Experimental and Numerical Investigation of Sonic Crystal and Acoustic Panel

A THESIS

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Preeti Gulia

DECLARATION

I hereby declare that the entire work embodied in this thesis is the result of investigations carried out by me in the **School of Engineering**, Indian Institute of Technology Mandi, under the supervision of **Dr. Arpan Gupta**, and that it has not been submitted elsewhere for any degree or diploma. In keeping with the general practice, due acknowledgements have been made wherever the work described is based on finding of other investigators.

Place: IIT Mandi   Signature:

Date: September 5, 2019   Name: Preeti Gulia

Indian Institute of Technology Mandi

CERTIFICATE

I hereby certify that the thesis entitled **"Experimental and Numerical Investigation of Sonic Crystal and Acoustic Panel"** submitted by Ms. Preeti Gulia, a Research Scholar in School of Engineering, Indian Institute of Technology Mandi, for the award of **DOCTOR OF PHILOSOPHY,** is a record of an original research work carried out by her under my supervision and guidance. The thesis has fulfilled all the requirements as per the regulations of the institute. The results embodied in this thesis have not been submitted to any other university or Institute for the award of any degree or diploma.

Signature:

Name of the Guide: Dr. Arpan Gupta

Date: September 5, 2019

ABSTRACT

Sonic crystal (SC) and acoustic panels have been successfully used for noise attenuation in various applications. SC is a periodic arrangement of scatterers embedded in a homogeneous material. Their ability to prevent sound wave from propagating in a particular range of frequency (band gap) demonstrates their use as potential noise barriers.

In this work, Sound transmission loss (STL) and band gaps are computed forSCusing various methods such as plane wave expansion method (PWE), Webster's horn method, and finite element (FE) method. FE simulations are performed to study the effect of the location of sidewalls on the performance of SC. Experiments are also performed to validate the FE simulation results. It is found that the outer wall ofSCsituated at a distance of half of the periodic constant from the center of end scatterers provides wide band gap and high STL. The optimal position of walls along withSCis used to design an enclosure for hard disk which experimentally results in 9 dB of noise reduction from a noisy hard disk.

Analytical methods are developed to analyze the acoustic panels. Double and triple panels separated by the air gaps offer high sound reduction due to multiple reflections and discontinuities in the path of wave propagation. Finite element simulations are performed for sound propagation through panels using acoustic structure interaction. The FE simulation predictions are validated by the exact analytical results. It is found that, due to the 1D periodic structure made by multiple panels (such as a triple or double panel), there can be sudden losses in sound attenuation, also referred to Bragg's dip in the STL curve.

There can also be sound leakage through the panel vibration, where vibrating panel acts as a sound source. To improve the performance of the panel, a novel acoustic panel is proposed by inserting SC in the panel. The porous material is used as a filler to increase the damping in the system. Both experimental and FE simulations are performed for various cases. It is found that the porous material helps to overcome Bragg's dips. SC has been designed according to the noise frequency content and inserted in the air cavities between the panels. Inserting SC in the panels significantly improves the STL (~10 dB - experimentally) through the novel panel, particularly in the band gap region which is centered around Bragg's frequency. However, it comes at the cost of making the panel somewhat bulky.

Application of SC can be further improved and made more compact by using the concept of local resonance in the scatterers. It leads to the study of locally resonant sonic crystal (LRSC), which mainly addresses the problem of low-frequency noise. To shift the band gap at low frequency in the acoustic panel, C-type scatterers are used to make a locally resonant periodic structure between the panels. C-type scatterer acts as a Helmholtz resonator and creates local resonance at a frequency lower than the Bragg's frequency. The result shows that insertion of C-type scatterers along with absorbing wool between the panels increase the STL at low frequencies as well as at high frequencies. The combined structure of the acoustic panel with locally resonant structure and absorbing wool provides an additional STL of 15 dB at low frequencies.

Lastly, a mass in mass locally resonant system is also analyzed using a numerical and analytical method. This study is performed to calculate the band gap and transmission coefficient of a mass-spring local resonant system and it is found that structure shows two band gaps below 500 Hz with negative effective properties.

TABLE OF CONTENTS