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Simulation of Routine Road Load Condition of Transportation Container to Assess Tie-down Arrangement

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ABSTRACT

Road transport plays an important role in routine transportation. The present research paper describes the tie down methodology for heavy container for safe transportation conditions. The methodology adopted comprises of applying known acceleration inputs to the given container and correlating the response on virtual simulation model. Hybrid approach is used for development of proposed transportation methodology. It consists of acceleration measurement in lateral, longitudinal and vertical directions on the transportation container in typical Indian road conditions. Finite element analysis (FEA) is used for determination of natural frequency and acceleration factors for assessing tie down methodology. As a first step for development of methodology, experimentally measured natural frequencies using modal testing approach are compared with frequencies obtained from FEA simulation.

The multi-axis simulation table (MAST) is used for determination of acceleration factors through testing, using low frequency excitation signals which are generally associated with transport vehicles. The obtained results were compared with FEA simulation results in order to develop methodology for prediction of acceleration factors on transportation container. The developed methodology is successfully validated on transportation container and obtained results were found to be reasonable.

Keywords - Acceleration Factors, Tie-down arrangement, MAST, Natural Frequency, Transportation Methodology, Validation.

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I. INTRODUCTION

Road transport plays an important role in routine transportation. Transport of goods with proper transportation methodology is much needed which is safe in all manners. When a package is shipped from one location to another, the package is subjected to regulations governing its structural integrity and shielding capability. One section of these regulations covers performance standards for tie-down systems used to secure the package to the transporting vehicle. If there is a system of tie-down devices that is a structural part of the package, the regulations require that the system be capable of withstanding a static force applied to the center of gravity of the package that has a vertical component of two times the weight of the package and its contents, a horizontal component along the direction of travel of ten times the weight of the package and its contents, and a horizontal component in the transverse direction of five times the weight of the package *[6]*and its contents without generating stress in any material of the package in excess of the yield strength of that material.

The differences in transport infrastructures and practices throughout the world, the national competent authorities and the national and international transport modal standards and regulations need to be consulted to confirm the mandatory or recommended package acceleration factors, together with any special conditions for transport, which should be used in the design of the packages and their retention systems. These acceleration factors represent the package inertial effects, and are simultaneously applied at the package mass centre either as equivalent quasi-static forces or as a force pulse waveform with a period of up to 1 s and peak

amplitude at the given acceleration factor*[11]*,against which the package retention system should be designed. Acceleration factors will need to be applied in the design and analysis of packages and their retention systems.

Table I: Acceleration Factors for various modes of transport *[11]*

Sr. No	Mode	Acceleration Factor		
		Longitudinal	Lateral	Vertical
1	Road	2g	1g	2gUp, 3g Down
2	Rail	5g	2g	2gUp, 2g Down
3	Sea/Water	2g	2g	2gUp, 3g Down
4	Air	1.5g	1.5g	2gUp, 6g Down

The basic objective behind this work is to develop tie down methodology for scaled down transportation container for safe transportation conditions

II. METHODOLOGY

a The following wok process is devised to meet the objective of developing tie down methodology for containers. Known acceleration inputs are given to container and simulated results are validated with experimental correlation using shaker table test. The experimented results are obtained from MAST (multi-axis simulation table) based on low frequency signals which are generally associated with transport vehicles.The presented work was carried out in following stages,

- Determination of natural frequency and corresponding mode shapes using simulation using FE software.
- Determine natural frequency and corresponding mode shapes using experimental modal testing method in order to validate the build model.
- Component was tested on multi axis shaker table with known low frequency input signals in order to measure the acceleration factors in predefined locations.
- Transient modal analysis was carried out on validated FEA model in order to correlate the results and develop the transportation methodology.

For pre-processing and post-processing HyperWorks tool was used and for FEA calculation NASTRAN solver was used.

