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VIBRATION CONTROL OF A CANTILEVER BEAM SUBJECTED TO SOUND WAVES

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Abstract. *Vibrations may arise in structures from different sources, such as engines, wind or sound waves. Depending on the nature and the cyclic frequency with which the source excites the structure, large amplitudes of displacement or acceleration can be generated. The vibration control of such structures has been very important as it provides an increase of its useful life, besides ensuring stability and security of these systems. This paper shows results in terms of acceleration of a cantilever beam, subjected to sound harmonic waves and white noise, using viscoelastic materials with different densities and fibrous materials, with the aim of reducing the amplitude of acceleration at the free end of the beam. With the analysis of the results was possible to determine the materials that showed the best results of acceleration levels, using low ratios between mass of the materials used as vibration dampers and the mass of the beam. The analysis of a simple cantilever beam serves as a basis for understanding the principle of operation of the passive control, from which it becomes possible to propose solutions for systems of greater complexity.*

Keywords: *Vibration control, Acceleration of beam, Acoustics materials*

1. INTRODUCTION

Noise control and vibration control are very useful nowadays in community life quality, either to avoid high level of vibration induced sound pressure in the receptors or to increase sound quality of a product, for example. Because of that, a large number of studies try to explore the interaction between vibration of a material and its sound radiation, its where vibration control connects with noise control where it is possible to reduce the sound radiation effect in a structure by reducing vibration.

This work seeks to explore the interaction between sound and vibration, but focused on the control of vibration induced by sound.

For experimental study, a steel beam, fixed at one end and free at the other was exposed to a diffuse sound field in a reverberant chamber to obtain the magnitude of acceleration at the free end due to acoustic excitation.

After measuring the accelerations at the free end of the beam, materials with different acoustic properties were used to lower sound energy which reaches the beam in order to control the vibration induced sound.

2. METHODOLOGY

2.1 Sample characterization

Three samples were used for testing as indicated in Table 1. They were chosen because of different characteristics such as density and porosity, for example. All samples have 54 cm long and 3 cm wide.

Table 1. Sample characterization

Sample	Characterization	Thickness	Density
1	Resilient material; Smoother than sample 2	1 cm	51.60 kg/m^3
2	Material absorption; Is rough	0.2 cm	172.8 kg/m^3
3	Viscoelastic materials. Smoother than sample 1	1cm	38.27 kg/m^3

2.2 Methodology of the tests

All measurements were performed in a reverberant room with 207 m^3 in the acoustics laboratory of the Federal University of Santa Maria. This room, usually used to evaluate sound power and sound absorption coefficients, has been chosen due to the high sound insulation from the outside to the inside. Furthermore, it has a diffuse sound field around the beam. This is justified, since only of interest in this study, the effect of the acoustic field on the beam and not the determination of relation between the direction of sound incidence and the response of the beam.

In order to determine the attenuation of vibration in the beam were used different sorts of materials listed in Table 1 and the instrumentation described below.

Software Pulse of the B&K was used to analyze the signals, a monoaxial accelerometer, type 4513B, a microphone for diffuse field model 4942A021, a power amplifier, the omnidirectional sound source and a beam of iron stuck on a table, keeping the other free end. Figure 1 shows how these devices were placed within the reverberation chamber.

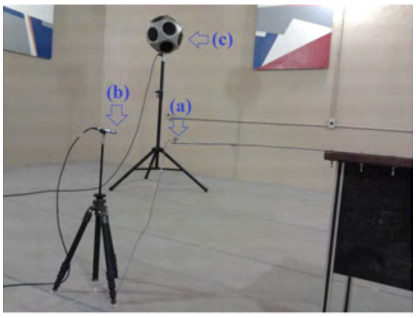

Figure 1. Beam with acelerometer (a), microphone (b) and omnidirectional sound source (c) in the reverberant room.

Following the assumption proposed in this paper, the beam was induced acoustically by omnidirectional sound source, with a white-noise signal. First, were induced vibrations in the beam, without any additional material to find their resonant frequencies. From this, acoustic materials were used, one at a time in the top and bottom of the beam to verify the attenuation of vibration of the beam.

Thereafter, the beam was analyzed using the material that best promoted the reduction of vibrations, placed differently on the beam.

The responses of the accelerations only of the support were also analyzed in order to verify if the vibrations of the support influenced on response of the beam. There have also been careful to keep the sound pressure level equal for all tests, with the equivalent sound pressure level of 75 dB inside reverberation chamber.

