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Determination of Natural Frequency of Transportation Container by Experimental Modal Analysis

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Abstract: *Road transport plays an important role in routine transportation. In the present research paper describes the natural frequency correlation for heavy container for safe transportation conditions. Finite element analysis (FEA) is used for determination of natural frequency for assessing tie down methodology. As a first step for development of methodology, frequencies obtained from FEA simulation are compared with experimentally measured natural frequencies using modal testing approach. The experimental modal analysis was carried out by roving hammer technique. Also, the observed mode shapes in FEA simulation was compared with experimentally obtained mode shapes to predict the behaviour of transportation container.*
Keywords: *Transportation Container,Natural Frequency, Modal Testing, Transportation Methodology.*

I. Introduction

Road transport plays an important role in routine transportation. To transport 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 packageand its contents without generating stress in any material of the package in excess of the yield strength of that material.

II. Methodology

The following wok process is devised to meet the objective of developing tie down methodology for container. 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.

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

III. Experimental Details

3.1 Component Details

The container used for transportation of harmful material is made of mainly 3 materials: IS2062B, SS304L, and 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.1: Actual component

3.2 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. 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 condition. The main advantage 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 using time temporal and spatial information. 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.

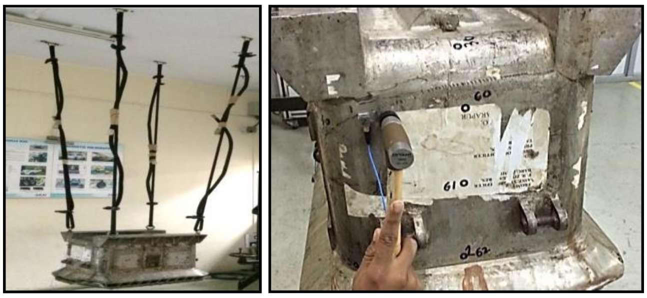

Fig. 2: Test Setup for container**.**

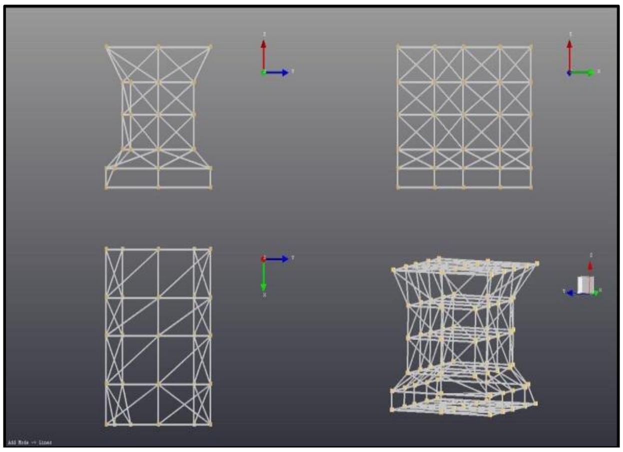

Fig. 3: Test Geometry

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. 4: Test setup for component without Lid

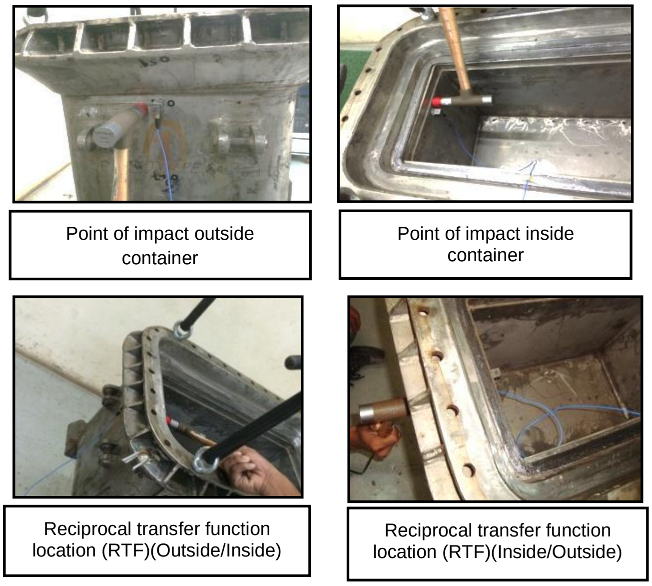

Fig. 5: Impact Hammer testing of container without lid

IV. FINITE ELEMENT ANALYSIS(FEA)

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.

