STUDY OF VIBRATIONS PROPAGATION ON A U-SHAPED BAR FINDING THE RESONANT FREQUENCIES

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ABSTRACT: The present work aims to present few studies regarding the vibrations of a U-shaped steel band (OLC 45), meant to identify its vibration modes and the resonance frequencies. The U-shape formed band represents a simplified model of an opto-mechanical device support working under special vibrational conditions. The vibrations were induced through a “Dongling ES-6-230” shaker, controlled by a piezoelectric accelerometer having a determined sensitivity. The induced frequencies were analyzed with a piezoelectric monitor accelerometer. To reach the objectives of the studies an entire frequency array, between 5 and 500 Hz, was tested using accelerations between 0 and 80 g (784,8 m/s^2).

KEYWORDS: vibrations, frequencies, excitation, acceleration, resonance.

1. INTRODUCTION

Vibration is defined as a periodic oscillatory motion of a body or particles of an environment, carried out around a position of equilibrium, with relatively high frequency.

Vibrations meet everywhere in the universe.

They are encountered from the heartbeat, engine noise during operation or nuclear fusion that takes place in the sun.

Most of the times, we call vibrations the unwanted movements that produce relatively high mechanical demands or noises.

In general, we are interested in the vibrations that directly affect the human, such as the vibrations that affect a building following an earthquake or the vibration of a car while walking. [1,2]

Sinus vibration is a vibration to which a frequency is applied at a certain time. If we have to perform a sinus test between certain frequencies range, the test will run forward and backwards and the vibration increases or decreases with a certain rate at a certain time, with a well-defined step. [3]

In general, sinus vibration is used to find resonance frequencies of a system or assembly being tested.

Random vibration is formed by the vibration energy at all frequencies within a specified range. These vibrations are combined in amplitude and phase to form a unique signal. This signal seen on an oscilloscope shapes as a noise/sound signal. [4]

The shock is a strong vibration in general with high accelerations and braking at extremely short times over extremely short distances.

The topic of propagation of the shocks and vibrations during transport is a topic of debate by engineers together with researchers in the field of structural monitoring, automotive or acoustic sensing.

In many cases, certain systems or objects are made with the explicit functionality to withstand during transport or to carry other objects safely.

Therefore, these vibrations and shocks are an important factor for different mechanical systems.[5]

Also, in the automotive industry, tests are made to ensure a high degree of protection of the cargo carried or comfort provided to the passenger.[6]

For these reasons, the goal is to reduce the vibrations that reach the passenger compartment or in direct contact with what the car is carrying.

Analysis of vibrations and shocks have as well a significant role on the diagnosis of different components or assemblies.

If the initial vibration mode is known, by comparing it with the current one, the life time of the equipment or of the assembly can be deduced; its current state being also another useful information regarding the structure itself.[7]

All these analyses are possible using new technologies of reading, recording and measure vibrational signals. These technologies undergo continuous changes and are improved for more accurate analysis.[8]

Another topic of interest is the isolation of the mechanical vibrations produced by the exploitation of the devices from those of the environment. Similarly, the isolation and characterization of vibrations that occur during the operation of vehicles in motion, such as cars on the highway or trains on railways.

These have a negative impact on the buildings in the vicinity but also on the quality of life of the people living nearby these facilities.

Consequently, different solutions are sought to minimize this environmental problem. [9]

2. Methodology and assembly.

For this experiment was used “Dongling ES-6-230” (fig. 1) shaker unit, which run vibration tests on three different modes : sinus, random and shock.

Figure 1. Shock and vibration system

Excitation and data the response in frequency domain was carried using PCB accelerometers, piezoelectric sensors with sensitivities of 19.65 mV/g (controller) and 19.68 mV/g (monitor) (fig. 2)

Figure 2. PCB accelerometer

For the tests, one U-shaped steel bar (OLC 45), 35 cm long was designed. Data is read automatically by dedicated software and recorded via a computer in a separate chamber.