3. RESULTS OF THE ANALYSIS

The results of the measurements of the vibration of the beam are shown in Figure 2 below, where you can see that the largest amplitude of vibration of the beam occurs at approximately 191 Hz com 28.4 cm^2/s. Also other natural frequencies are visible in 314Hz and 466Hz.

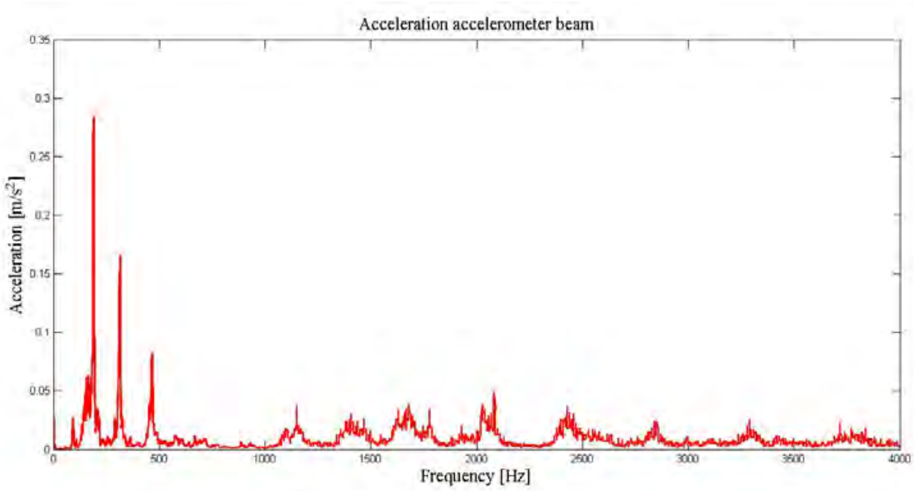

Figure 2. Frequency response of the beam in terms of acceleration induced by noise white.

To verify if the support of the beam influences these resonant frequencies, the beam was removed from the support

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by performing measurements of accelerations only support. The result is shown in Figure 3 where one can see that the support does not influence the results of acceleration of the beam.

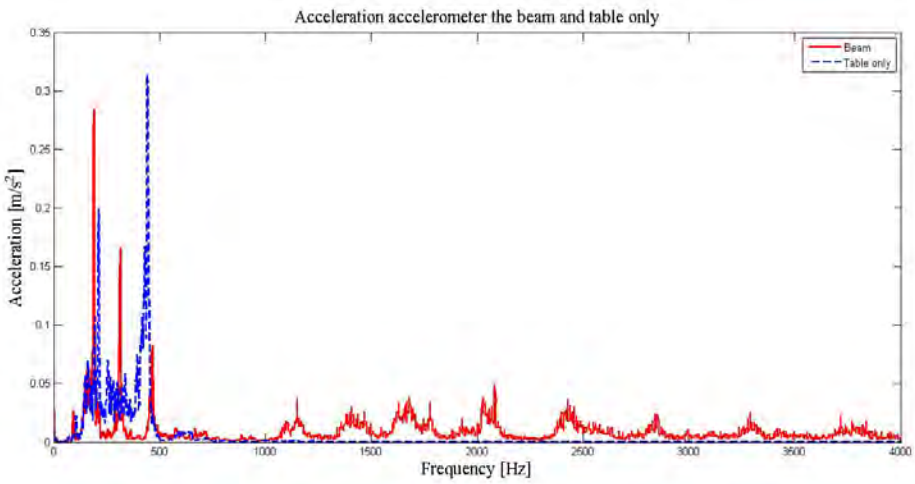

Figure 3. Frequency response of the support only (in blue) in terms of acceleration induced by noise white.

Then, it started the tests with the samples described in Table 1. For the sample of viscoelastic material, the acoustic efficiency of attenuation in the amplitude of vibration of the beam, in the frequency band of major interest (between 100 Hz and 500 Hz), the attenuation was about $8.9cm^2/s$ (31.34 %) at approximately 191Hz. It is observed in Figure 4 that the resonant frequency is shifted somewhat downward, around 180 Hz, which may be due to the small increase in mass of the beam.

