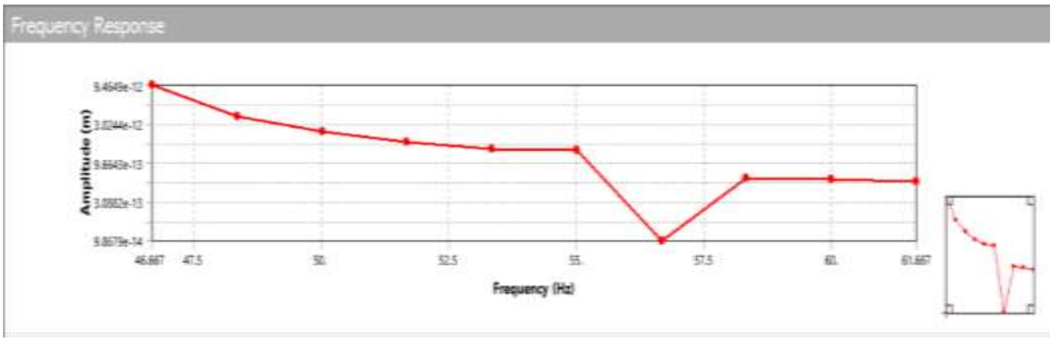


Fig. 29 : Frequency response between Amplitude v/s Frequency.

Frequency(Hz)	Amplitude(m)
45Hz	1.7125e-011
53.334Hz	1.4706e-012
61.667Hz	5.5409e-013

Table 6 :Frequency, amplitude on uneven surface

4.3 Vehicle speed is 80,100 and 120km/h on dip or bounce surface.

For dynamic analysis, in this condition we have only speed parameter by the calculation we get rpm and frequency datas. For data the following table are –

Speed(km/h)	RPM	Frequency(Hz)
80km/h	1500	65Hz
100km/h	2000	73.333Hz
120km/h	2500	81.667Hz

Table 7 : For speed, rpm, and frequency on dip or bounce surface.

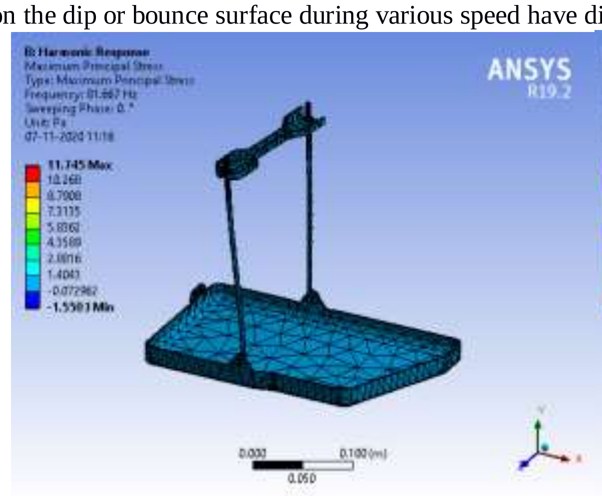
In this condition analysis will not be done on a complete structure. It will be done in two parts like-

(i) Battery Carrying Structure without Tray & Battery Cover.

(ii) Only Tray & Battery Cover.

(i) Battery Carrying Structure without Tray & Battery Cover.

For this condition we perform a analysis part on the harmonic response criteria by this we get total deformation and maximum principal stress because this condition have a speed, rpm, frequency parameter and it will be done on the dip or bounce surface during various speed have different frequency.



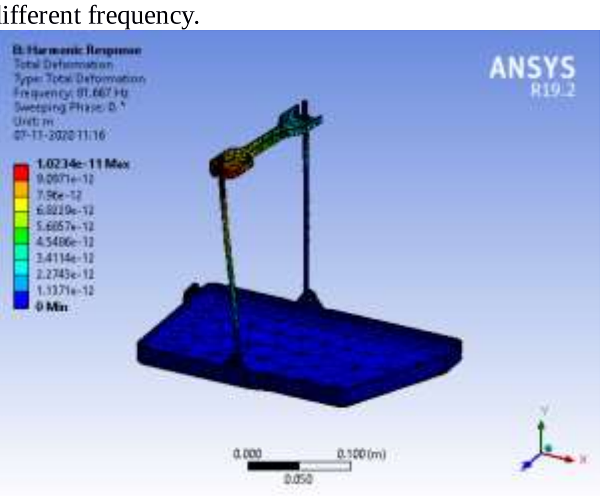


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Fig. 30 : Maximum principal stress   Fig. 31 : Total deformation

In the above figures we can see maximum principal stress is 11.745Pa & total deformation is 1.0234e-11 m at maximum frequency 81.667Hz during harmonic response.

