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International Journal Of Modern Engineering Research (IJMER)

Design of Vibration Test Fixture for Opto-Electronic Equipment

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ABSTRACT : *In this paper an attempt is made in designing vibration test fixture for opto-electronic equipment. It can be achieved by formulating basic or preliminary 3D CAD assembled model followed by attaching material to its components. The analysis carried by defining the contact conditions of every part of it, defining the fixing conditions, applying loads virtually, good quality meshing, followed by optimization of the same by taking concurrence from the results of Linear Harmonic Structural Vibration Analysis. SolidworksSimulation premium software is used for modelling and solving the Linear Harmonic Structural vibration analysis for all Environmental Stress Screening (ESS) tests like vibration, shock for elimination of failures before physical testing. The comparison between experimental results and simulation results are presented in this paper.*

Keywords: *Accelerometer(bob), Frequency display monitor, Opto-electronic Equipment, Vibration test machine, vibration test fixture.*

I. INTRODUCTION

Vibration is the most important mode of failure in equipment. The equipment induced into the field has to withstand high vibrations. As vibration equipment cannot be placed directly on the vibration machine shaker table, a mechanic structure called fixture is placed between the equipment and the machine. The equipment under the test has to withstand excitation with a well-defined frequency range. These fixtures are generally used for supporting opto-electronic equipment. The fixture also to be designed such that the equipment under test shall experience exact range of base excitation or within certain tolerance. The same is achieved by providing the feedback device placing on equipment under test. The best, suitable model of vibration fixture is designed as per the requirement, once it is analyzed by using finite element analysis.

The equipment, without isolator, shall be fastened to the vibration table, either directly or by means of mounting fixtures, by means of attachments otherwise stated in the relevant Opto electronic equipment. The test equipment is Sinusoidal (sine) Vibration System. Sinusoidal Vibration is a special class of vibration. The structure is excited by a forcing function that is a pure tone with a single frequency. Sinusoidal vibration is not common in nature, but it provides an excellent engineering tool that enables us to understand complex vibrations by breaking them down into simple one tone vibrations. The motion of any point on the structure can be described as a sinusoidal function of time. When performing a sine test, one frequency is exited at each time. During sine vibration test each part of a complex structure is resonating at a different frequency. The basic motion shall be sinusoidal and such that all the fixing points of the equipment are moving substantially in phase and in straight parallel lines. The characteristics required of the vibration generator and fixture when loaded for the conditioning process.

As per the norms of JSSStandards%5CJSS 55555 -2000 testing fixture and equipment are used in the following cases: 1) Equipment Installed in Tracked Vehicles. 2) Equipment installed in Wheeled Vehicles and Trailers Shipborne Equipment. 3)(a) Equipment Installed in Major Warships. 3) b) Equipment Installed in Minor Warships. 4) Equipment Installed in Submarines. The equipment used in the current work is the one used in Tracked Vehicles. Its frequency ranges between 5-350Hz.The mounting fixtures shall enable the specimen to be vibrated along the various axes specified for conditioning. The relevant equipment specification shall state whether the effect of gravitational force is important. In this case the equipment shall be mounted on fixture, then the force acts in the same direction as it would be in use.

There have been many researchers using finite element method to analyze thefixtures.Avitable [1] P-Space Launch Vehicles are subjected to rigorous dynamic environment during lift-off and ascent phase of launch.Noonan. Edward [2] F-Unlike traditional vibration test controllers that rely heavily on an external computer for real-time operation. The Spider-81 is the first vibration controller that directly integrates time-synchronized Ethernet connectivity with embedded DSP technology. C. D. Pengelley[3] Curtiss- Wright Corporation-the dynamics of a rigid body having two degrees of freedom is presented with the complete solution for nodal and coupled frequency.Crede [4] Charles E-way to identity some critical developments that provide tools that accelerated advanced shock and vibration technology. Harrison[5] T- The launch vehicles are manufactured at different environmental conditions and exposed to extreme environmental conditions during liftoff and ascent phase. Scarton[6] TD- Space Launch Vehicles are subjected to rigorous dynamic environmental conditions during launch.

