Design and Analysis of a Container with Vibration Shock Isolators during Transporting Small Rocket Motors

M. Uday Kumar[1] Y.Lakshmipathi[2]
[1]M.Tech Student [2]Assistant Professor
[1,2]Department of Mechanical Engineering
[1,2]MLRIT, Hyderabad

Abstract— Rocket motors when transported in a container, there is a definite chance of development of vibrations due to the unevenness of the transportation path selected. This may damage the rocket motor inside. It is required to see that, the rocket components are not affected by vibrations during the transportation. This work attempts to design a suitable container with vibration isolators for absorbing the shock produced. Container is designed to carry 2 rocket motors each weighing 70 kg, made up of composite material, E-glass epoxy, and Isolators (generally made up of different materials) are placed symmetrically below the container. While transportation, the truck (the vehicle carrying container) is assumed to undergo an acceleration of 15 times of gravity, which is to be damped to less than 3 times of gravity, as 3*g is the maximum vibration the container can resist. Mathematical model based on Laplace Transformations is built and solved for checking the shock response with and without Vibration Isolators, for this MATLAB software is used. The 3D model of the container with Rockets is modeled in CATIA and the structural and Dynamic Analysis is performed using OPTISTRUCT of Hyper works.

Key words: E-glass epoxy, Structural Analysis, CATLA and MATLAB

I. INTRODUCTION

In the military, vehicles such as trucks or Tractor units are used to transport or launch missiles (rockets with warheads), essentially a form of rocket artillery. Such a vehicle may transport one or multiple missiles. The missile vehicle may be a self-propelled unit or the missile holder/launcher may be on a trailer towed by a prime mover [1]. They are used in the military forces of a number of countries in the world. Long missiles are commonly transported parallel to the ground on these vehicles, but elevated into an inclined or vertical position for launching [2]. All machines, by the very function of their operation create a vibration or shock of varying intensity or amplitude. The moment you turn a machine to a running or operational mode, vibration is generated. In simple terms, vibration in motor-driven machinery is just the back and forth oscillation of the machines and their components [3]. In order to prevent or control the vibration of any machine or equipment from affecting their surroundings, a vibration isolator is recommended as a more cost-effective solution. Vibration isolation is achieved by using special mounts designed to absorb the vibrations or movements caused by the machinery or equipment [4].

In this project the aim is to design a Transportation container made of composite material along with suitable number of Vibration Isolators placed below the container. Container with Composite material and accompanied with Vibration isolators will reduce the weight of the container to transport and also prevent the missiles placed inside to undergo allowable amount of disturbance caused by the shocks during the transportation.

In this project an E-Glass/Epoxy material made container along with Vibration shock Isolators is considered, Theoretical and Software results are recorded and compared for validation.

II. EXPERIMENTAL DETAILS

A. *Materials Used:*

- E-glass epoxy
- Vibration shock Isolators

B. *Material Properties:*

Young's Modulus	Rigidity Modulus	Poisson's Ratio	Density
$E_x = 40.9*10^9$ N/ m^2	$G_{xy} = 3.07*10^9$ N/ m^2	0.2	1910 kg/m^3
$E_y = 6.21*10^9$ N/ m^2	$G_{yz} = 1.55*10^9$ N/ m^2		
$E_z = 40.3*10^9$ N/ m^2	$G_{xz} = 2.39*10^9$ N/ m^2		

Table 1: Material properties of E-glass/epoxy

C. *Geometry of the Container:*

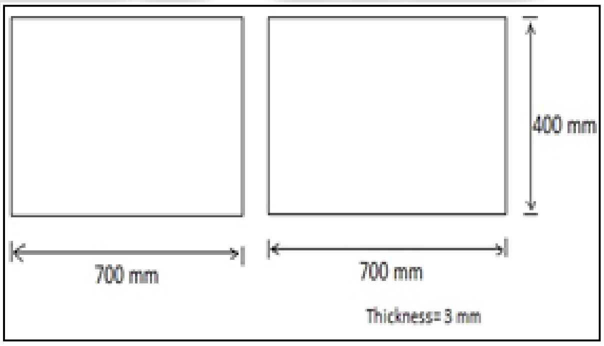

Fig. 1: 2Ddimensions of the container

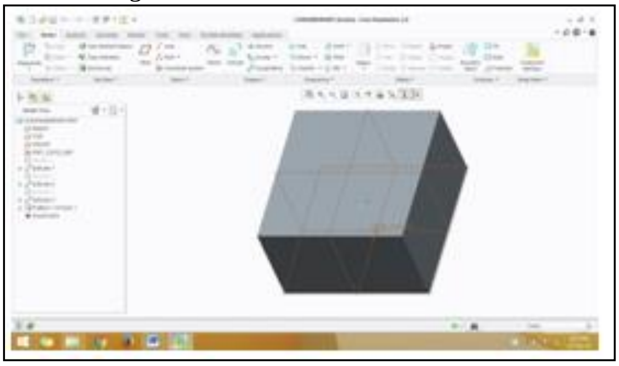

Fig. 2: 3Ddimensions of the container

D. *Loading Conditions:*

15g shock input which a worst case scenario is considered for cases:

- A Single Degree freedom system- without Isolators
- A Double Degree freedom system- with Isolators

E. *Isolator Considered:*

Broad Temperature Range Mounts HTC Series is considered and specifications are furnished below:
Load capacity: 110 to 150 lb (50 to 68 kg) per amount

F. *Materials:*

- Outer member – 2024-T351 aluminum alloy
- Inner member – 2024-T351 aluminum alloy
- Bottom Plate – 5052-0 aluminum alloy casting
- Elastomeric – LORD BTR® Silicone

G. *Finish:*

Outer member – sulfuric acid anodized
Inner member – chromate treated perMIL-DTL-5541, Class 1A
Bottom Plate – sulfuric acid anodized
Natural Frequency = 20 Hz
Spring rate = 1071 KN/m

1) Case 1: Setup without Isolators

a) Modeling the container along with the truck

In this stage, we are required to model a Hollow cubical shaped Container made of Composite material E-Glass/Epoxy with dimensions taken approximately to fit in a pair of small rocket motors, along with a solid cubical representing Truck.

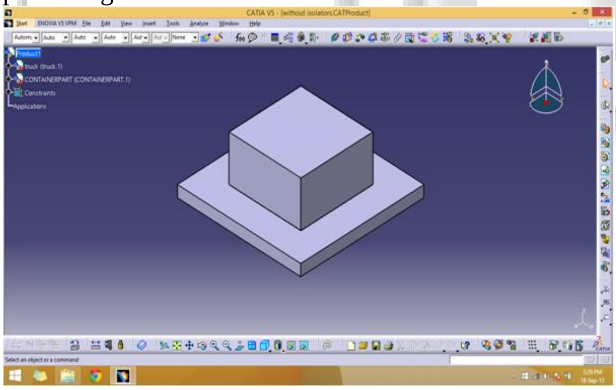

Fig. 3: Assembled model of Truck along with Container

H. *Meshing:*

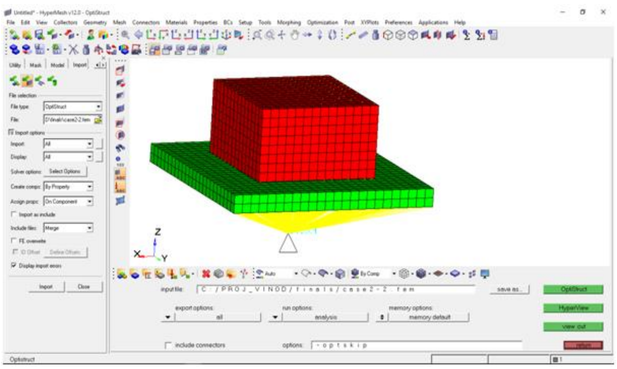

Fig. 4: Mesh view of the Container along with the Truck

To maintain the connectivity between the Container and the Truck, rigid (RB2) connection is modeled between Missile Box and Truck.

1) Transient Analysis for a Shock input of 15G 5milli second:

The meshed model is imported to OPTISTRUCT for further process to calculate the response of the Container for the shock input applied onto the Truck.

The Input excitation which has to be given to the setup is applied on the Master node of magnitude 15G acting for a time pulse of 5 milli second as shown on the figure below:

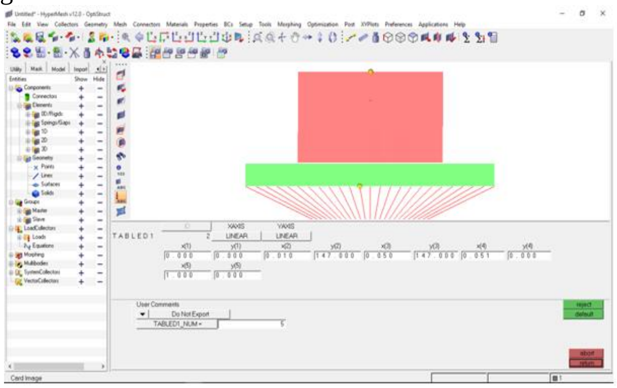

Fig. 5: Applying the Shock input onto the Master node

A graph is plotted between time and the Acceleration's, both the input and output are taken on the same axis (so that it gets easier to compare the amount of damping done) as shown below:

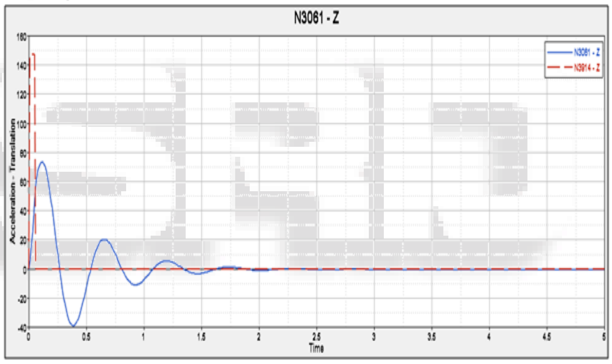

Fig. 6: Variation of Input and Output Accelerations without Isolators

From the graph above, the peak response recorded is about 73 m/s^2 at the container, which is very much larger than what a missile can sustain. Thus we move onto the Second case of setup involving Isolators.

2) Case 2: Setup with Isolators:

All the components are modeled and assembled using CATIA V5 as shown below

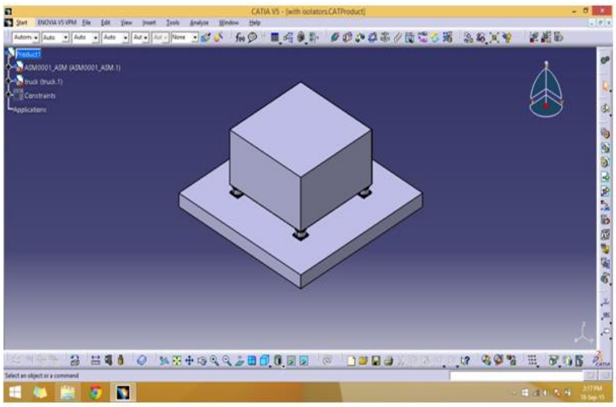

Fig. 7: Isometric View of the Setup along with Isolators attached at four corners

a) Mesh Generation for the Container, Truck and the Isolators:

Assembled setup has to be imported to the hyper mesh for Finite Element Discretization. Imported Assembly appears as shown below:

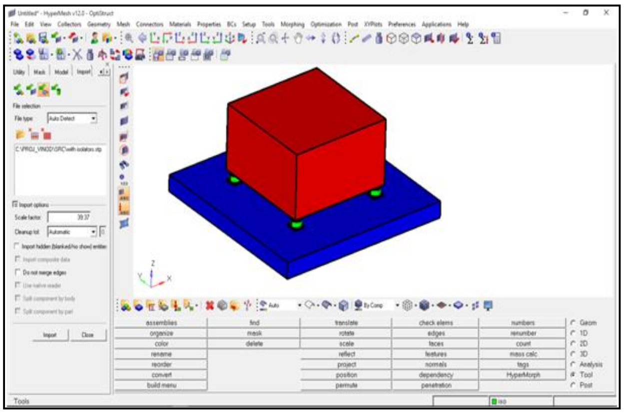

Fig. 8: Assemble of case 2 in hyper mesh

b) Transient Analysis for a Shock input of 15G 5milli second:

The meshed model is imported to OPTISTRUCT for further process to calculate the response of the Container for the shock input applied onto the Truck. The Input excitation which has to be given to the setup is applied on the Master node of magnitude 15G acting for a time pulse of 5 million second similar to the case 1 analysis.

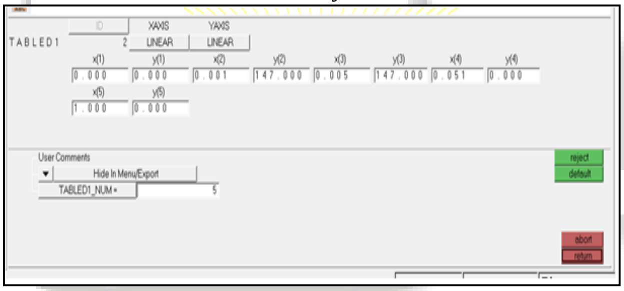

Table 2: Shock input Variation with time

A graph is plotted between time and the Acceleration's, both the input and output are taken on the same axis (so that it gets easier to compare the amount of damping done) as shown below:

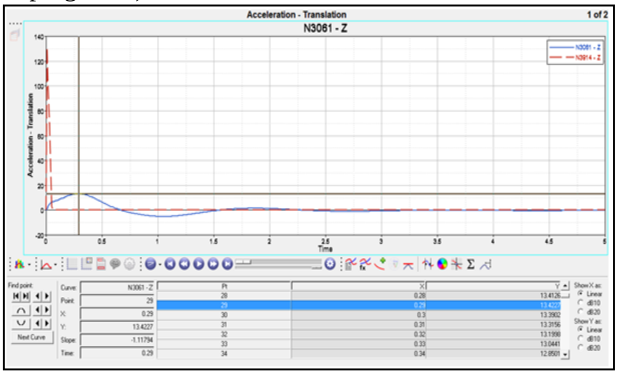

Fig. 9: Variation of Input and Output Accelerations with Isolators

From the above graph, we can observe that the Maximum Shock Response generated is less than 3G, after attaching the isolators. Therefore, we now can state that Rocket motors can be safely transported following the second scenario as described in the work.

A comparison is made between both the above stated analyses results for the components along with specified boundary conditions as shown below:

Case	Shock Input	Shock Response	
		Theoretical	Software
Without Isolators	147.15 m/s^2	78 m/s^2	75 m/s^2
With Isolators		~ 1 m/s^2	13.4 m/s^2

Table 3: Summary of the results obtained

III. Conclusions

When the system i.e. without Isolator is acted upon by 15g shock input, it responded with 7g output response, which is well over the limit of 3g. Therefore, the components that are transported will be affected. When the system is modified as Two-Degree freedom system with 4 Isolators, the output response is reduced to less than 1.5g which is well below the allowable 3g. The Transient Analysis simulations are performed in Optistruct module of hyper works. Thus, finally we can state that addition of Vibration Isolators to the Truck and container setup during the transportation of rocket motors, there is no shock transmitted to the container. Thus, Rocket motors are safely transported.

References

[1] Tongue, Benson, Principles of Vibration, Oxford University Press, 2001ISO 18431-4 Mechanical vibration and shock Signal processing Part 4: Shock response spectrum analysis
[2] Harris' Shock and Vibration Handbook, Cyril M. Harris, editor, Allan G. Piersol, editor, 5th ed., McGraw-Hill 2002. Chapter 23: Concepts in shock data analysis.
[3] Ahlin K., Magnevall M., Josephson A. Simulation of forced response in linear and nonlinear mechanical systems using digital filters.
[4] C.E. Crede, Vibration and Shock Isolation, Wiley, New York (1951).

