Acoustic Characterization of Helmholtz Resonators based Metamaterial

A THESIS

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Declaration by the Research Scholar

This is to certify that the Thesis entitled **“Acoustic Characterization of Helmholtz Resonators based Metamaterial”,** submitted by me to the Indian Institute of Technology Mandi for the award of the Degree of Master of Science (by research) is a bonafide record of research work carried out by me under the supervision of ***Dr. Arpan Gupta.*** The content of this Thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any Degree or Diploma.

Date:

Place: Mandi

Signature: Sourabh Dogra

Declaration by the Research Advisor

This is to certify that the Thesis entitled **"Acoustic Characterization of Helmholtz Resonators based Metamaterial** submitted by ***Sourabh Dogra*** to the Indian Institute of Technology Mandi for the award of the Degree of Master of Science (by research) is a bonafide record of research work carried out by him under my supervision. The content of this Thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any Degree or Diploma.

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Abstract

Noise control is one of the major challenges with rapid urbanization due to its adverse effects on living beings. To keep the noise level up to an adequate limit, various noise insulation materials such as sound insulation panels, and noise barriers are available. But transmission loss of these materials is based on the mass law, which intends to increase the mass and volume of the materials to achieve higher transmission loss, and thus these materials cannot be used in lightweight applications. Therefore, controlling the sound of lower frequencies is always a major concern in acoustics. The sound attenuating properties of these materials should be known when choosing a suitable material for a particular case. The sound attenuation characteristics of these materials are determined by calculating the different coefficients such as absorption coefficient, reflection coefficient, and transmission coefficient. A design of a four-microphone impedance tube of brass is proposed to estimate these coefficients of noise absorbing materials. Transfer matrix formulation and two-load boundary condition method are used to calculate the absorption coefficient, reflection coefficient, and transmission coefficient. The accuracy of the impedance tube is confirmed by comparing the experimental data with the data provided by an accredited laboratory.

The acoustic metamaterial is an artificially engineered structure that provides an extraordinary sound absorption property that is not achievable with conventional materials. A design of an acoustic metamaterial plate with inbuilt Helmholtz resonators is proposed. Helmholtz resonator is a well-proven design for the attenuation of the desired frequency. This is achieved by altering the geometric parameters of the Helmholtz resonator. The plate was made of Polylactic acid (PLA) and fabricated using an additive manufacturing technique. It consists of Helmholtz resonator-shaped cavities of different sizes. We have analyzed the acoustic properties of the plate experimentally in impedance tube as well as numerically in COMSOL Multiphysics. The plate behaves as a reflective surface at lower frequencies, while at higher frequencies, the resonators start absorbing the sound. There is an additional

advantage of being lightweight because of the Helmholtz resonator-shaped cavities built inside the plate. Thus, these types of metamaterial plates can find their application in the design sector, requiring lighter materials with high sound transmission loss. Finally, to control the sound of the lower frequencies in the duct, a Helmholtz resonator arrangement in series and the parallel combination is proposed. The arrangement is studied numerically as well as theoretically. This arrangement can broaden the attenuation band over the different frequencies band. The proposed arrangement can control the noise coming from the ducts due to air movement in the ventilation system.

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