

Experimental study of the attenuation properties of metal-viscoelastic bi-layered materials

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Abstract. Phononic crystals (PCs) are multi-layered materials with functional elastic wave band gaps where propagation of vibration within these band gaps is restricted. PCs have vibration attenuation properties dependent on their periodic structure and material constituent. In this study, the band gap and vibration attenuation of a one-dimensional PC subjected to longitudinal vibration were evaluated experimentally. Two bi-layered specimens composed of Aluminum and a Silicone Rubber (Elite double 8) were manufactured and tested. The specimens were subjected to vibration from an electrodynamic shaker to obtain pseudo-transfer functions.

1. Introduction

Extreme applications in construction drove to a high demand on engineered materials that have enhanced mechanical properties such as high-energy absorbance, vibration control, and acoustic shielding. Mechanical metamaterials (MMs) incorporating viscoelastic constituents hold a great promise to solve extreme loadings problems. The impetus for the incorporation of viscoelastic constituents in MMs mainly stems from their strong energy absorption property, their natural damping and the possession of a low elastic modulus which allows reaching practical low-frequency band-gaps (<20 kHz) that human body is highly affected by. Several researchers introduced simple rheological models (e.g., Kelvin model [1, 2], Zener model [3-5], generalized Maxwell model [6]) in order to simulate material damping pertinent to the bulk material dissipation of MMs. Many studies numerically observed that viscoelasticity not only attenuates wave transmission but also modifies the frequency band-gaps which are substantially displaced and widened [1-6].

Compared to existing and significant numerical research efforts targeting linear viscoelastic MMs, only a limited number of experimental studies [3, 7-11] have validated the aforementioned numerical models. The paucity of experimental results is mainly attributed to the complexities related to material viscosity.

In this paper, we will discuss the experimental results of the electrodynamic shaker test on bi-layered specimens composed of a metallic component: Aluminum and a viscoelastic component: Silicone rubber (Elite double 8).

2. Methodology

The polymers have been mixed and cast in the Structural Laboratory at Qatar University, as illustrated in Figure 1.





Figure 1. Casting of silicone rubber (Elite double 8) after vigorous mixing.

Cylindrical specimens have been manufactured using cylinders of Aluminum and Elite double 8. Two specimens have been tested. Specimen “A” had a unit cell of 10 mm of Aluminum and 10 mm of Elite double 8, while specimen “B” had a unit cell of 5 mm of Aluminum and 10 mm of Elite double 8. The experimental set up for the vibration test is shown in Figure 2. The specimens were placed on a circular base connected to the force transducer and were attached to an accelerometer at the top. Consequently, the force transducer and accelerometer supplied the input and the output signals of the specimen, respectively. These linear perturbation tests were performed by applying chirp sine sweep signal to the specimen up from 1 Hz to 20 kHz. The pseudo-transfer functions were determined from the fast Fourier transform (FFT) ratio of acceleration and force signal as below:

$$FRF(\omega) = \frac{|A_{out}(\omega)|}{|F_{in}(\omega)|} \quad (1)$$

where $|A_{out}(\omega)|$ and $|F_{in}(\omega)|$ represent the frequency spectrum of acceleration and force signals, respectively.

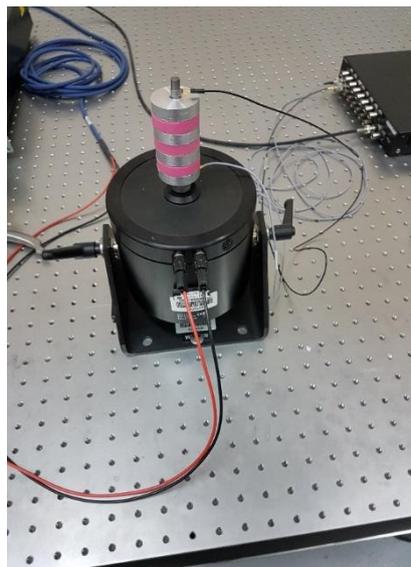


Figure 2. Vibration shaker experiment set-up for pseudo-transfer function test (From top: Accelerometer, Specimen, Force transducer, Shaker).

3. Results and discussion

The input and output signals for specimen “A” measured by the force transducer and the accelerometer, respectively, are shown in Figure 3.

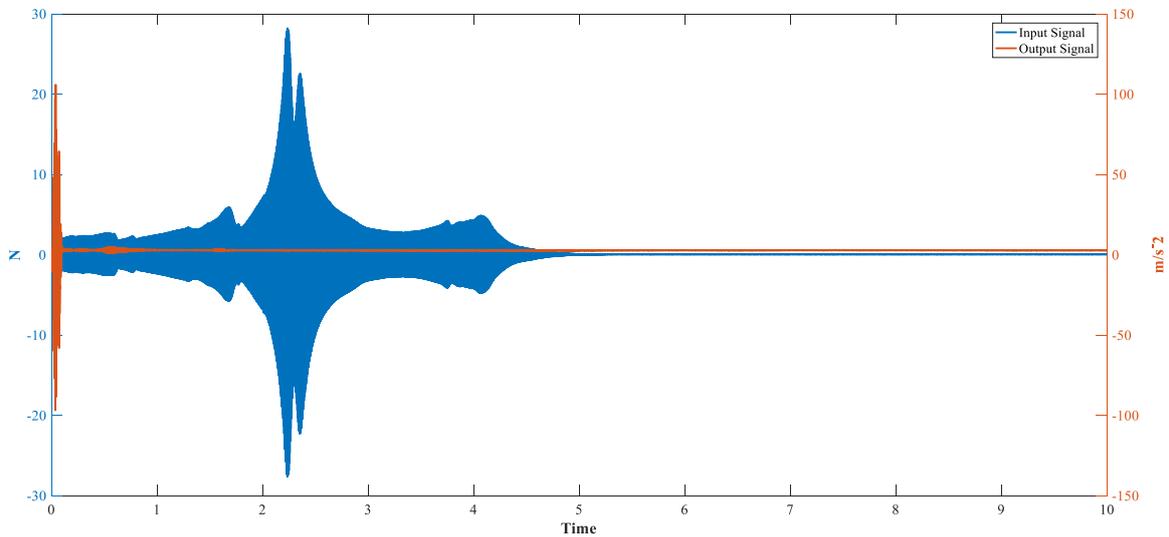


Figure 3. The input signal (blue) and the output signal (green) for specimen “A”.

The pseudo-transfer function for specimen “A” is shown in Figures 4. It can be observed that there was a drop in the frequency response at 415 Hz. Then, there was a plateau beyond the frequency of 544 Hz for specimen “A”. Observing this FRF of the periodic material, we could see the formation of the bandgap in the frequency range of 0-1500 Hz.

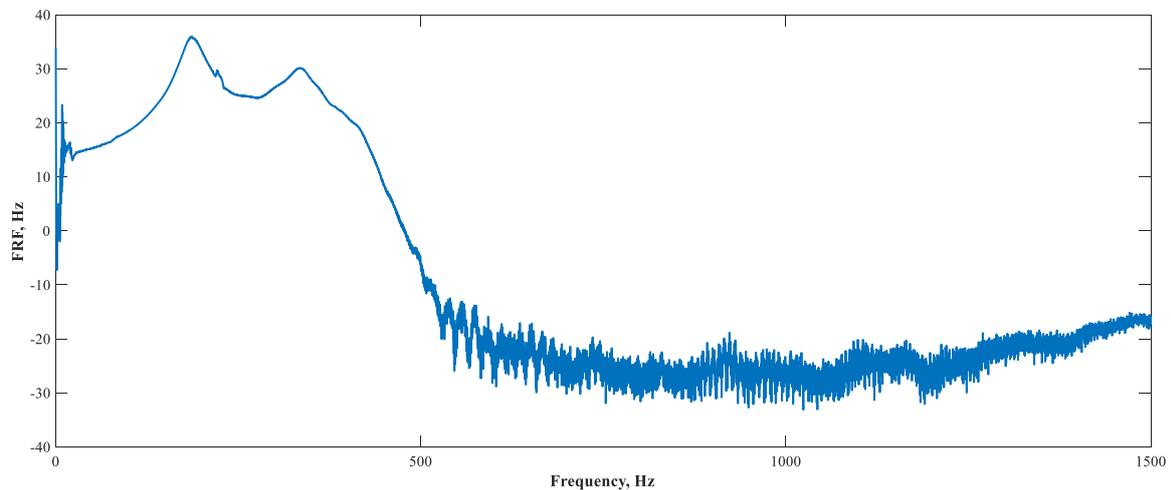


Figure 4. Frequency response function of the specimen “A”.

The input and output signals for specimen “B” measured by the force transducer and the accelerometer, respectively, are shown in Figure 5.