It is worth mentioning that in the laboratory there are two suspended platforms on which the equipment sits, to avoid the propagation of waves to other equipment such as the monitoring and control of the shaker.

2.1 Procedure

Firstly, the shakers front platform was designed three-dimensional via “Autodesk Inventor Professional 2019 “software to make it easier for us to design future test pieces so they could fit into the table mounting holes (fig. 3)

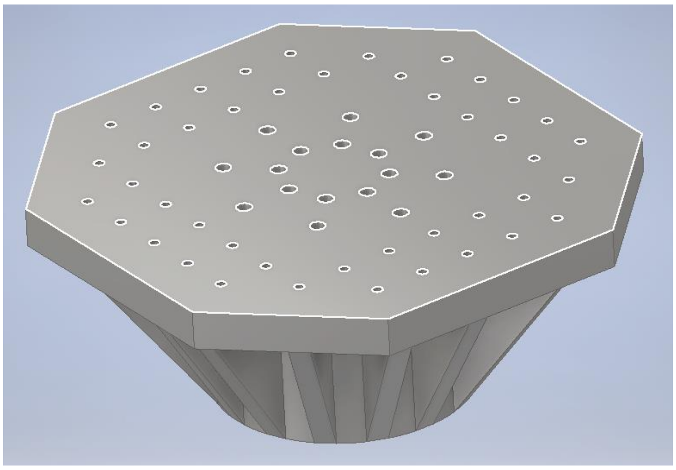


Figure 3. Shaker table

Secondly, same procedure was applied to design de U-shaped bar. It will be used to sundue the subject to shock and vibration testes to study the different effects that appear during these tests. Our bar is an OLC 45 tool steel bar with great flexibility.

The dimensions of the bar on the side on which the monitor accelerometer is mounted are 350 mm long, 50 mm wide and 5 mm thick.

After mounting the bar to XY mm position, the monitor and control accelerometers were mounted on the control table to check for differences.

The first test was performed with both accelerometers mounted on the table. This test was performed to test and provide accelerometers calibration and accuracy.

On the next step, the control accelerometer was placed on the table and the monitor accelerometer was positioned on the U-shape plate. It was sequentially was moved 10, 20 and respectively 30 centimetres towards the end of the bar (fig. 4).

Its position is represented in the figure bellow.

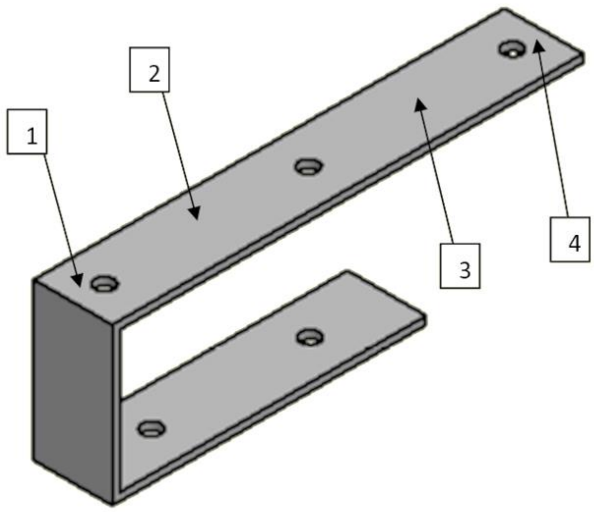
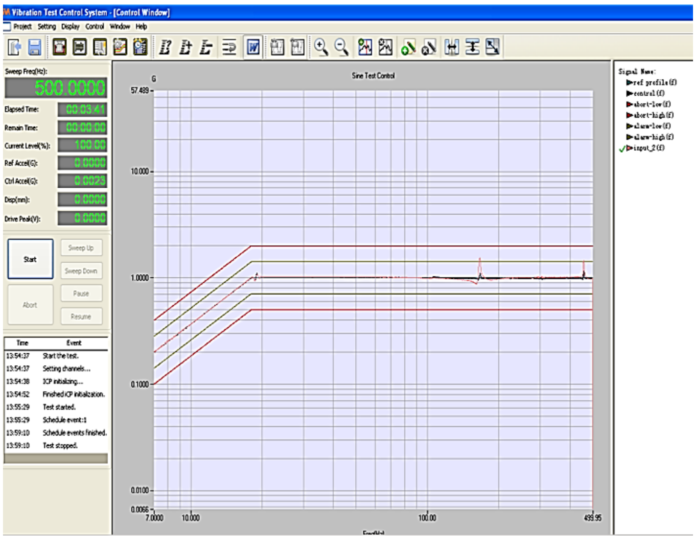