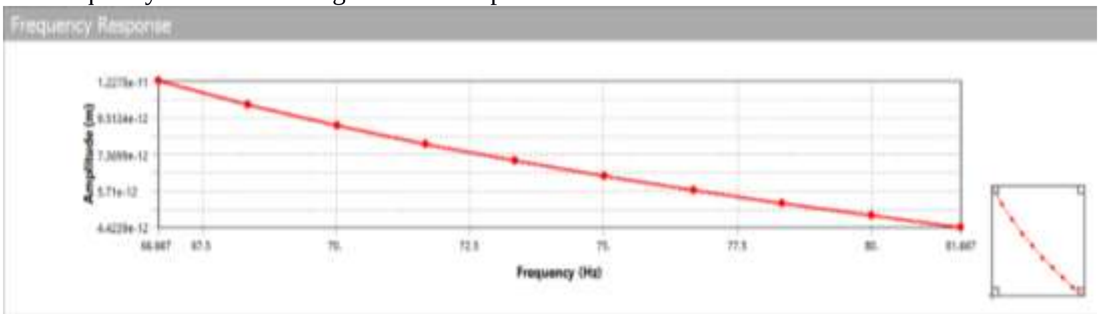


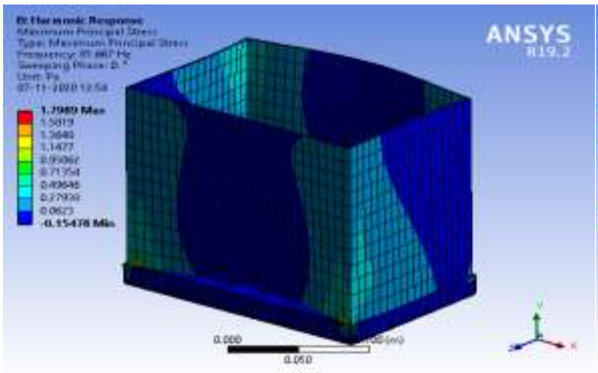
Fig. 32 : Frequency response between Amplitude v/s Frequency.

Frequency(Hz)	Amplitude(m)
65Hz	1.4928e-011
73.334Hz	7.0216e-012
81.667Hz	4.4239e-012

Table 8 :Frequency, amplitude on dip or bounce surface

(ii) Only Tray & Battery Cover.

In this case the operation will perform on only tray and battery cover, for this condition the engine rpm, frequency & force will be considered same as above condition.



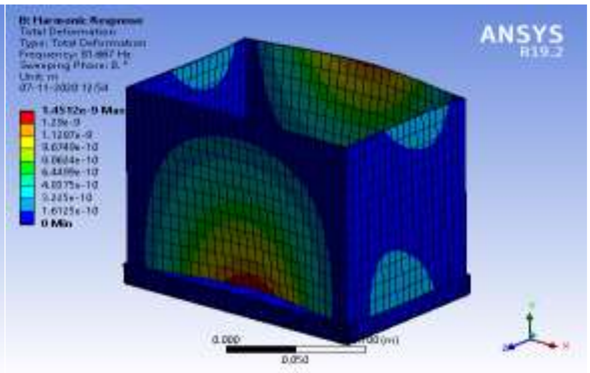


Fig. 33 : Maximum principal stress   Fig.34 : Total deformation

In the above figures we can see maximum principal stress is 1.7989Pa & total deformation is 1.4512e-9 m at maximum frequency 81.667Hz during harmonic response.

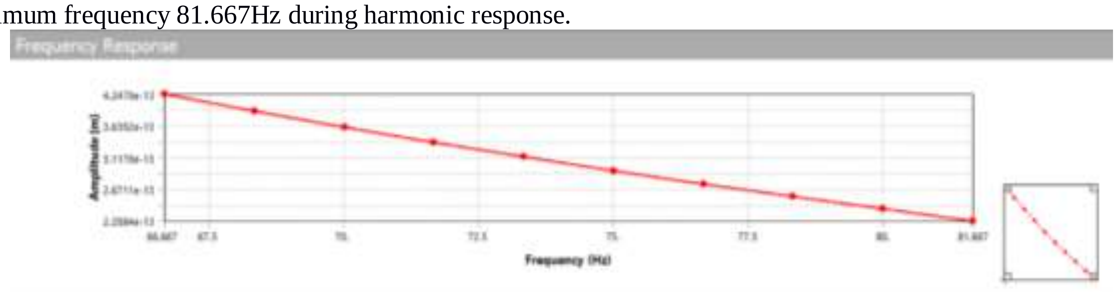


Fig. 35 : Frequency response between Amplitude v/s Frequency.

Frequency(Hz)	Amplitude(m)
65Hz	1.4928e-011
73.334Hz	7.0216e-012
81.667Hz	4.4239e-012

Table 9 :Frequency, amplitude on dip or bounce surface

5. Calculation

- To convert 11Kg-force into Newton.

11Kg is a weight of a Battery
11kg-force X 9.81 m/s^2= 107.87 N
(Note:- Considering acceleration due to gravity in the above equation)

- To convert RPM into Hz.

When a engine running at 60rpm
1minute = 60second
So, we say 60rpm = 1 Revolution Per Second (rps)
When, 1rps = 1Hz
Then , 60rpm = 1Hz

From the data, we get RPM value of engine on various speed and on different surfaces(like Plane, Uneven and dip or bounce).

Speed	Surface		
	Plane	Uneven	Dip or Bounce
80Km/h	1500Rpm	1500Rpm	1500Rpm
100Km/h	2000Rpm	2000Rpm	2000Rpm
120Km/h	2500Rpm	2500Rpm	2500Rpm

Table 5(A) : Speed and rpm of engine on different surface.
(NOTE :- when a engine running at specific speed on specific rpm then the rpm of the engine and wheels of vehicle rotates have same rpm. So, there is no different rpm on Plane, Uneven, dip or bounce surface.)

RPM	Frequency on different surface		
	Plane	Uneven	Dip or Bounce
1500rpm	25Hz	45Hz	65Hz
2000rpm	33.333Hz	53.333Hz	73.333Hz
2500rpm	41.667Hz	61.667Hz	81.667Hz

Table 5(B) : Frequency on different surface at specific rpm.
(Note :- In the above table rpm is same but frequency is different because of different surfaces.)

6. Conclusion

In this paper, we analysing static and dynamic parameter of the battery carrying structure. In the static and dynamic analysis, we defining stresses and deformation characteristics under extreme loading condition. By the analysis results the engineers have to improve its design and structure. And also by the harmonic response of vibration, the structure and design of the battery carrying structure will be improved. In the end of the result of the static and dynamic analysis of battery carrying structure we improve the battery stability on the structure and reduce the maintenance cost and increases the life of the battery.

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