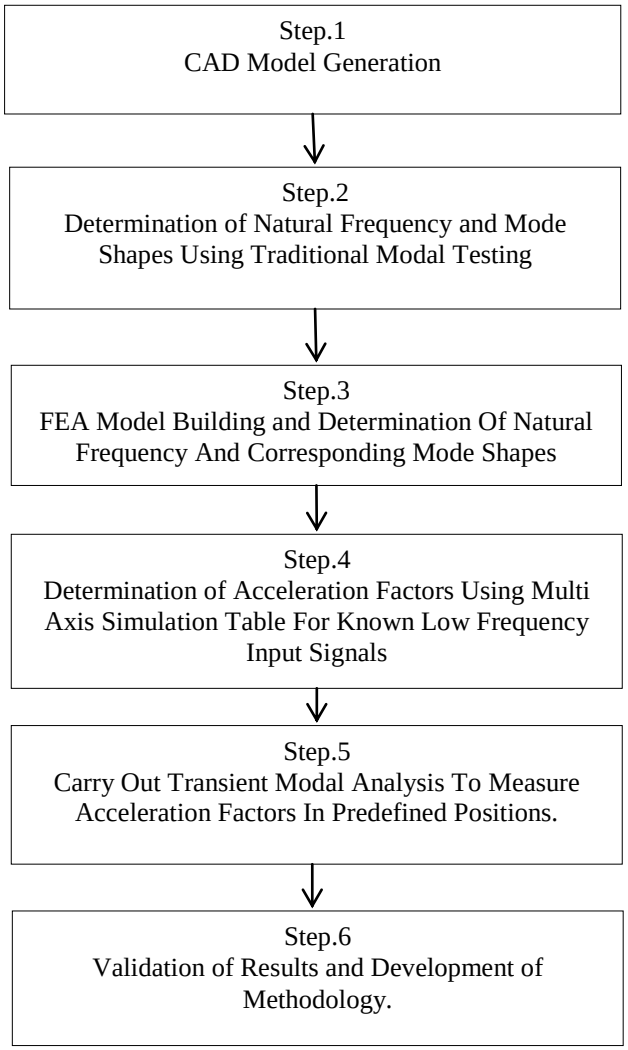


Fig. 1: Methodology Flowchart

III.EXPERIMENTAL DETAILS

1.1 Component Details

The container used for transportation is made of mainly 3 materials: IS2062B, SS304L, Lead. The reason behind selection of these materials is IS2062 grade material contains carbon and manganese which acts as strengthening elements which governs the minimum ultimate tensile strength from about 410 to 440MPa and minimum Yield strength from about 230 to 300 MPa. Also it has got high thermal conductivity.

The reason behind use SS304L material is the minimum ultimate tensile strength 480MPa and minimum Yield strength 170 MPa. The main advantage is that it is readily available in wide range, also it has got has good corrosive resistance.

The lead is soft, dense and ductile in nature and is known to be malleable and corrosion resistant. The reason behind usage of lead is that it acts as a shield for exposed radiations.

Fig. 2: Actual Component

1.2 Experimental Setup

1.2.1 *Determination of natural frequency and associated mode shapes*:

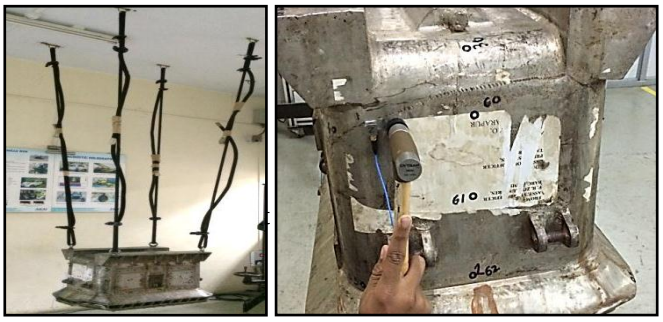
For determining natural frequency traditional modal testing approach is used. Experimental modal analysis is the process of determining the modal parameters (natural frequencies, damping factors, modal vectors, and modal scaling) of a linear, time invariant systems *[8]*. Modal data presentation/validation is the process of providing a physical view or interpretation of the modal parameters. For example, this may simply be the numerical tabulation of the frequency, damping, and modal vectors along with the associated geometry of the measured degrees-of-freedom. Assumptions made in modal testing are

- Structure is assumed to be Linear
- Structure is Time Invariant
- Structure should obeys Maxwell's Reciprocity
- Structure is Observable.

To evaluate the natural frequency and corresponding mode shapes the multiple input and multiple output (MIMO) is used,since the data are collected in the shortest possible time with the fewest changes in the test conditions*[8]*.The mainadvantage of multiple input frequency response function estimations is the increase in the accuracy of estimates of the frequency response functions along with reduction in test time.