Figure 4. U-shaped band model and the monitoring accelerometer position.

Tests then performed are sinus, random and shock tests for each position on the monitor accelerometer and the data are collected and interpreted.

It is worth mentioning that the entire assembly is controlled by the “Vibration Test Control System” program (fig. 5).

The program controls the tests input parameters and at the same time it records the value given by the monitor accelerometer.



Sweep Freq(Hz): 500.0000
Elapsed Time: 00:03:41
Remain Time: 00:00:00
Current Level(%): 100.00
Ref Accel(G): 0.0000
Ctrl Accel(G): 0.0023
Disp(mm): 0.0000
Drive Peak(V): 0.0000

Time	Event
13:54:37	Start the test.
13:54:37	Setting channels...
13:54:38	ICP initializing...
13:54:52	Finished ICP initialization.
13:55:29	Test started.
13:55:29	Schedule event:1
13:59:10	Schedule events finished.
13:59:10	Test stopped.

Figure 5. Software interface

3. Experimental results.

Firstly, as shown in Figure 6, a calibration test was performed, with both accelerometers on the table, to settle the slightly different values of the two, because they cannot be positioned on the same point on the table but in two different points.

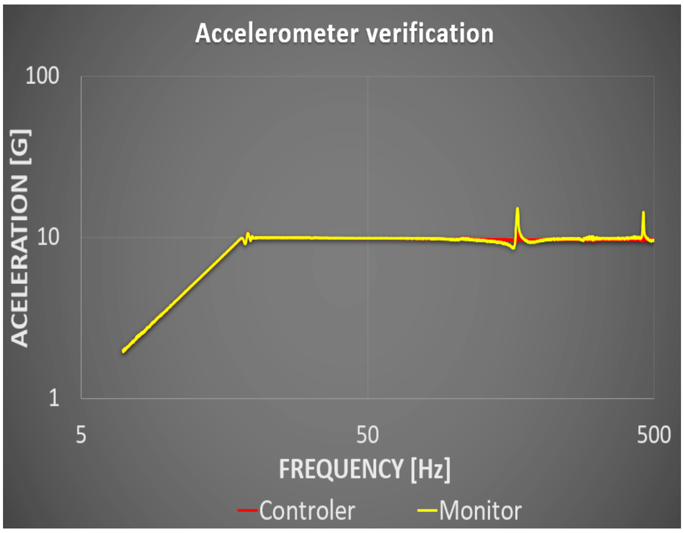


Figure 6. Accelerometer verification

In the case of the sinus test, it starts at a low frequency of 7 Hz and reaches up to 500 Hz. The acceleration is increasing up to 18 Hz and after them she remains constant up to 500 Hz with a value of 1g.

The next plot shows the data obtained in the experiment.

At the mentioned frequencies, the monitor accelerometer records much higher values than the table control accelerometer, regardless of where it is placed on the bar. Also, it can be observed that additional resonant frequencies may be found, but these are reached when the accelerometer is fixed only at 20 cm from the support base (Position 3, fig 4) at 48 Hz frequency or at 10 cm (position 2, fig 4) respectively 23 Hz and 256 Hz.