In this paper, acceleration is calculated numerically by using SolidworksSimulation Premium softwareand experimentally using vibration test bed and suitable fixture is taken for experimentation. Acceleration is calculated on Opto-electronic equipmentwith frequency range of 5 to 350Hz.

II. DESIGN AND ANALYSIS

Vibration test fixture was designed inSolidworksSimulation Premium software is used to determine the acceleration on fixture and opto-electronic equipment. The dimensions of the Vibration test fixtureare show in the “Fig.1”. The properties of the Vibration test fixture are shown in below table. In this, Linear Elastic Isotropic Properties are along three axes (x, y, z)

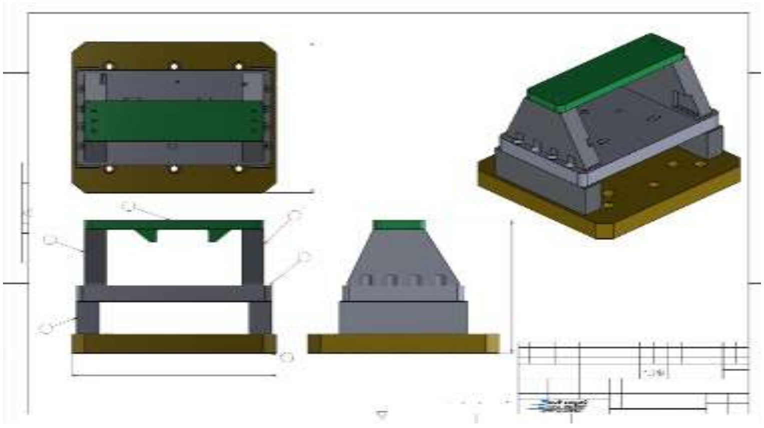


Fig.1 Dimension of vibration test fixture

Table 1: Linear Elastic **Isotropic** properties

Yield strength	2.75 x 10^8 N/$\mathbf{m^2}$
Tensile strength	3.1x 10^8 N/$\mathbf{m^2}$
Elastic modulus	6.9 x 10^{10} N/$\mathbf{m^2}$
Poisson’s ratio (V_{XY}),V_{YZ}),(V_{XZ})	0.33
Shear modulus (G_{XY}), (G_{YZ}), (G_{XZ})	2.6 x 10^{10} N/$\mathbf{m^2}$
Density (ρ)	2700kg/m^3
Thermal expansion coefficient	2.4x 10^5/Kelvin

The modeling of fixture is done using Solidworks Simulation Premium software and analysis is done on FEA approach using the same software. The basis of FEA relies on the decomposition of the domain into a finite number of sub-domains (elements) for which the systematic approximate solution is constructed by applying the variable or weighted residual methods. In effect, FEA reduces problem to that of a finite number of unknowns by dividing the domain into elements and by expressing the unknown field variable in terms of the assumed approximating functions within each element. These functions (also called interpolation functions) are defined in terms of the values of the field variables at specific points, referred to as nodes. The finite element method is a numerical procedure that can be used to obtain solutions to a large class of engineering problems involving stress analysis, vibration analysis heat transfer, electro-magnetism, and fluid flow.