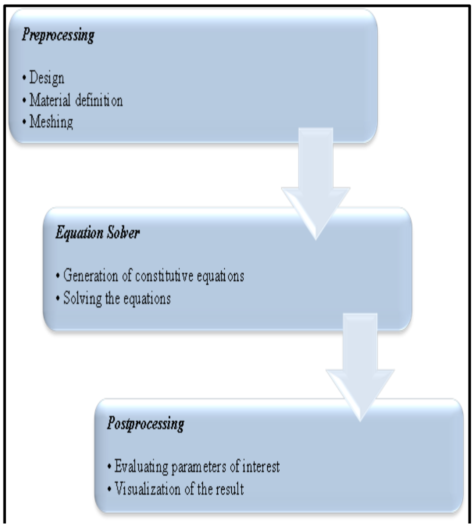

Fig. 6: Flow process involved in FEM

4.1 Selection of Material Properties.

Table I: - 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. 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 II: - FEA Parameters

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

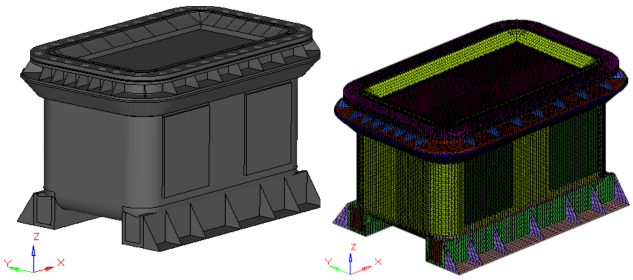

Fig7: FEA Model

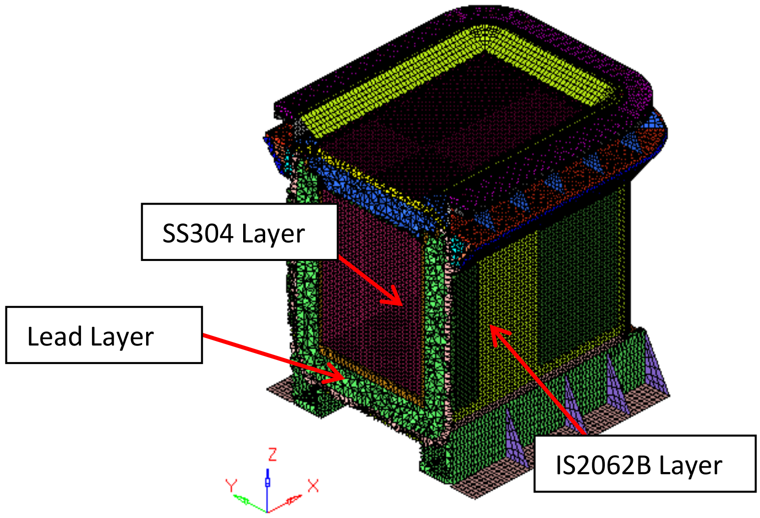

Fig8: Meshed Model

V. Result And 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 III: % 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%

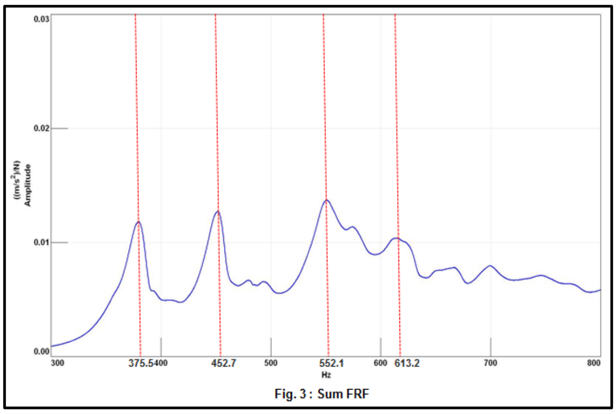

Fig 9: Experimental Frequency Chart for complete model

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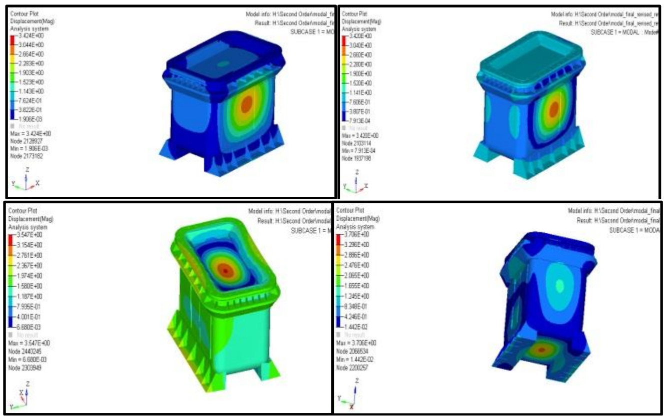

