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Design and Analysis of Electric Vehicle Battery Fixture

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Abstract – *This research paper focusses on design of electric vehicle battery vibration testing fixture which will capable of withstanding random vibration loads as per AIS 156 standards. The process involves selecting appropriate material and fixture configurations, creating CAD model and using Finite element analysis to find out natural frequencies and mode shapes. To validate the design, the fixture is tested experimentally using FFT analyzer. The experimental results are compared to the Finite Element results to conclude the fixture's suitability for testing four-wheeler env 200 battery pack.*

Key Words: E-Vehicle, Battery Vibration Testing, Fixture Design, Modal Analysis, Natural Frequency, FFT Analyzer

1. INTRODUCTION

The testing machines available for testing components in real life do have some limitations. They have a restricted area for mountings. These vibration components are unable to mount directly on the respective machine. So, we need to design such fixtures which can hold the component and can be mounted on the testing machine, so that the testing can be carried out to find out the best possible results. Moreover, the fixture should also be capable of sustain those vibrations without its own fatigue failure under repeated vibrational disturbance.

1.1 Objectives

1. Selection of appropriate material for the fixture.
2. Design a Fixture for Electric four-wheeler battery using Catia V5
3. FEA analysis of Fixture by using ANSYS Workbench 19.
4. Manufacturing the fixture
5. Experimental validation of battery fixture by using FFT Analyzer.

1.2 Material Selection

We have three options in materials. Magnesium has high tensile strength to weight ratio but it is not easy to machine and also costlier. steel and aluminum have similar strength-to-weight properties, it may be more cost-effective to select steel due to its lower cost. However, aluminum has a significantly lower density than steel, allowing for the creation of larger and stiffer features without adding weight. As a result, aluminum is a superior material for high-frequency vibration fixtures.

2. DESIGN OF FIXTURE

The 3D Model of fixture is drafted using CATIA V5 software. The dimensions of fixture chosen from the env200 mountings and shaker table hole to hole distance.

The dimensions are as follows:

1. Base plate hole radius= 5 mm
2. Base plate length= 1300 mm
3. Base plate breadth= 1400 mm
4. Base plate height= 5 mm
5. Overall width of fixture= 325 mm
6. Overall length of fixture= 400 mm
7. Square channel thickness= 2 mm
8. Square channel size= 25×25 mm
9. Highest support member height = 40 mm
10. Shortest support member height= 25 mm
11. Base plate hole centre to centre= 100 mm

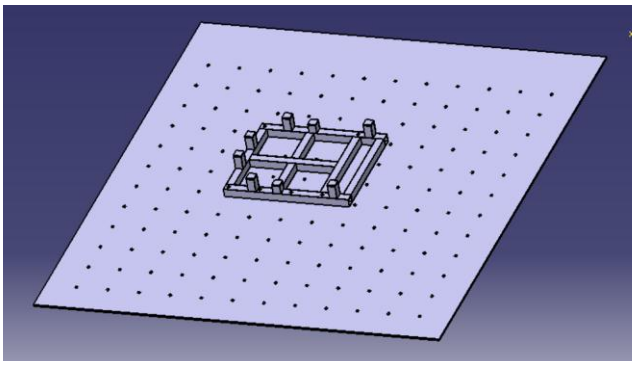


Fig. 1 Fixture and Base Plate Design Assembly

The env200 battery model:

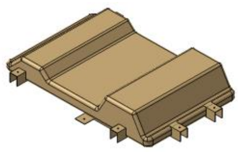


Fig. 2 Env200 Baterry Mockup

Primary member of fixture:

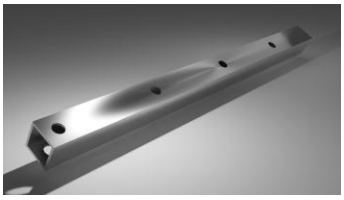


Fig. 3 Primary Member

Battery Mounting Support:

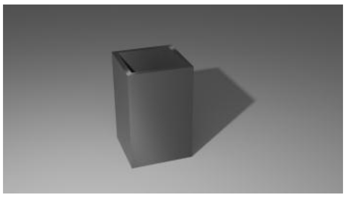


Fig. 4 Battery Mounting Support

Base Plate:

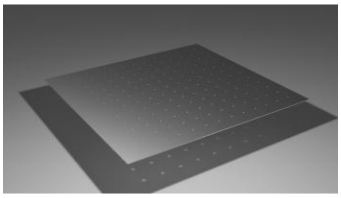


Fig. 5 Base Plate

Fixture Assembly:

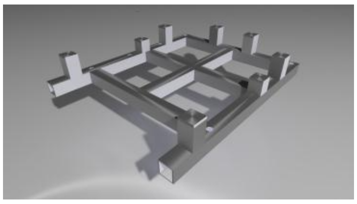


Fig. 6 Fixture Assembly

Battery Over Fixture:

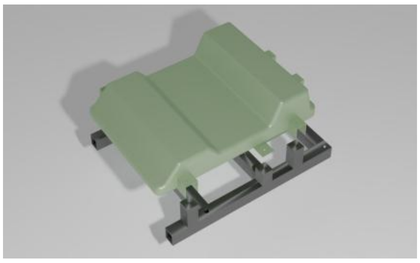


Fig. 7 Rendering of battery mounting over fixture

3. FINITE ELEMENT ANALYSIS

3.1 Modal Analysis

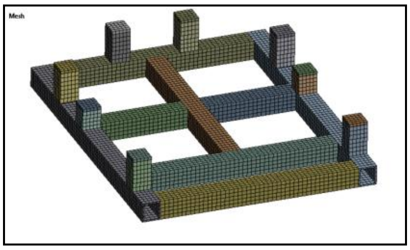
Modal analysis is performed to find out the natural frequency and mode shapes. The desired fixture should have natural frequency of first mode beyond the operational testing frequency range. Modal analysis is carried out using Ansys workbench.

The material properties used as follows:

Table 1: Material Properties of Structural stel

Property	Value
Young's Modulus	210 GPa
Poisson's Ratio	0.3
Density	7850 kg/m^3

Meshing in Ansys:



Statistics	
Nodes	56741
Elements	9123

Fig. 8 Meshing in Ansys

Boundary conditions in Ansys:

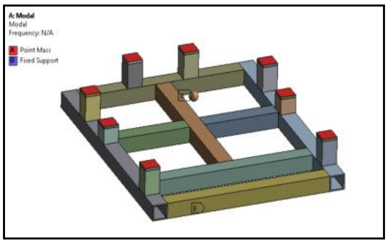


Fig. 9 Boundary Conditions

Results: Total deformation results of respective mode shapes

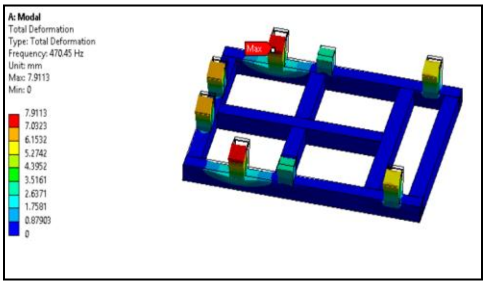


Fig. 10 Mode Shape 1

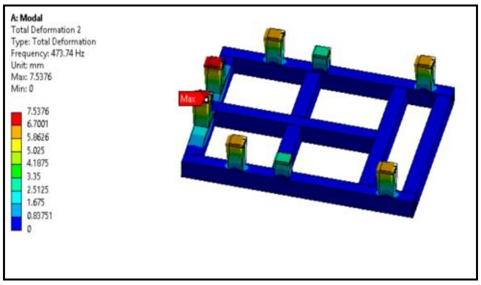


Fig. 11 Mode Shape 2

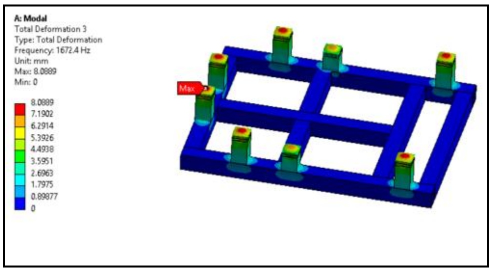


Fig. 12 Mode Shape 3

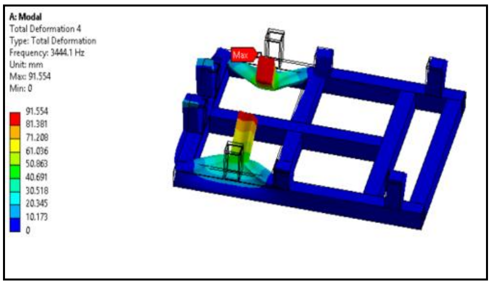


Fig. 13 Mode Shape 4

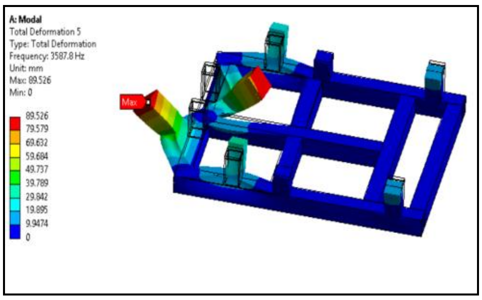


Fig. 14 Mode Shape 5

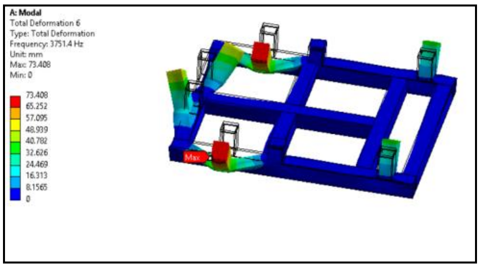


Fig. 15 Mode Shape 6

Natural Frequency obtained are as follows:

Tabular Data

	Mode	Frequency [Hz]
1	1.	470.45
2	2.	473.74
3	3.	1672.4
4	4.	3444.1
5	5.	3587.8
6	6.	3751.4

Fig. 16 Natural Frequency Results

Natural frequencies obtained from modal analysis lying beyond 200 Hz which is maximum operating range. the first mode shape obtained as 470.45 Hz which is way beyond 200 Hz.

3.2 Harmonic Response

Harmonic response in X-axis are as follows:

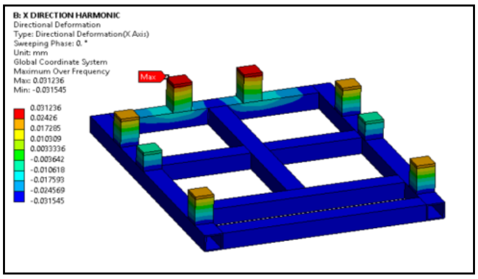


Fig. 17 Directional Deformation(X-Axis)

Harmonic response in Y- axis are as follows:

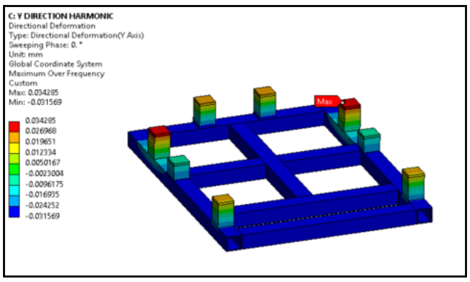


Fig. 18 Directional Deformation(Y-Axis)

Harmonic response in Z- axis are as follows:

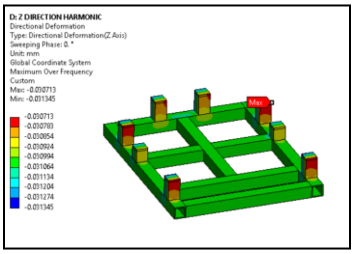


Fig. 19 Directional Deformation(Z-Axis)

3.3 Experimental FEA

Total deformation results of respective mode shapes are as follows:

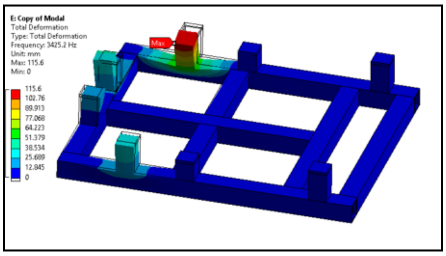


Fig. 20 Mode Shape 1

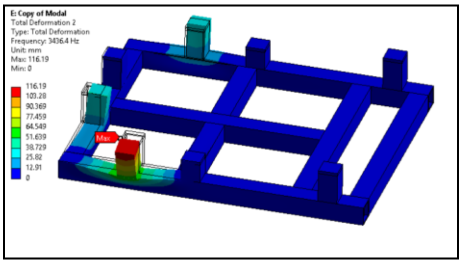


Fig. 21 Mode Shape 2

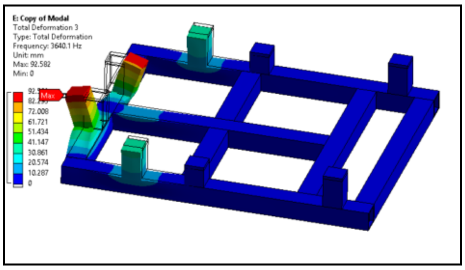


Fig. 22 Mode Shape 3

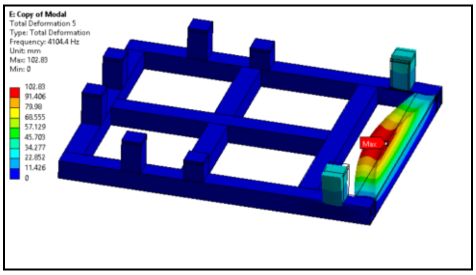


Fig. 23 Mode Shape 4

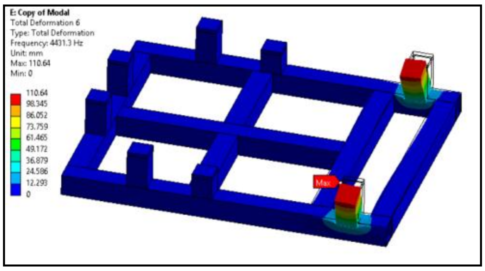


Fig. 24 Mode Shape 5

Results obtained from experimental FEA are as follows:

Tabular Data

	Mode	Frequency [Hz]
1	1.	3425.2
2	2.	3436.4
3	3.	3640.1
4	4.	3675.6
5	5.	4104.4
6	6.	4431.3

Fig. 25 Results

4. EXPERIMENTAL TESTING

The experimental validation is done by using FFT (Fast Fourier Transform) analyzer

4.1 Impact Hammer Test

Impact Excitation method is commonly uused for experimental modal testing. Hammer impacts are widely recognized for their ability to generate a broad and diverse excitation signal, making them highly suitable for modal testing purposes. With minimal equipment and setup requirements, this method offers convenience and flexibility. Its versatility and mobility enable efficient testing in various settings, while consistently delivering dependable results.

Although it has limitations with respect to precise positioning and force level control, overall its advantages greatly outweigh its disadvantages making it extremely attractive and effective for many modal testing situations.

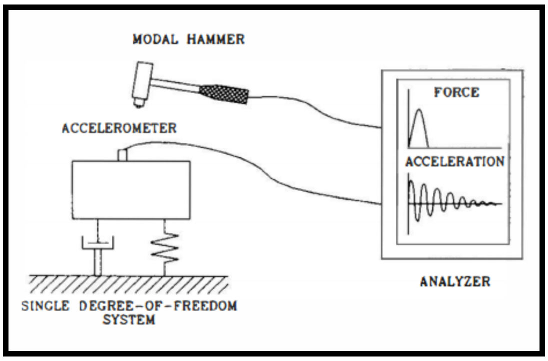


Fig. 26 FFT Construction

4.2 Experimental Procedure

1. Initially fixture is designed according to existing boundary condition as per FEA results.

2. FFT consists of impact hammer, accelerometer, data acquisition system in which each supply is applied to DAS and laptop with DEWSOFT software to view FFT plot.

3. Accelerometer is mounted at edge as per high deformation observed in FEA results along with initial impact of hammer are placed for certain excitation to determine frequency of respective mode shapes.

4. After impact FFT plot are observed on laptop and comparison of FEA and experimental results are analyzed.

Fig. 27 Experimental Setup

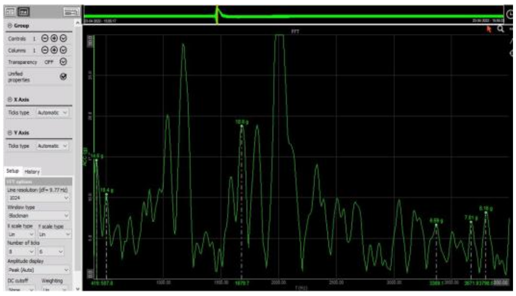


Fig. 28 FFT Plot

4.3 Comparison of Numerical and Experimental Results

Table 2 Comparison of numerical and experimental results

Mode Shapes	FEA(Hz)	Experimental (Hz)
1	3425.2	3369.1
2	3436.4	3369.1
3	3640.1	3671.9
4	3675.6	3798.8

5. CONCLUSIONS

The fixture design is most important part in industry due to checking of component in real world condition. In this project study on the design parameter required to design the automobile component holding vibration fixtures develop the literature survey on the design parameter of the vibration fixture. The fixture needs to sustain all types of loading condition. Perform the modal analysis on the fixture to find out the natural frequency of the battery holding fixture. The fundamental frequency of 4-wheeler battery fixture at loading condition observed is 470.45 Hz. Experimental testing done by FFT and compared Numerical results with experimental results.

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