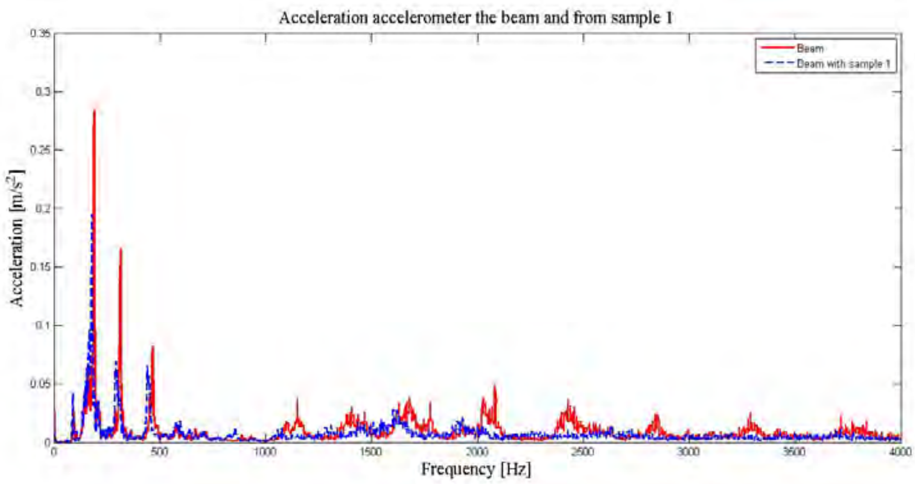

Figure 4. Comparison between frequency response of the beam with sample 1, in terms of acceleration induced by noise white.

Figure 5 shows how the sample 1 was placed in the beam.

Figure 5. Sample 1 in the beam.

The second test sample consisting of a material normally used against impact noise. For this case, was not obtained good results when compared with other cases. Figure 6 shows the results of acceleration levels obtained for this case, with

ISSN 2176-5480

an attenuation of 7.4 cm^2/s (26.06 %) and a moderate amplification on the magnitude of acceleration at a frequency of 466Hz.

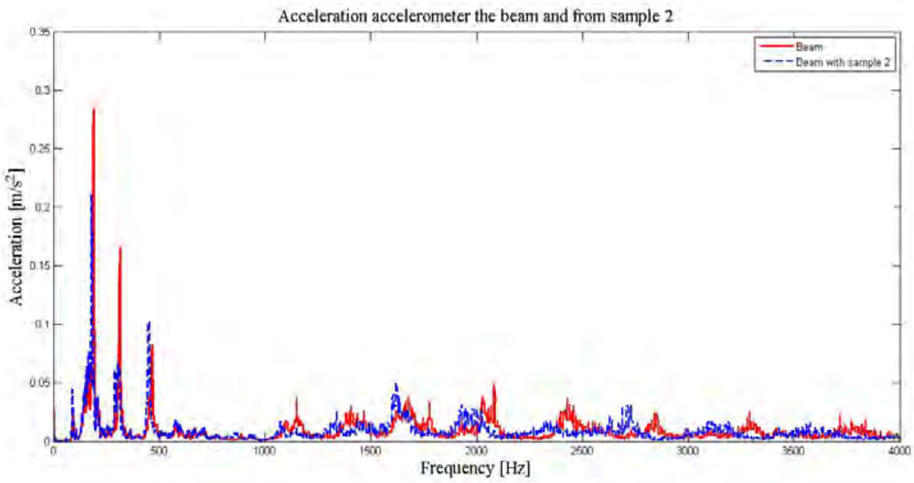

Figure 6. Comparison between frequency response of the beam with sample 2, in terms of acceleration induced by noise white.

Figure 7 shows the sample 2 in the beam.

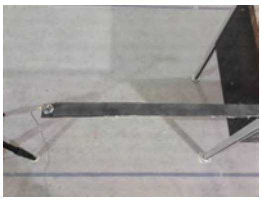

Figure 7. Sample 2 in the beam.

The sample 3 of absorbent material, which obtained better results for the attenuation in the frequency range of interest, consists of a polymers wool, the polyethylene terephthalate or simply PET. Figure 8 shows the results,where the vibration amplitude attenuation was 21.75 cm^2/s (76.58 %).