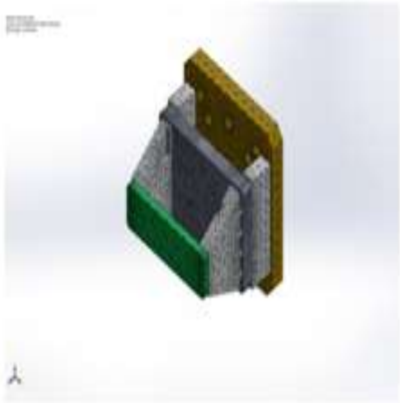


Figure2: Modeling of test fixture **Figure 3**: Meshing analysis of test fixture

III. EXPERIMENTATION

An experimental test setup is required to conduct environmental vibration testing fixture on Opto-electronic equipment. The existing vibration test facility is having capability to produce a force of 16ton by using single shaker system. The facility is modified to meet the short fixture. As part of the modification, a single control system is commissioned to operate the single shaker system. A load bearing platform which acts as a platform for specimen is used to make different axis's test setup. A large slip table of size 3.0m x 3.4m is commissioned to the test specimen for horizontal testing. In addition to these modifications two new power amplifiers are also commissioned to get higher efficiency.

Test Setup Configuration: The test setup configuration for simulation and control vibration levels on Opto electronic equipment is shown in the "Fig.4""Fig.5". It is basically a closed loop feedback control system. It consistsof sub-systems like vibration controller, power amplifiers, single mode controller, control accelerometers and data acquisition.

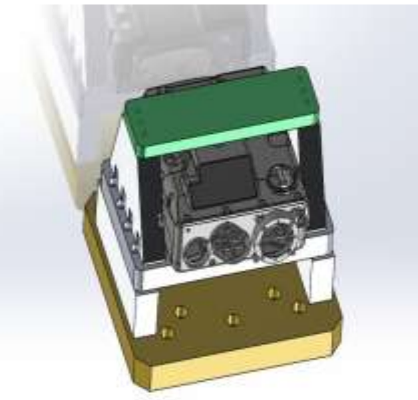


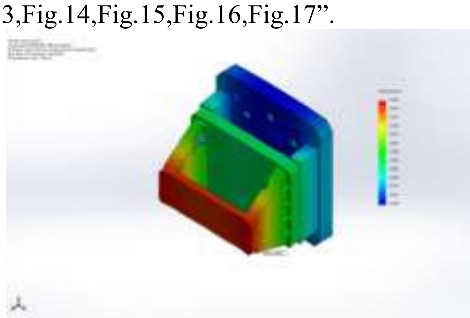
Figure 4: Vibration test machine **Figure 5:** Vibration test fixture with
courtesy:Labtone test equipment Opto-electronic
co,ltdequipment

The required test profile is programmed into PC based control system. The vibration controller generates and feeds a low level signal into the power amplifier based on the test specifications. This signal is amplified by the power amplifier and drives the armature of the shaker in case of single shaker mode. The power amplifier is an air-compressor, modular type with very high efficiency. The power amplifier output is connected voltage meter through display monitor.Asingle control system is used,which consists of Single Amplifier Controller (SAC), Phase Control Unit (PCU) and Current Monitoring Unit (CMU). The SAC allows operation of maximum of 4 numbers of shale shakers. The SMU monitors in the load currents (armature currents) through CMUs and in conjunction with the PCU. It corrects the amplitude and phase of the singleshaker load currents within the specified tolerances. Ultimately, the SAC allows a smooth and synchronized operation of Single amplifiers, in turn the operation of Shale shaker systems.

Finally, the feedback signals from the shakers and test specimen via vibration test fixture through opto electronic equipment reach a control accelerometer. From there the signals with increased the frequency ranges reach the vibration controller. During the vibration testing, the effects caused by the fixture are important. Vibration test fixtures exhibit resonant frequencies in the test frequency range due to the mass/stiffness characteristics. The resonant frequencies cause significant problem when conducting vibration tests. However, vibration controller controls the shaker input through a feedback accelerometer and controls the level of vibration input into the test specimen. But, the control accelerometer controls the level of vibration where the control accelerometer is bonded. This indicates that the resonant behavior of the vibration fixture is dependent on the fixture itself. Thus opto electronic equipment vibration testing poses a challenge to design and realize a good vibration fixture. The feedback signal is measured, digitized and compared with the specified control spectrum. Then the drive signal is adjusted, if any corrections are required, to change the input signal to the shaker through power amplifier to maintain the required /specified test profile.

IV. RESULT

Modal analysis is done using SolidworksSimulation Premium software and experimentation is done using Vibration test bed (shale shaker)for the fixture withopto electronic equipment having frequency ranges 5to350 Hz. The acceleration is calculated by changing frequency from 5 to 350 Hz. Later the analysis is continued by varying the frequencies along the three axes (x, y, z) to meet different military required frequency conditions. Frequency curves for different conditions are shown below through "FIg.12,Fig.13,Fig.14,Fig.15,Fig.16,Fig.17".



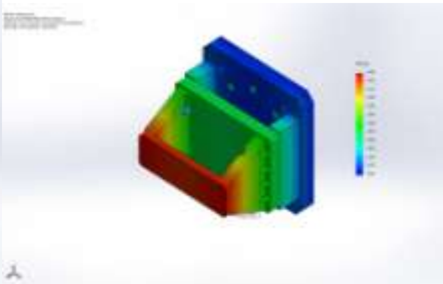
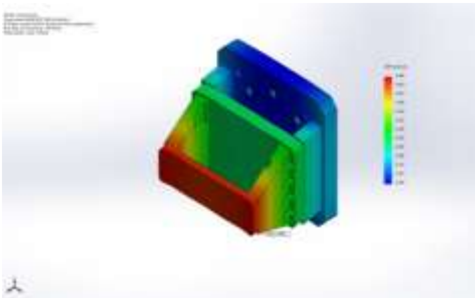


Figure 6: Harmonic vibration X-displacement**Figure 7:** Harmonic vibration X-acceleration



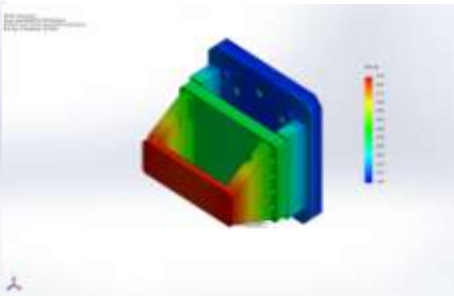
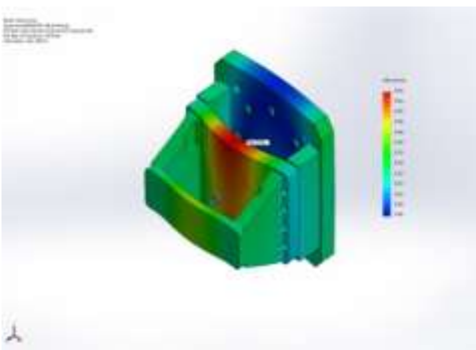


Figure 8: Harmonic vibration Y-displacement **Figure 9:** Harmonic vibration Y-acceleration



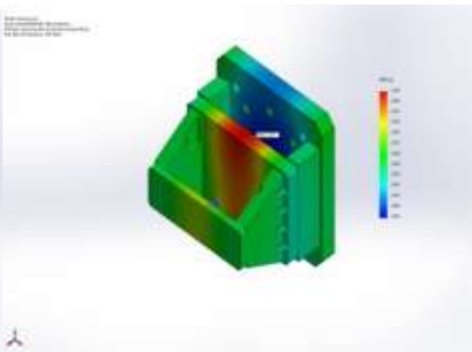


Figure 10: Harmonic vibration Z-displacement **Figure 11:** Harmonic vibration Z-acceleration

Table 2: Experimental of Results Table

Hz	N/A-X	N/A-Y	N/A-Z	Hz	N/A-X	N/A-Y	N/A-Z
5	0.301926	0.301926	0.301926	7.4382	0.66819	0.666819	0.66819
5.0116	0.303324	0.303324	0.303324	7.612	0.699775	0.699775	0.699775
5.0231	0.304728	0.304728	0.304728	7.7898	0.732853	0.732853	0.732853
5.0348	0.306138	0.306138	0.306138	7.9718	0.767494	0.767494	0.767494
5.2606	0.334217	0.334217	0.334217	8.158	0.803772	0.803772	0.803772
5.3835	0.350015	0.350015	0.350015	8.3486	0.841765	0.841765	0.341765
5.5092	0.36656	0.336656	0.36656	8.5437	0.881554	0.881554	0.881554
5.6379	0.383886	0.383886	0.383886	8.7433	0.923225	0.923225	0.923225
5.7697	0.402032	0.402032	0.402032	8.9475	0.966864	0.966864	0.966864
5.9044	0.421036	0.421036	0.421036	9.1565	1	1	1
6.0424	0.440938	0.440938	0.440938	9.3705	1	0.952355	1
6.1835	0.46178	0.446178	0.46178	9.5894	1	1	1
6.328	0.483608	0.483608	0.483608	9.8134	1	1	1
6.4758	0.506467	0.506467	0.506467	10.0195	1	1.00325	1
6.6271	0.530407	0.530407	0.530407	320	1	1	1
6.7819	0.555479	0.555479	0.555479	350	1	0.966756	1
6.9404	0.581736	0.581736	0.581736				
7.1025	0.609234	0.609234	0.609234				
7.2684	0.638032	0.638032	0.638032				