Fig 10: Observed Mode Shapes From Simulation

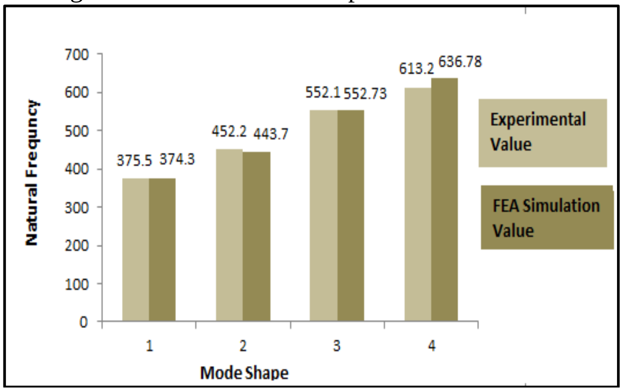

Fig11: Comparison between Natural Frequencies**.**

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 IV: % 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%

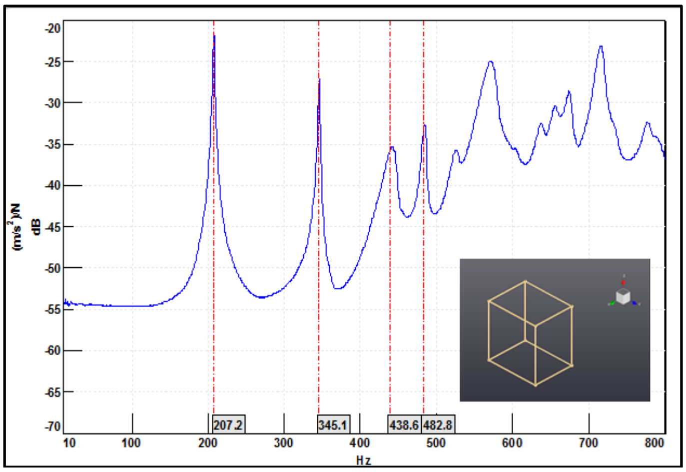

Fig 12: Experimental Frequency Chart

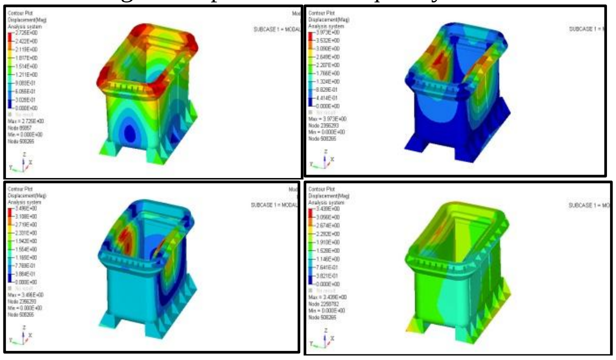

Fig13: Observed Mode Shapes from Simulation for component without lid

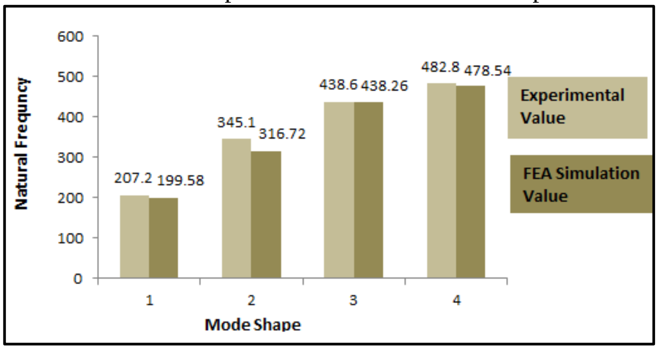

Fig 14: Comparison between Natural Frequencies for component without lid.

VI. Conclusion

The tested natural frequencies were in reasonable deviation as compared to observed Natural frequenciesdetermined using FEA for predefined locations. The observed mode shapes helps to predict the behaviour of transportation container. So, based on the observed results the transportation methodology is successfully developed and can be implemented for any other component.

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