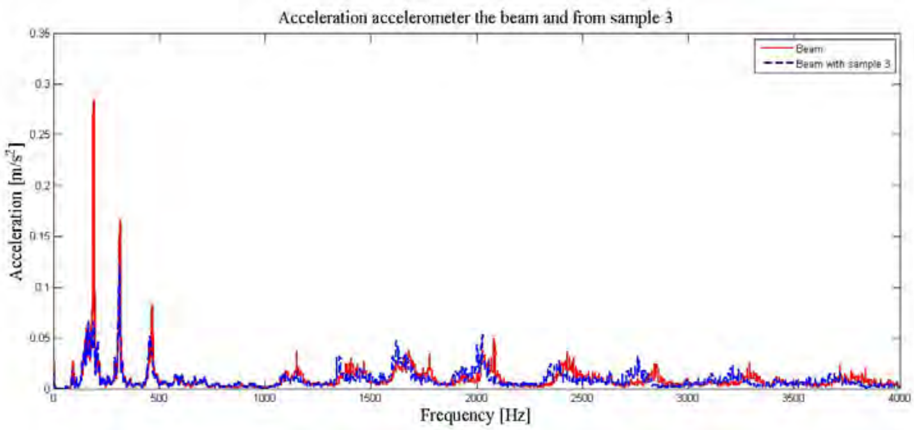

Figure 8. Comparison between frequency response of the beam with sample 3, in terms of acceleration induced by noise white.

The Sample 3 installed in the beam is shown by Figure 9.

Investigating a little more this sample was also performed another test, but only with the sample at the bottom of the beam. Also, comparing the results of sample 3 on both sides of the beam with sample 3 only below beam, the latter showed more satisfactory results. Figure 10 shows behavior of the beam, in which the attenuation was 22.07 cm^2/s (77.71 %).

Table 2 summarizes the percentage attenuation of the vibrations induced by sound waves on the beam, for the three cases studied.

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Figure 9. 3 sample in the beam

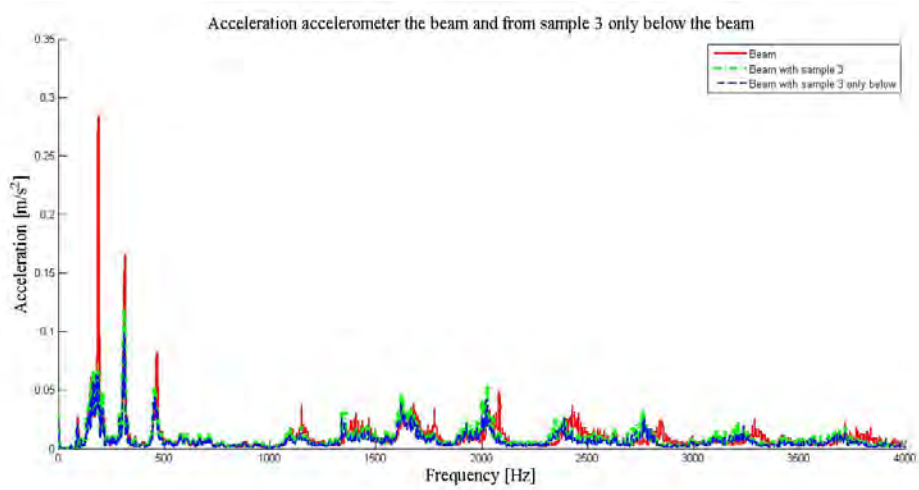

Figure 10. Comparison between frequency response of the beam with sample 3 only below of the beam, in terms of acceleration induced by noise white.

Table 2. Percentage attenuation of the vibrations induced by sound waves on the beam

Sample	Max without	Attenuation cm^2/s	Reduction %
1	28.4	8.9	31.34
2	28.4	7.4	26.06
3	28.4	21.75	76.58
3 only below	28.4	22.07	77.71

4. CONCLUSION

In view of the results presented, this work reached its goal in finding a material that best mitigate the magnitude of the induced vibration sound on a beam for some of the same natural frequencies. After the tests, it was found that the use of sample 3 (wool polymer) resulted in lower levels of acceleration to a frequency band lower. On the other hand, sample 1 was more effective in attenuating the amplitude of vibration, although tiny, for higher frequencies. This leads to the use of two different materials to attenuate vibrations in different frequency bands. It would be appropriate to use, for example, a combination of the material 1 and material 3. Although not shown here, the results are motivators.

For sample 3, the result in the attenuation of the amplitudes of vibration of the beam, using one or both sides of this, were nearly equal, with a slightly better efficiency when the sample 3 is placed only below the beam. Also, comparing the results of sample 3 on both sides of the beam with sample 3 only below beam, the latter showed more satisfactory results.

5. REFERENCES

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6. RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper.