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DEVELOPMENT OF TRANSPORTATION METHODOLOGY BY PREDICTING DYNAMIC BEHAVIOR OF CONTAINER FOR SAFE TRANSPORTATION

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ABSTRACT:

Road transport plays an important role in routine transportation. This paper describes the tie down methodology for transportation container for safe transportation conditions. The methodology adopted for safe transportation conditions comprises of applying known acceleration inputs (varying frequencies) to the given container and correlating the response on virtual simulation model using FEA software. The required input for FEA are taken from Indian road conditions includes accelerations in lateral, longitudinal and vertical directions on the transportation container. The multi-axis simulation table (MAST) is used for determination of acceleration factors through experimentally, using low frequency excitation signals which are generally associated with transport vehicles. These obtained results are compared with FEA results in order to develop methodology for prediction of acceleration factors on transportation container. The developed methodology has been successfully tested on taking an industrial component and found to be reasonable. The same can be used for prediction of dynamic behaviour of industrial component.

KEYWORDS: Transportation Container, FEA, MAST, Industrial component.

I. INTRODUCTION

Road transport plays an important role in transportation. To transport goods with proper transportation methodology is much needed which is safe in all manners. When a package containing goods is shipped from one location to another, it is subjected to regulations governed by the International Atomic Energy Agency (IAEA) about its structural integrity and shielding capability. The integrity of the tie-down system is important from the point of view of safeguarding the general public from injury, protecting the transporting vehicle and its contents, and insuring against damage to the package and its contents. Two basic schemes which are generally used for shipping of container can be categorized as the rigid or bolted tie-down and the tension member tie-down. The bolted tie down arrangement offers the most promise for compliance with the regulations. Also the physical situation of bolting the container base directly to the bed of a vehicle or to a sub-base which then becomes a part of the tie-down system if the sub-base is subsequently secured to the vehicle. These are governed by the regulation which 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 centre 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 [7] and its contents without generating stress in any material of the package in excess of the yield strength of that material. The response of the container for the known acceleration inputs can be evaluated on Multi Axis Shaker Table (MAST). This can be done by using the transportation modal standards and regulations need to be consulted to confirm the mandatory or recommended package acceleration factors provided by the national and international competent authorities. 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 1s and peak amplitude at the given acceleration factor [6], 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 shows the associated generalized acceleration factors for various modes of transport. Table I shows the associated generalized acceleration factors for various modes of transport.

Table I: Acceleration Factors for various modes of transport [7]

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

II. EXPERIMENTAL SETUP

The container used for transportation of goods is made up of mainly 3 materials namely IS2062B, SS304L, and Lead shown in Fig.1. The reason behind selection of these materials is IS2062 grade material contains carbon and manganese which acts as strengthening element and also has high thermal conductivity. The reason behind use SS304L material is the minimum Ultimate Tensile strength and Yield strength. The main advantage is that it is readily available in wide range, also it has got has good corrosive resistance.

Fig. 1. Actual Container

- **TESTING OF CONTAINER ON MULTI AXIS SHAKER TABLE (MAST):**

The Multi-Axial Shaker Table (MAST) was introduced to the vehicle exhaust system durability test in the late 90's. The objective of the MAST is to duplicate the frame motion of the vehicle by using the servo-hydraulic system. This servo-hydraulic simulator is capable of reproducing 6 DOF rigid body chassis motions, including vertical, lateral, and longitudinal translation as well as the rotational modes of roll, pitch, and yaw. The 6 DOF motion of the MAST is provided by the hydraulic actuators as shown in Fig.2. 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.

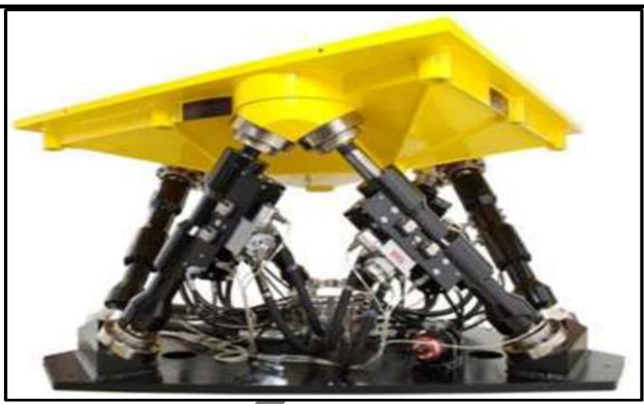


Fig. 2. MAST System

- **TEST SET-UP FOR CONTAINER ON MAST SYSTEM:**

The container was bolted to additional Plate which will act as a vehicle base. The container with plate was fastened to the MAST system as shown in Fig.3.

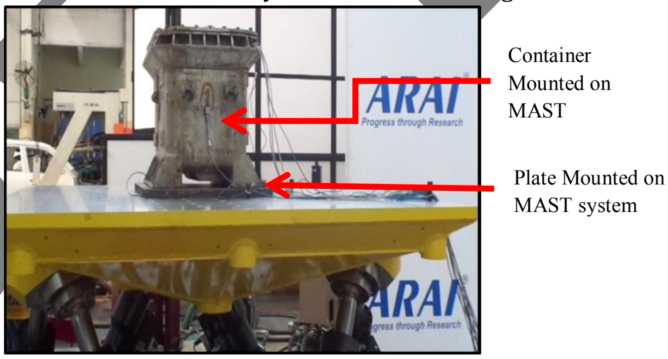


Fig. 3. Instrumented Container on MAST

- **DATA ACQUISITION SYSTEM FOR MAST:**

The container was tested on MAST system under known input signals and its behavior to respective input signals was collected through 16 channels data acquisition system. Out of 16 channels 4 were dedicated to uniaxial accelerometers which were used to collect the response in vertical direction (Z Direction), 9 channels for 3 Tri-axial accelerometers and remaining 3 channels were given to delta rosette strain gauge. Out of 3 Tri-axial accelerometer one was mounted on additional plate just near to the container whose signals can be considered as the signals of vehicle base and other are directly mounted on container as shown in Fig.4. The same signals later on will be used as input signal in FE simulation for correlation of acceleration factors. The known input signals given to the MAST system contain;

- Signal with Constant frequency of 5Hz, 10Hz, 20Hz, 30Hz and 40Hz with constant amplitude of 1.5 g.
- Random signal with varying frequency range for 0.5 to 100 Hz.

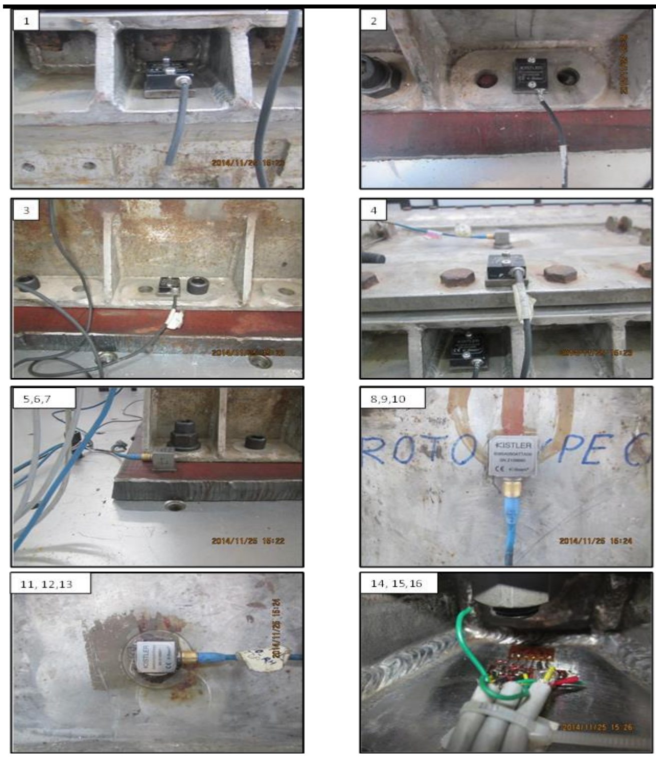


Fig. 4. Transducer Locations on Container

III. FE MODELLING:

- **SELECTION OF MATERIAL PROPERTIES:**

The component is made up of total 3 materials which consist of IS2062B, SS304L, and Lead. In order to build the FEA model appropriate properties should be considered. Based on this following properties are considered as shown in Table II.

Table II: Material Properties

Sr. No.	Material	Young's Modulus (MPa)	Density (Kg/m³)	Poisson's ratio
1	IS2062B	2.1E+5	7.8E-9	0.3
2	SS304L	2.1E+5	7.8E-9	0.3
3	Lead	1.7E+4	1.17E-8	0.4

The selection of properties should be done in such a way that the weight of the build FEA model should match with the actual weight of component as shown in Table III. Based on selected material properties the weight of build FEA model comes to be 870Kg.

Table III: Weight Comparison Table

Sr. No.	Weight of Build FEA model	Actual Weight of Container
1	870Kg	872

- **CONTACT AND FE MODEL DETAILING:**

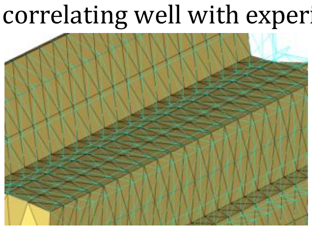
The FE simulation was related to modal analysis, so all the components of the container must be in contact with each other. But the container is combination of metal and non-metal. The interaction between metal and non-metal at the point of contact was not known so initially homogeneous contact i.e. bonded contact or node to node connectivity was maintained throughout the container. This contact was properly defined, but the obtained results were on the much higher side than expected. Thus the bonded contact option gets violated. As the metal part is steel and non-metal part is lead, the actual container was casted as hollow and later on lead is poured into the cavity of container. As, Lead is soft material as compared to other material, and in order to create metallurgical bond between them proper surface preparation need to be done [9]. But this is not possible as the container is having intricate cavity and higher complexity. Thus intensive work has been carried out to obtain correlation between experimental values and FEA simulated values which includes;

• Bonded Contact between metal and non-metal
• Geometry refining (The outside dimensions were modified in order to match weight of the component)
• Variation in Material properties ('E' value for both steel and lead to check material sensitivity over the model)

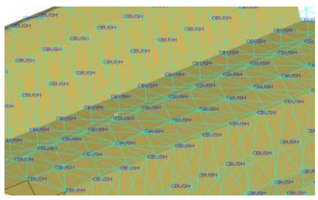
  ➢ The obtained result shows that Lead is the major material which is responsible for causing the large deviation.
  ➢ Thus the bonding between lead and steel was more focused from correlation point of view.

• Providing gap between lead and steel bonding.

Even after carrying out all the above mentioned iteration it was found that the predicted results were much more deviating from the experimental values. The observed component level results helped us to understand the behaviour between lead and steel. Based on the observed results, spring elements with varying stiffness were used for defining contacts between lead and steel as shown in Fig.5. Spring elements stiffness was varied from 1 N/mm to 1500 N/mm for modelling contact between lead and steel. 15-20 sub iterations were carried out and it was found that with spring elements having stiffness 750N/mm predicted results were correlating well with experimental results.



Contact with nodal Connectivity



Contact With spring Elements

Fig. 5. Contact detailing

By defining contact with spring elements wherever lead and steel are in contact and for remaining components nodal connectivity is maintained.

- **TRANSIENT RESPONSE ANALYSIS:**

When some external excitation is applied to a system two types of motion, namely the steady state and transient motion are generated. The steady state motion is not dependent on time and so it persists. The transient motion is temporary and time dependent so it vanishes soon. In many cases we only consider steady state motion. However, the transient vibration or motion is important in either the cases when the excitation is sudden and unexpected (like road conditions) or continuous excitations. The system vibrates with its natural frequency and the amplitude is purely dependent on the magnitude, time and nature of excitation. The examples of transient vibrations are the air pressure pulse created by gun fire, the dropping of package on hard floors, punching operations, moving of automobiles on uneven surface of curbs on the roads.

The transient response analysis is most general method for computing forced dynamic response. The purpose of a transient response analysis is to compute behaviour of a structure subjected to time varying excitation. The transient excitation is explicitly defined is time domain. All the forces applied to the structure are known at each instant in time. The forces can be in the form of applied forces and/or in forced motions. The important results obtain from a transient analysis are typically displacements, velocities and accelerations of grid points and, forces and stresses in elements. Depending upon the structure and the nature of the loading two different numerical methods can be used for a transient response analysis: direct and modal. The direct method performs a numerical integration on the complete coupled equations of motion. The modal method utilizes the mode shapes of structure to reduce and uncouples the equations of motion (when modal and no damping are used); the solution is ten obtained through the summations of individual modal response.

- **BOUNDARY CONDITIONS AND EXCITATION METHOD:**

FEA model was built in order to carry out transient response analysis. The build FEA model was constrained at the same location as that of constrained on MAST system. During experimentation on MAST system the container was subjected to excitations for known input signals through MAST platform. Similar type of excitation was given to the container by fixing the all nodes centrally. The output response of the accelerometer placed just near to the container was used as input for FE simulation. The output of the same accelerometer will act as a vehicle base input for container. And based on this input, output at same predefined location was analyzed and then compared with the experimental output in order to develop the transportation methodology. The schematic of build FEA model for transient response method is shown in Fig. 6.

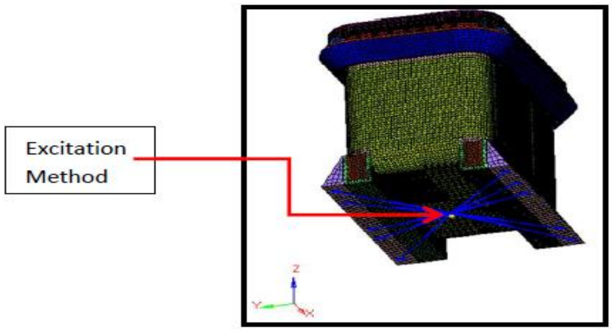


Fig. 6. Excitation Location and Boundary Condition

IV. RESULTS AND DISCUSSION:

To develop transportation methodology, the experimental observed response at predefined locations should correlate with FE simulation response. It is necessary that the trend and the RMS value of the observed responses in both situations should match with each other, so as to develop the methodology. For experimental testing, as stated in earlier chapter, the input signal varied from 5Hz to 40 Hz excited in each direction namely X, Y and Z keeping 'g' level constant as '1.2g' along with one random signal which would represent actual road surface excitation signal. All the signals were last for 3 min which will results in 180000 data points. For analysing purpose, on sampling purpose 5000 data points i.e. for 5 Sec. were analysed from 20Hz frequency range. The 20Hz frequency band was selected because, it was assumed that if it's get correlated in this band, it will serve the purpose for other bands too. For development of transportation methodology output response in the direction of excitation was more focused. The results were experimentally evaluated for multiple readings and average response considered for comparison of 'g' value for development of transportation methodology. It is observed that the trends of experimental response and FE response were matching to the expected levels which are shown below;

EXCITATION IN X DIRECTION:

- Input Signal band:- 5 Hz to 40Hz
- Duration:- 3 min

As prescribed earlier, the input signal given to container was a combination of 'XYZ' response obtained from the Tri-axial accelerometer placed just near to the container shown in Fig7. The experimental as well as FE simulated output response has been compared at locations which are in the direction of excitation i.e. in 'X' Direction shown in Fig. 8.

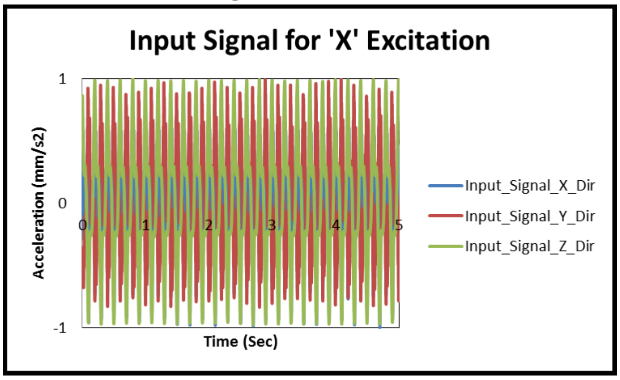


Fig. 7. Input Signal for 'X' Excitation

Accelerometer Location Response Comparison

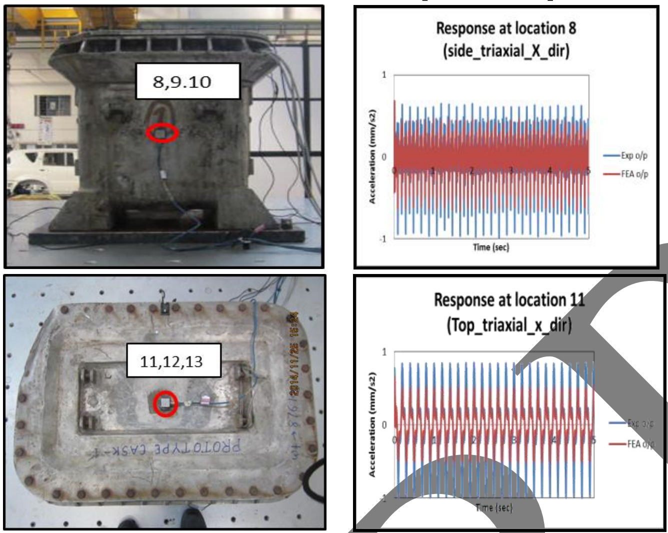


Fig. 8. Response comparison for Excitation in X Direction

EXCITATION IN Y DIRECTION:

- Input Signal Band: - 5 Hz to 40Hz
- Duration: - 3 min

As prescribed earlier, the input signal given to container was a combination of 'XYZ' response obtained from the Tri-axial accelerometer placed just near to the container as shown in Fig. 9. The experimental as well as FE simulated output response has been compared at locations which are shown in Fig. 10.

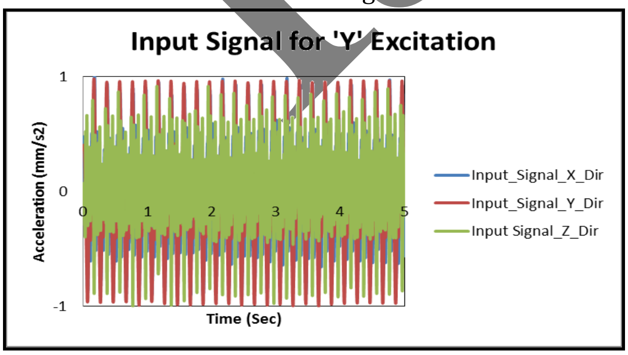


Fig. 9. Input Signal for 'Y' Excitation

Accelerometer Location Response Comparison

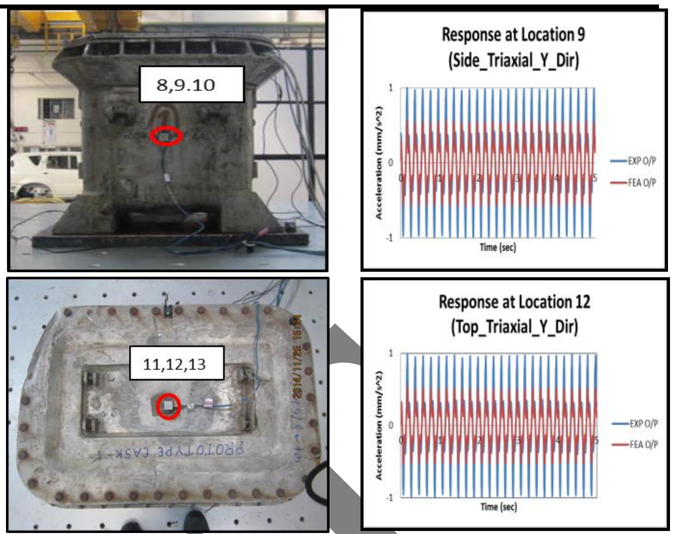


Fig. 10. Response comparison for Excitation in Y Direction

From the compared responses, it can be inferred that the trends of the response obtained from both experimental as well as FE simulation are almost similar in nature. The constant difference in the amplitude of observed trends was noticed for which RMS values need to be calculated.

EXCITATION IN Z DIRECTION:

- Input Signal Band:- 5 Hz to 40Hz
- Duration:- 3 min

As prescribed earlier, the input signal given to container was a combination of 'XYZ' response obtained from the Tri-axial accelerometer placed just near to the container as shown in Fig. 11. The experimental as well as FE simulated output response has been compared at locations which are in the direction of excitation i.e. in 'Z' Direction shown in Fig. 12.

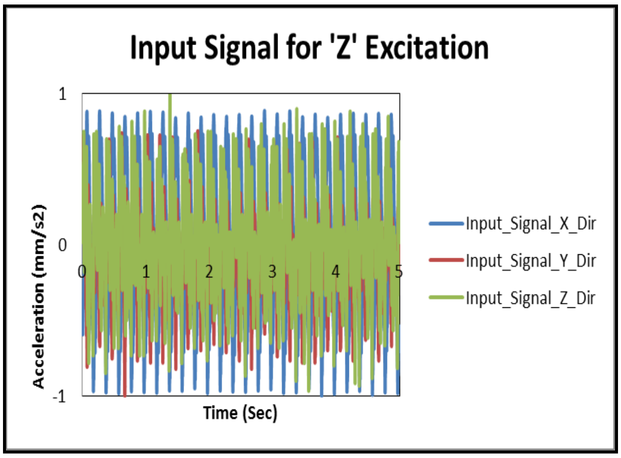


Fig. 11. Input Signal for 'Z' Excitation

Accelerometer Location Response Comparison

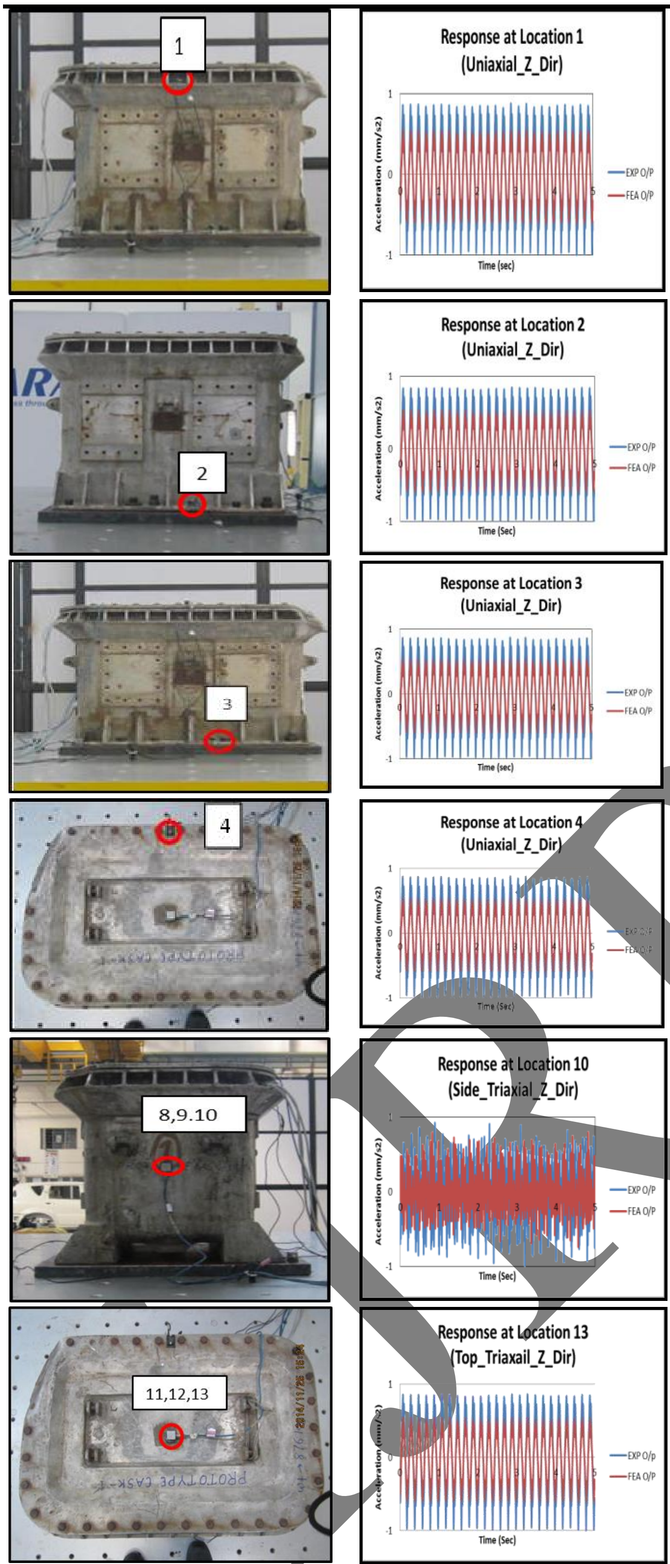


Fig. 12. Response comparison for Excitation in Z Direction

From the compared responses, it can be inferred that the trends of the response obtained from both experimental as well as FE simulation are almost similar in nature. The constant difference in the amplitude of observed trends was noticed for which RMS values need to be calculated.

RANDOM SIGNAL EXCITATION:

- Input Signal Band: - 0.5Hz to 100 Hz

As prescribed earlier, the input signal given to container was a combination of 'XYZ' response obtained from the Tri-axial accelerometer placed just near to the container as shown in Fig.13. The experimental as well as FE simulated output response has been compared at all locations as shown in Fig. 14.

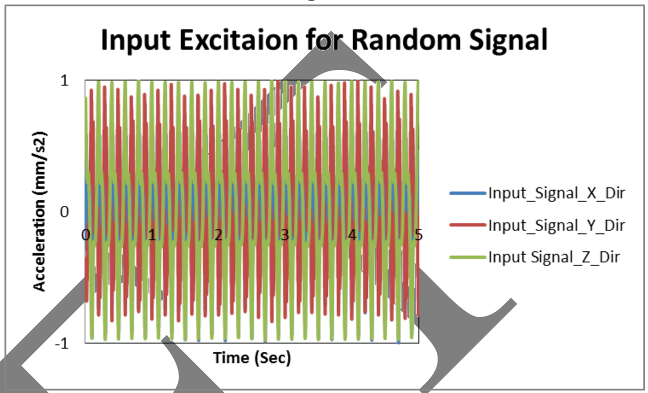
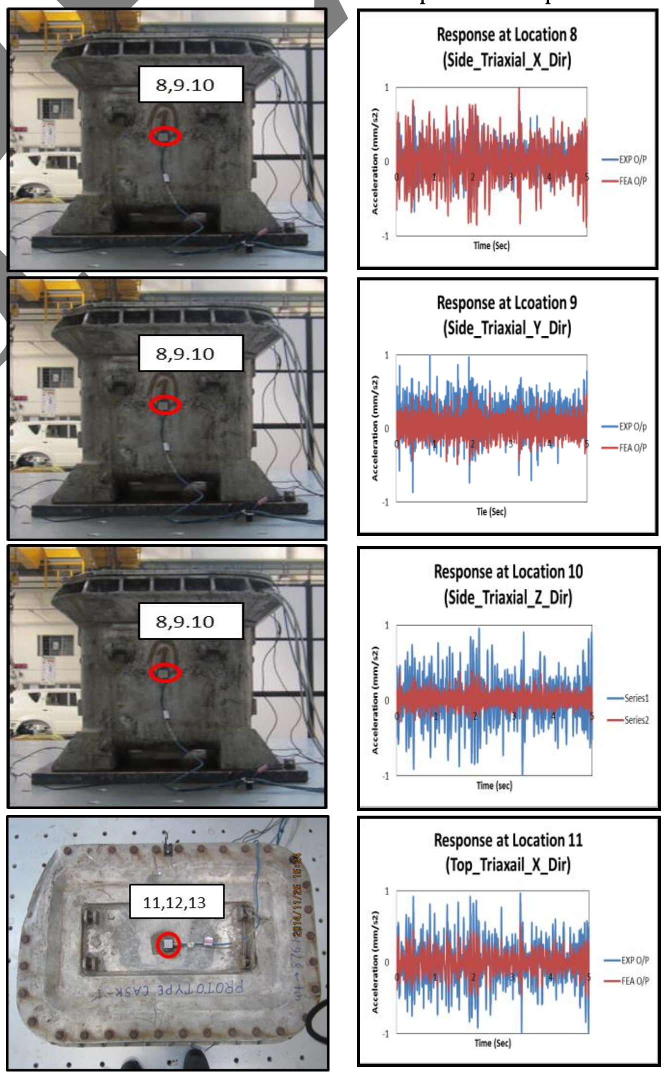


Fig. 13. Input Signal for Random Signal Excitation

Accelerometer Location Response Comparison



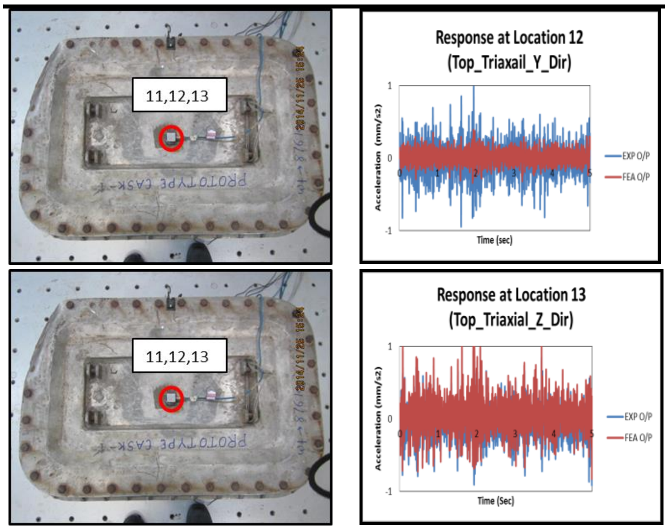


Fig.14. Response comparison for Excitation for Random Signal

From the compared output responses, it clears that the output trends at respective locations as matches satisfactorily, which are sufficient enough to define the transportation methodology. In order to develop the co relation and formulate transportation methodology for given problem, it is necessary to match the peaks of response along with the trend of response.

Root Mean Square, also known as quadratic mean, in statistics is a statistical measure defined as the square root of the mean of the squares of a sample. The RMS can also be calculated for continuously varying function. The RMS over all time of a periodic function is equal to RMS of one period of the function. The RMS value of a continuous function or signal can be approximated by taking the RMS of a series of equally spaced samples. The RMS value at individual locations has been calculated for corresponding excitation for both experimental and FE simulated values. Initially, the RMS value for excitation in 'X' direction has been calculated and following results were obtained as shown in Fig. 15

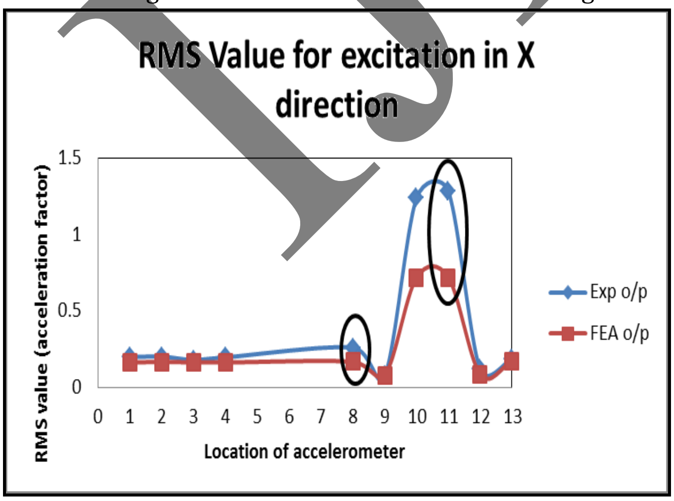


Fig.15. Graphical comparison for RMS Value for Excitation in X Dir.

Similarly RMS value for excitation in 'Y' and 'Z' direction has been calculated and following results were obtained as shown in Fig. 16 and Fig. 17.

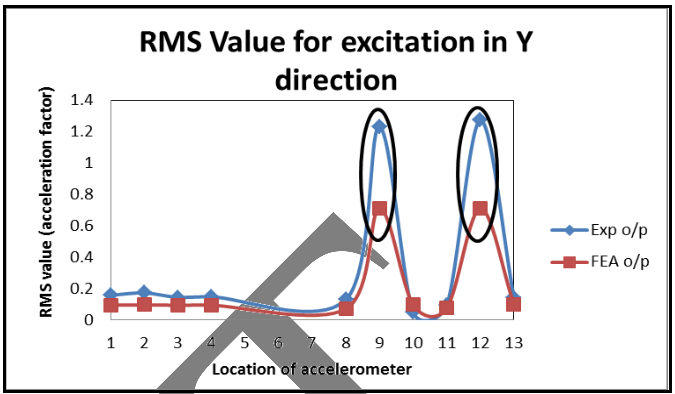


Fig.16. Graphical comparison for RMS Value for Excitation in Y Dir.

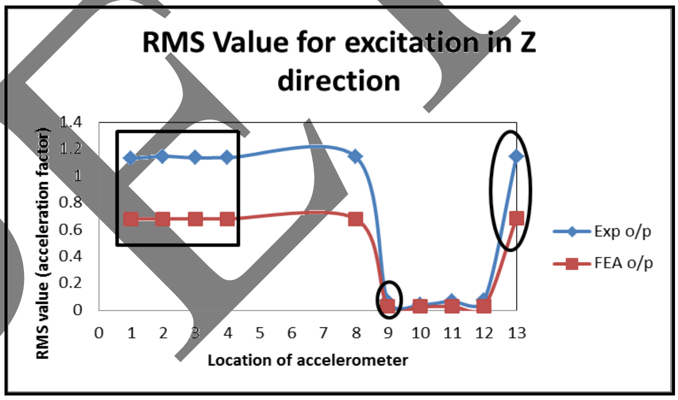


Fig. 17. Graphical comparison for RMS Value for Excitation in Z Dir.

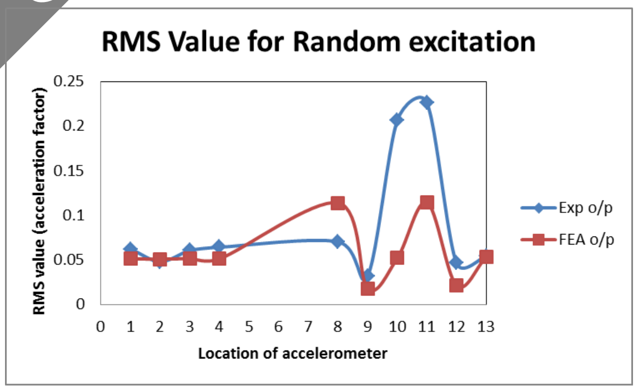


Fig. 18. Graphical comparison for RMS Value for Random Excitation.

V. CONCLUSION:

From the work carried out to develop transportation methodology for prediction of dynamic behaviour of transportation container following inferences can be drawn;

- Work carried on Transportation Container under scope of project demonstrated sequence of activities and typical methodology to be adopted for prediction of acceleration levels under transportation conditions for heavy transportation containers.

- Proposed methodology of virtual prediction of dynamic behaviour of container for routine condition is validated.

REFERENCES:

1) Wu, T., and Hoang, D. S., *Analysis of Statically Indeterminate Tie-Down Systems*, Savannah River Technology Center, Westinghouse Savannah River Company, Aiken, South Carolina, (803) 25-8201.
2) Wan, D. and Kim, H., *Evaluation of MAST Transfer Function in the Vehicle Exhaust System Full System Durability Test,* SAE Technical Paper 2002-01-0802, 2002, doi: 10.4271/2002-01-0802.
3) Yang, F. and Cheng, H., *Modal Transient FEA Study to Simulate Exhaust System Road Load Test,* SAE Technical Paper 2011-01-0027, 2011, doi: 10.4271/2011-01-0027
4) Pachpore, S., et.al., *Determination of Natural Frequency of transportation container by Experimental Modal Analysis*, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), 2015, pp. 115-122.
5) Pachpore, S., *Behavioral Prediction of Transportation Container by Experimental Modal Analysis*, 2nd National Conference on Mining Equipment: New Technologies, Challenges & Applications (MENTCA-2015), Dhanbad.
6) Evans, J.H., Structural Analysis of Shipping Cask, Vol.7*, Container Tie Down Design Manual, Union Carbide Corporation, Nuclear Division, U.S. Atomic Energy Commission*
7) IAEA Safety Standards*, Regulations for the Safe Transport of Radioactive Material, Specific Safety Requirements.*
8) *Joint Service Specification standard on Environmental Test Methods for Electronic and Electrical equipment's*.
9) Guruswamy, S., *Engineering Properties and Application of Lead Alloys*, CRC Press, pp.413-430
10) *Multi Axis Simulation Table, User Guide*
11) *Nastran Quick Reference Guide.*