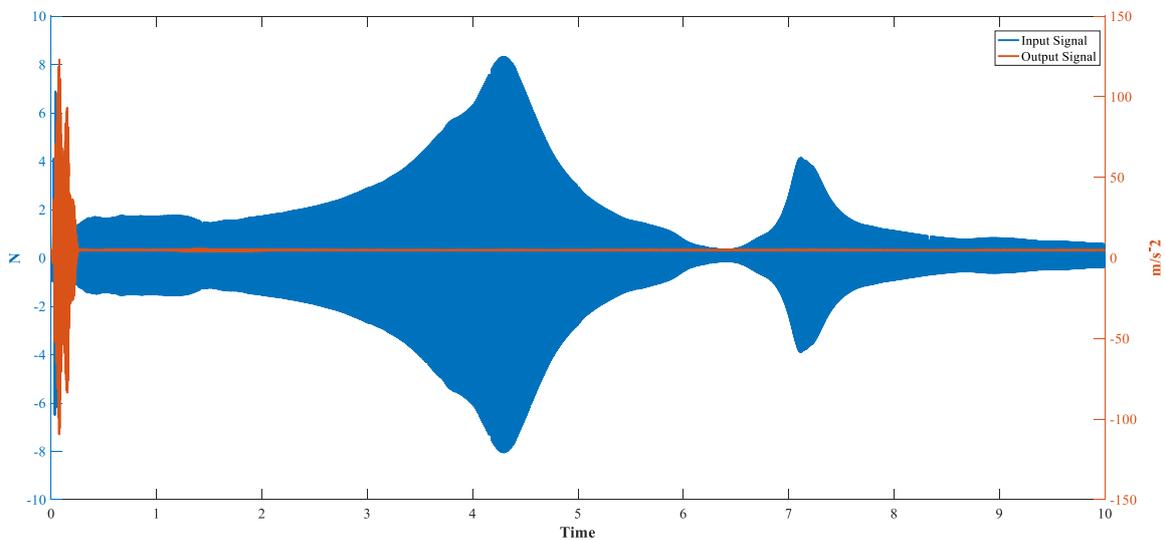


Figure 5. The input signal (blue) and the output signal (green) for specimen “B”.

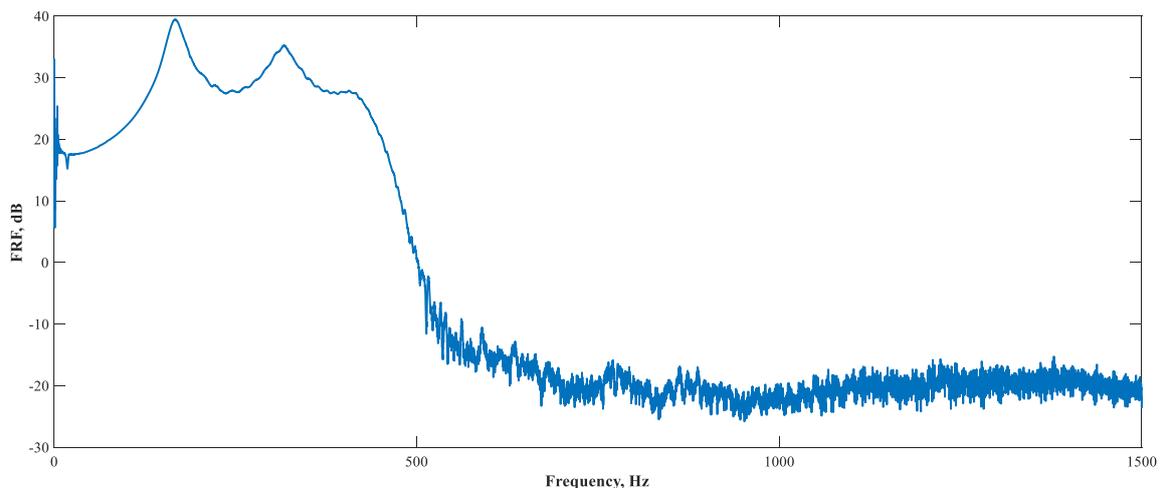


Figure 6. Frequency response function of the specimen “B”.

The pseudo-transfer function for specimen “B” is shown in Figures 6. It was observed that there was a drop in the frequency response at 407 Hz. Then, there was a plateau beyond the frequency of 500 Hz for specimen “B”. Investigating the FRFs in Figures 4 and 6, one can find the attenuation in the frequency range start earlier with increasing the viscoelastic material ratio.

4. Conclusion

Phononic crystals with a viscoelastic component have been experimentally investigated in this paper. PCs have vibration attenuation properties dependent on their periodic structure and material constituent. In this study, the band gap and vibration attenuation of a one-dimensional PC subjected to longitudinal vibration were evaluated experimentally. Two bi-layered specimens composed of Aluminum and a Silicone Rubber (Elite double 8) were manufactured and tested. The specimens were subjected to vibration from an electrodynamic shaker to obtain pseudo-transfer functions. Experimental test results showed a clear drop in frequency response at 415 Hz and 407 Hz for

specimen “A” and “B”, respectively. That was followed by a plateau beyond the frequency of 500 Hz. This is an ongoing research effort, additional tests are required in order to determine the parameters that influence the optimal vibration attenuation.

5. Acknowledgments

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6. References

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