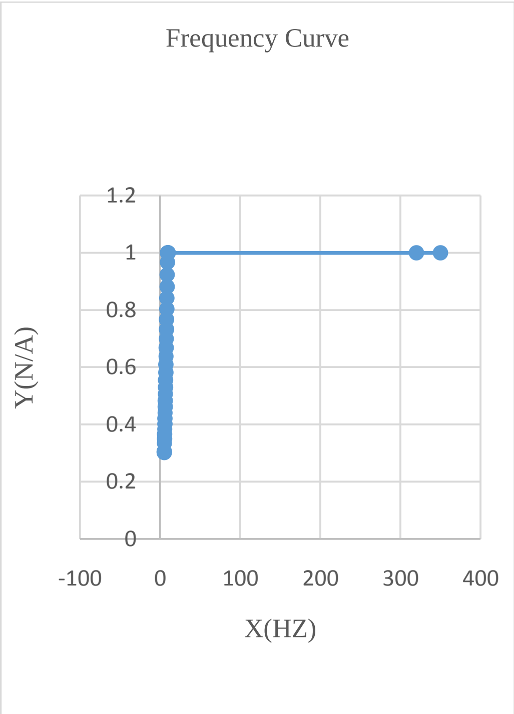


Figure 12: Experimental of frequency Vs Acceleration curve along X-axis

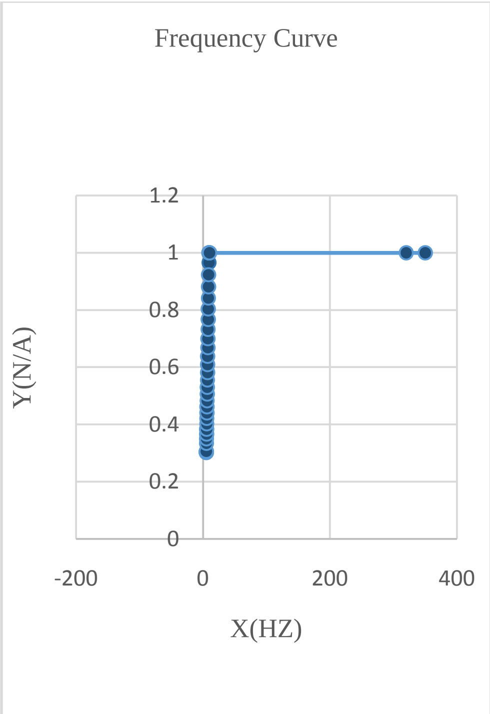


Figure 13: Simulation of Frequency Vs Acceleration curve along X-axis

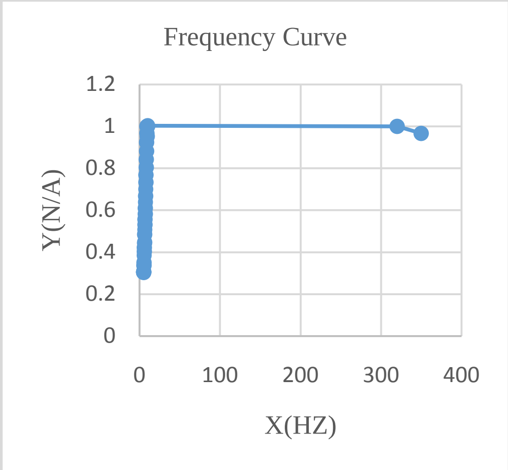


Figure 14: Experimental of frequency Vs Acceleration curve along Y-axis

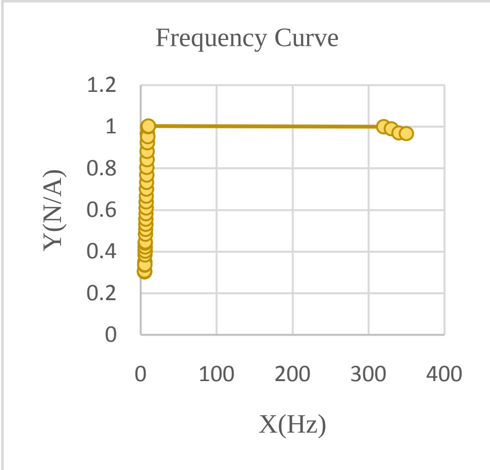


Figure 15: Simulation of Frequency Vs Acceleration curve along Y-axis

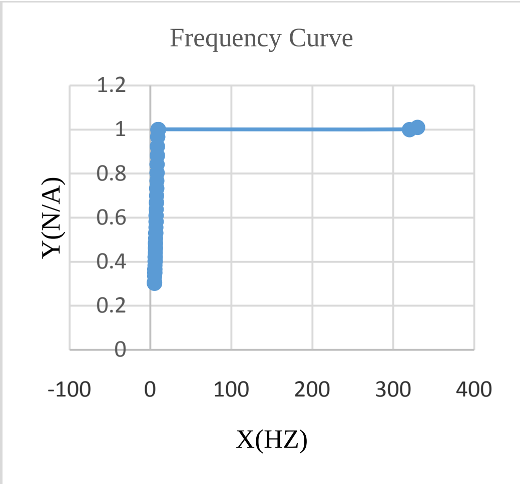


Figure 16: Experimental of frequency Vs Acceleration curve along Z-axis

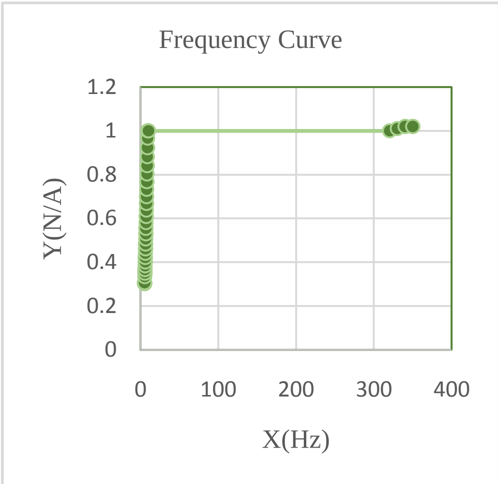


Figure 17: Simulation of Frequency Vs Acceleration curve along Z-axis

V. CONCLUSION

Harmonic analysis is carried out by using SOLIDWORKS Simulation Premium software and experimentation is done by using vibration testfixture. The acceleration is calculated at deferent frequency ranges from 5 to 350 Hz in x,y,z axes. The acceleration results in x,y,z directions by using Experimentation and simulation are compared.

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