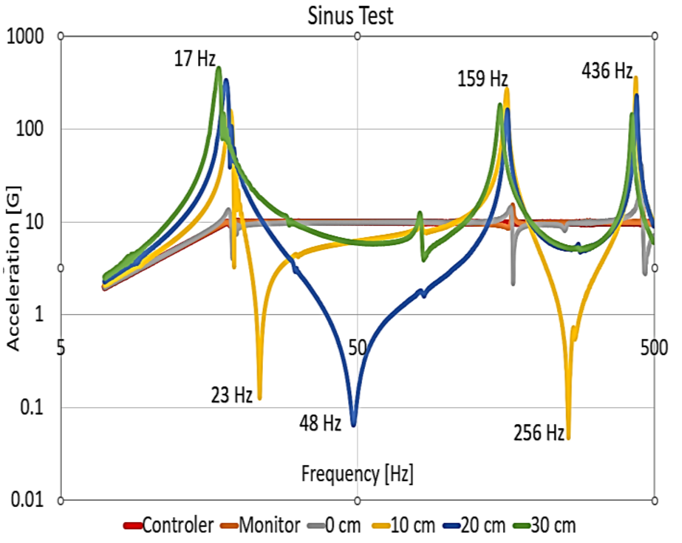


Figure 7. Sinus testing graph

Concerning the random test, it was performed between 5 and 500 Hz with accelerations varying between 0 and 0.8 g. In this case, unlike on the sinus test, the vibration doesn't have a slope, but a random value within the above-mentioned frequency range.

The same steps were carried out for the random test. In Figure 8 is presented the graphical representation of the values obtained during these tests.

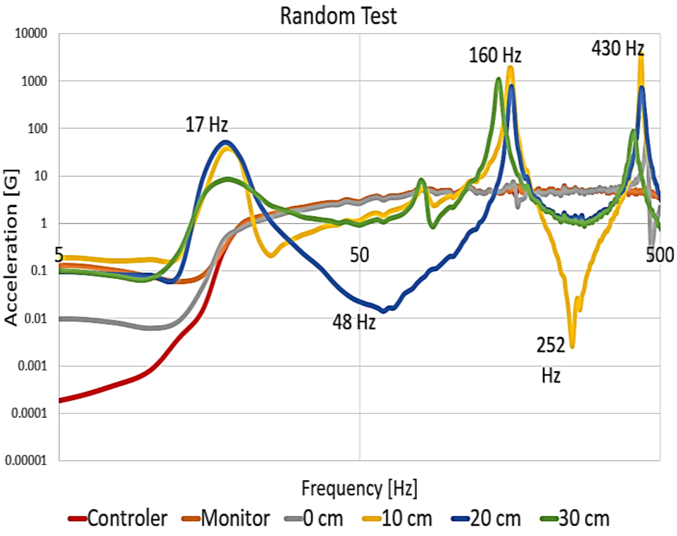


Figure 8. Random testing graph

On Figure 8 the determined resonance peaks are around the same values as in the sinus test.
This certifies that the tested U-shape band resonates around these values regardless the undergoing test type.

However, there are also significant differences between the two tests. Thus, the originate value of the acceleration, from which the test starts, is different for each position of the accelerometer on the testing band. As well, certain values of the resonance frequencies are disappearing, and the test is much noisier throughout its duration, regardless of the position of the monitor.

It is also noteworthy that the random test is generally more aggressive than a sinus test and this is also the cause of some more noisy results and damage over the structures.

The final test consisted in multiple shocks applied to the test piece.

The results can be observed in Figure 9, were an acceleration of 80 g in 13 ms was set for all experiments. Unlike the other graphs, here were considered as significant only two datasets.