Modal parameter estimation involves estimating the modal parameters of a structural system from measured input-output data. Most modal parameter estimation is based upon the measured data being the frequency response function or the equivalent impulse-response function, typically found by inverse Fourier transforming the frequency response function. Therefore, the form of the model used to represent the experimental data is normally stated in a mathematical frequency response function (FRF) model usingtime temporal and spatial information*[8]*.Every frequency response or impulse-response function measurement theoretically contains the information that is represented by the characteristic equation, the modal frequencies, and damping.

Considering this the container was divided into adequate number of points with appropriate spatial distribution. The total no. of points considered for container was 78 and total DOF's were 234.The container was excited using an Impact hammer as shown in figure.



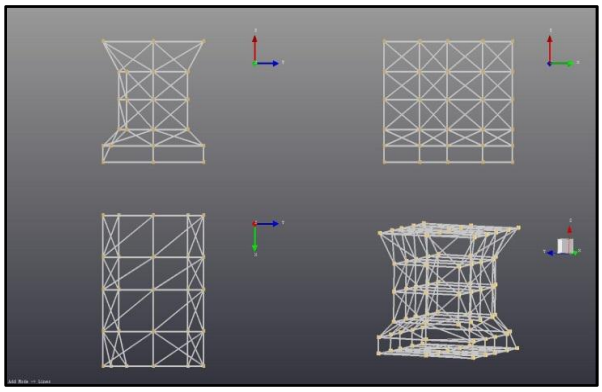


Fig. 4: Test Geometry

As a part of Model validation, similar type of experimental modal testing was carried out for container without lid in order to determine natural frequency and corresponding mode shapes using 8 no. of points. As the component was open the Frequency response function was measured by giving impact inside as well as outside the container.

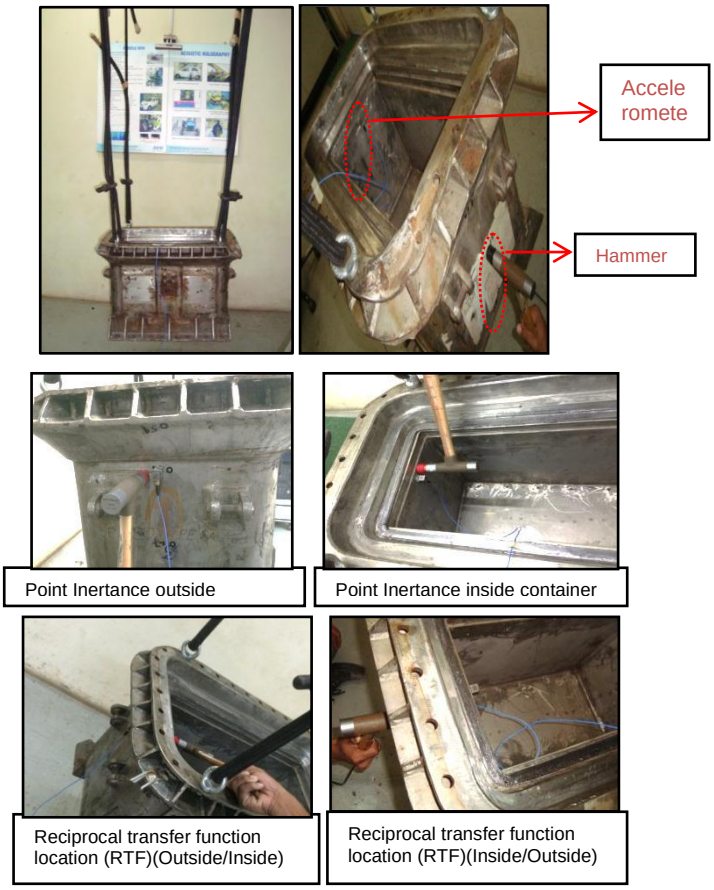


Fig. 5: Test setup for component without Lid

1.2.2 Testing of component of Multi axis simulation table:

A multi axis simulation table (MAST) is a test rig used for high frequency testing of vehicle component. It can simulate the acceleration and displacement outputs and reproduce key data collected on proving grounds, by providing a full six degree of freedom*[14]*. The test systems consist of hexapod platform with a low resonance table on top which can be used to simulate any kind of vibration in all six degrees of freedom. The movements of the test system are tightly controlled by a digital test controller. A low frequency hydraulic simulation table is used having payload capacity of 1000kg and it can easily reach from 0.1Hz to 50 Hz.

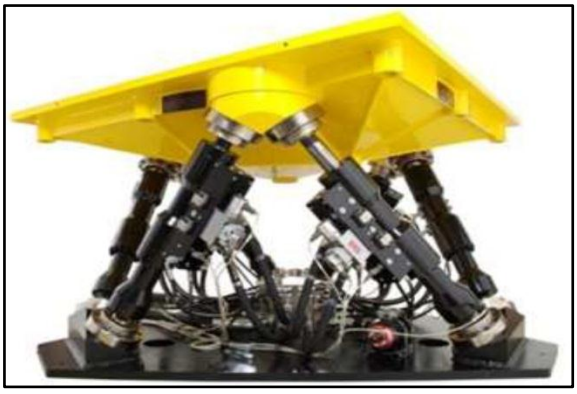


Fig. 6: Test Geometry

The collect the response data based on simulated input acceleration a 16 channel data acquisition system is used*[5]*. The data acquisition system was having TEDS (Transducer Electronic Data Sheet) compatibility by which sensor data gets detected automaticallyand was operated through PC loaded with dedicated software for acquisition, pre and post processing of data.

Fig. 7: 16 Channel data acquisition system

The adopted test methodology was consisting of following considerations,

1. The container was instrumented with 3 Tri-axial accelerometers, 4 Uni-axial accelerometer and 1 Rosette strain gauge.
2. The container was bolted to the Multi Axis Shaker Table (MAST) through steel plate which will act as vehicle platform.
3. Following input signals were given to the container through MAST system
   a. Sine sweep of 0.1 to 5 Hz with constant displacement of 10mm &and sine sweep of 5 to 100 Hz with constant 1.2 g
   b. Signal with Constant frequency of 5Hz, 10Hz, 20Hz, 30Hz and 40Hz with constant amplitude of 1.5 g.
   c. Random white noise signal i.e. Signal with Flat Power spectral density containing equal power within fixed bandwidth at any center frequency was applied for 0.5 to 100 Hz.

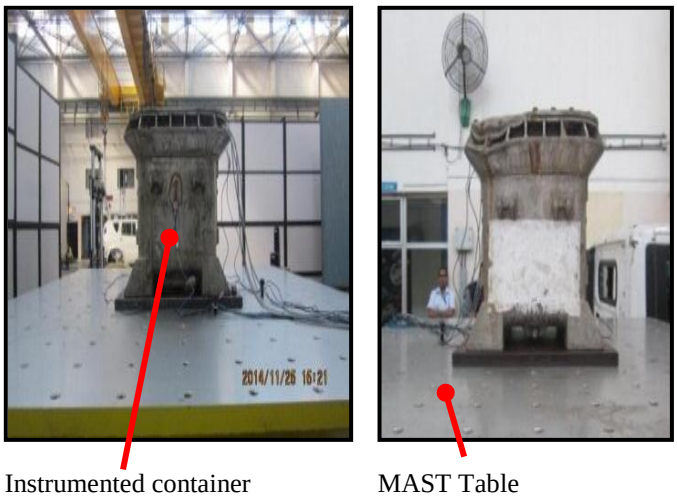


Fig. 8: Test Setup for Container on MAST.

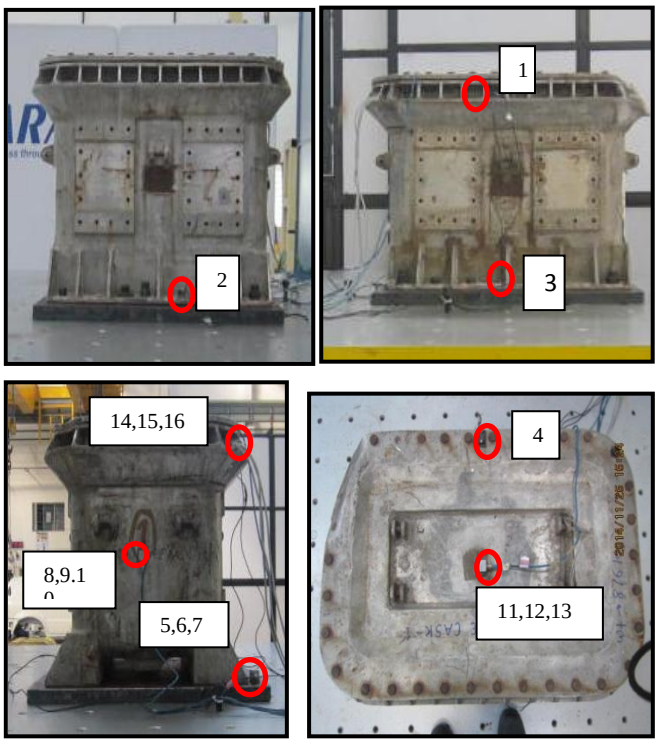


Fig. 9: 16 Instrumentation Layout on MAST System

The numbers represent the Channel numbers in the data file. They are as follows:

- 1 – Accelerometer Front (Z Direction)
- 2 – Accelerometer Rear (Z Direction)
- 3 – Accelerometer Left (Z Direction)
- 4 – Accelerometer Right (Z Direction)
- 5, 6,7 – Bottom Accelerometer (X,Y,Z Direction)
- 8,9,10 – Side Accelerometer (X, Y, Z Direction)
- 11, 12,13 – Top Accelerometer(X, Y, Z Direction)
- 14,15,16 – Strain gauge Rosette

IV. FINITE ELEMENT ANALYSIS

The FE analysis was carried out for determine the natural frequency and corresponding mode shapes of the component. Also it is used for predicting the behaviour of the system when excited through known low frequency input signals.

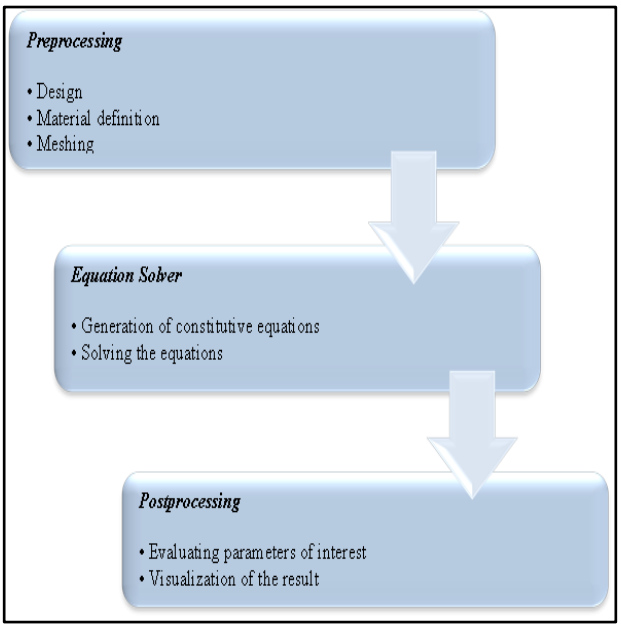


Fig. 10: Flow process involved in FEM

1.3 Selection of Material Properties.

Table II: - Selection of Material Properties

Sr. No.	Material	Modulus of Elasticity	Density	Poisson's Ratio
1	IS2062 B	2.0e+5	7.8e-9	0.3
2	SS304 L	2.1e+5	8e-9	0.28
3	Lead	1.7e+4	1.137e-8	0.4

4.2 Contact between two metals

In order to carry out any simulation along with selection of material properties, defining contacts between to mating parts is also very important. As the component is having combination of metals and non-metals, so it becomes non homogeneous*[7]*. Hence to define friction contact between metal and non-metal lead and steel, spring elements having stiffness 750N/mm were used all over.

4.3 Meshing details

The component having combination of shell and solid elements, all the solid elements was meshed with second order tetrahedral structural element and all shell element were meshed with second order C-Tria and C-Quad elements. The details of total no. of nodes, total no. of elements and degrees of freedom are mentioned in table III.

Table III: - FEA Parameters

Sr. No.	Parameter	Value
1	Total no. of nodes	1112249
2	Total no. of elements	749339
3	Degrees of freedom	

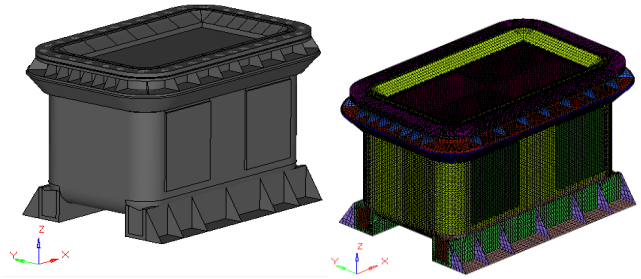


Fig11: FEA Model

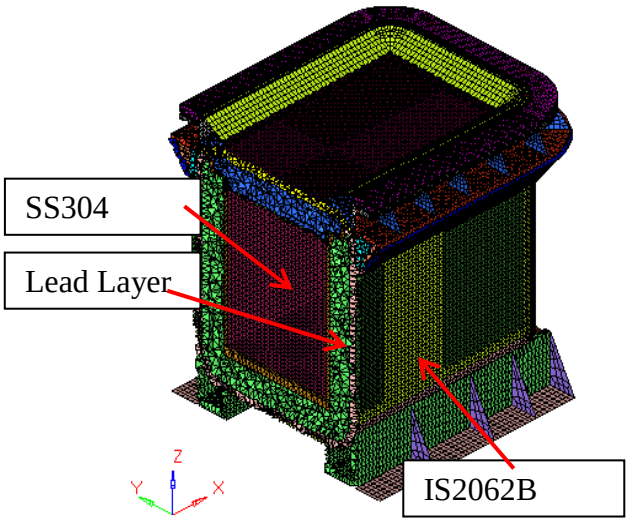


Fig 12: Meshed Model

V. RESULT & DISCUSSION

The experimental results and FEA simulation results for determination of natural frequency and corresponding mode shapes was found to be reasonable. The observed deviation was due to assumption of material to be isotropic and homogeneous. Although the component was previously used for drop test simulation so the possibility of lead sump need to be considered. Considering all this factors the observed results found to reasonable.

Table IV: % Deviation in frequency for Complete Model

Sr. No.	Natural Frequency		% Deviation
	Experimentation	FEA Simulation	
1	375.5	374.4	0.29%
2	452.2	443.6	1.9%
3	552.1	552.73	0.11%
4	613.2	636.78	3.84%

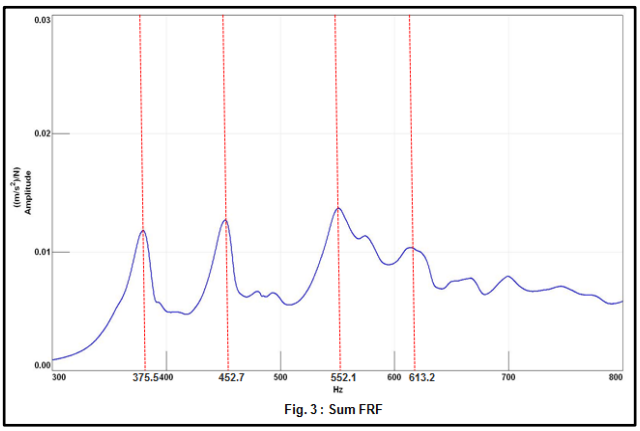


Fig13: Experimental Frequency Chart for complete model

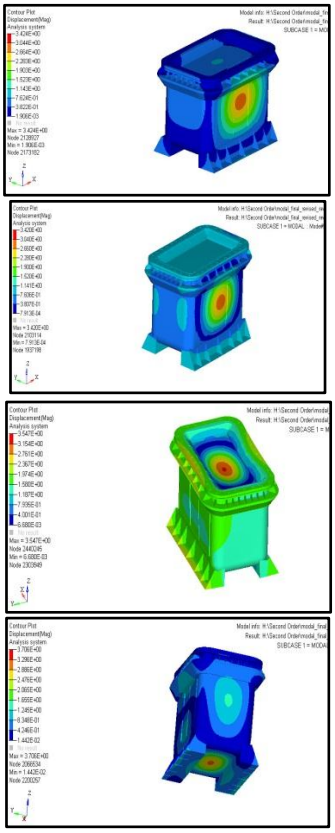


Fig 14: Observed Mode Shapes From Simulation

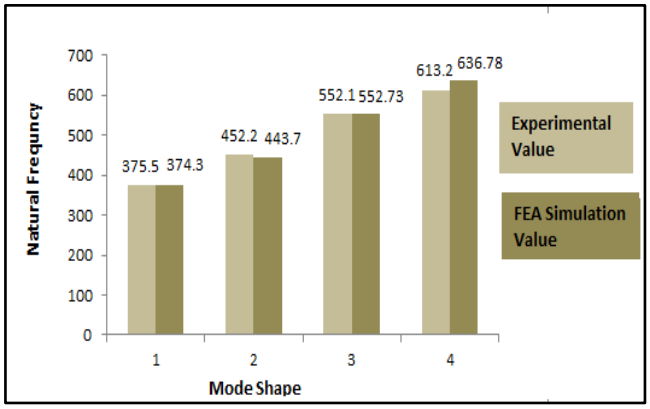


Fig15: Comparison between Natural Frequencies.

In order to validate the model, the experimental modal analysis was carried out to determine the natural frequency and mode shapes of the component without lid. The observed results to be reasonable and corresponding mode shapes observed in FEA simulation were almost similar to that of observed experimental mode shapes.

Table V: % Deviation in frequency for component without lid

Sr. No.	Natural Frequency		% Deviation
	Experimentation	FEA Simulation	
1	207.2	199.58	3.67%
2	345.1	316.72	8.22%
3	438.6	438.26	0.07%
4	482.8	478.54	0.8%

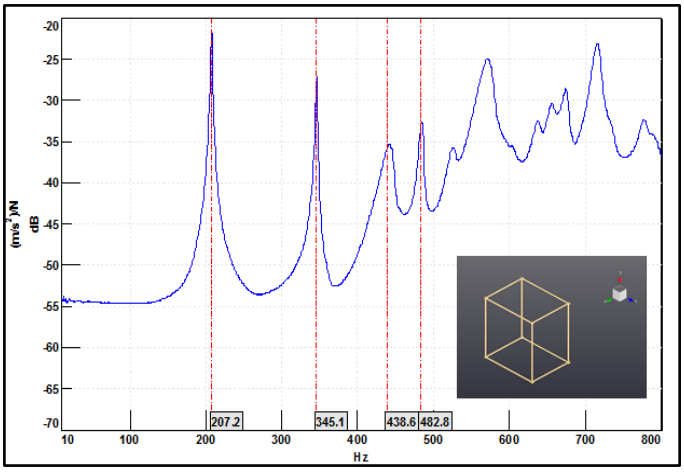


Fig 16: Experimental Frequency Chart

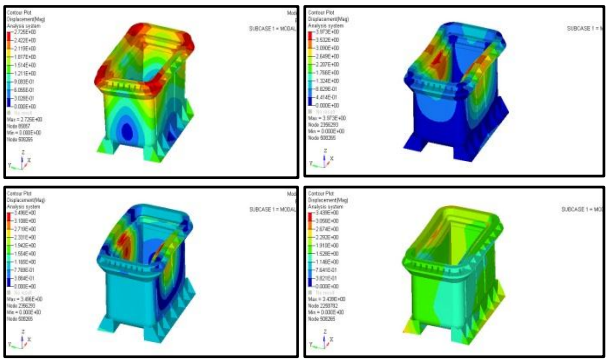


Fig17: Observed Mode Shapes from Simulation for component without lid

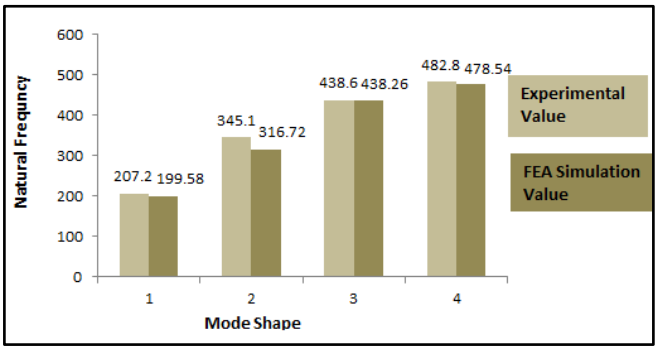


Fig 18: Comparison between Natural Frequencies for component without lid.

VI.CONCLUSION

The tested natural frequencies and acceleration factors were in reasonable deviation as compared to observed Natural frequencies and acceleration factors determined using FEA for predefined locations. So, based on the observed results

the transportation methodology is successfully developed and can be implemented for any other component.

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