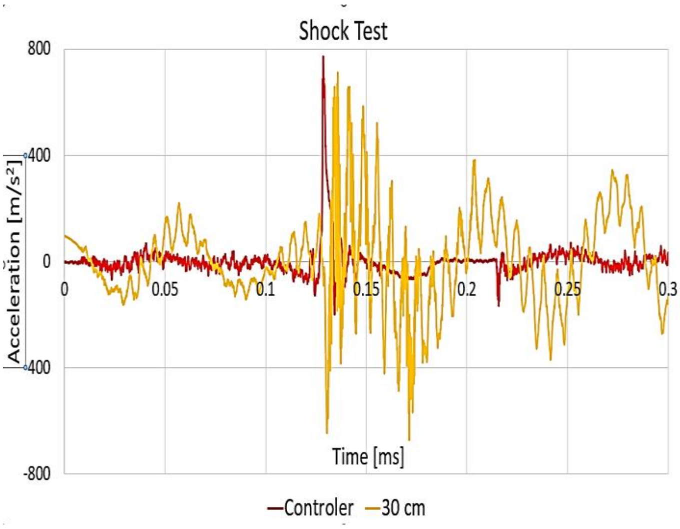


Figure 9. Shock testing graph

In the image above the red line corresponds to the control accelerometer and the yellow one corresponds to the monitor accelerometer, which is positioned 30 cm from the support point of the bar we tested.

It can be observed that the shock applied to the bar has with a delay of 0.5 ms and is goes to negative scale. This phenomenon appears because of the elasticity of the bar that bends during the movement in the opposite direction.

4. CONCLUSIONS

It can be observed that in both the sinus test and the random test, resonance frequencies are found around the same frequency ranges. This fact shows us that although there are totally different vibration modes, our bar reacts the same in those frequency ranges.

Major difference between the two plots (sine and random) can be observed.

In the sinus test, all resonance frequencies are represented by peaks that can be reached by going through a steep slope, after which the return to normal is also made by an abrupt slope. This indicates that some parameters are changing fast then return to the initial state.

In the random test it can be observed that the resonant frequencies are achieved by going through a slightly slower slope which is also characterized by a few noises and imperfections.

It can also be noticed that in the sinus test, the accelerometer positioned at 30 cm (position 4 in Fig. 4) reaches the highest acceleration at the frequency of 17 Hz and the lowest acceleration at the frequency of 436 Hz. From this it appears that at low frequencies where the displacement is high, the more we move away from the support point the more the movement will be faster and faster, but at high frequencies where the displacements are small, the more we depart from the support point, the vibrations are less felt.

This happens due to the fact that our bar is an elastic element.

At large displacements it undergoes an amplification of vibration due to inertia and the displacements on the bar are much larger than the actual movements of the shaker.

At high frequencies where the displacements are small, our bar attenuates the vibrations, taking over the applied vibrations.

It is also worth mentioning that the graphs also show areas where the monitor accelerometer mounted in different positions has lower values than the control accelerometer.

This informs us that the monitor has less movement than the control accelerometer, so our bar moves less than the table. This denotes a vibration attenuation effect and can best be observed when the accelerometer is positioned 20 cm from the tip point between the frequencies of 17-159 Hz (blue line).

In the graph resulting from the random test it can be observed that the control accelerometer reaches very low accelerations that cannot be reached by the monitor accelerometer.

The control accelerometer reaches values close to 0.0001 g. These cannot be reached by the bar because it is light and easily excited. It is influenced by the background noise in the room in which it is located.

At shocks, we also observe some phenomena that occur during the test.

It can be seen that the shock arrives with a delay of 0.5 ms and the movement occurs in the opposite direction from the shaker table. This phenomenon occurs because of the elasticity of the bar that bends during the movement in the opposite direction and because of the inertia force.

The first shock with positive movement on the y axis appears with a delay of one millisecond and is somewhat lower as intensity.

The shockwave applied on the table is 80g, and the one felt by the monitor accelerometer mounted on the bar at 30 cm from the support point recorded only 76g.

The difference between these values, comes from the absorbed shockwave.

5. REFERENCES

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