Inverse design of a Helmholtz resonator based low-frequency acoustic absorber using deep neural network

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ABSTRACT

The design of low-frequency sound absorbers with broadband absorption characteristics and optimized dimensions is a pressing research problem in engineering acoustics. In this work, a deep neural network based inverse prediction mechanism is proposed to geometrically design a Helmholtz resonator (HR) based acoustic absorber for low-frequency absorption. Analytically obtained frequency response from electro-acoustic theory is deployed to create the large dataset required for training and testing the deep neural network. The trained convolutional neural network inversely speculates optimum design parameters corresponding to the desired absorption characteristics with high fidelity. To validate, the inverse design procedure is initially implemented on a standard HR based sound absorber model with high accuracy. Thereafter, the inverse design strategy is extended to forecast the optimum geometric parameters of an absorber with complex features, which is realized using HRs and a micro-perforated panel. Subsequently, a quasi-perfect low-frequency acoustic absorber having minimum thickness and broadband characteristics is deduced. Importantly, it is demonstrated that the proposed absorber, comprising four parallel HRs and a microperforated panel, absorbed more than 90% sound in the frequency band of 347–630 Hz. The introduced design process reveals a wide variety of applications in engineering acoustics as it is suitable for tailoring any sound absorber model with desirable features.

I. INTRODUCTION

Noise is considered as one of the pervasive environmental pollutants that adversely affects human health and wildlife. In particular, low-frequency sound emission from aircraft, road traffic, wind turbines, and air conditioning units can propagate a long distance with less attenuation and can cause annoyance, sleep disturbance, fatigue, cardiovascular problems, and hearing impairment.[1–5] Thereby, effective mitigation of low-frequency noise is a challenging problem in engineering acoustics. Indeed, natural structures such as trees and vegetation or artificial structures such as walls or highway barriers are not sufficient to stop the propagation of low-frequency noise.[6,7] Even traditional passive absorbers such as fibrous or porous materials are needed to be extremely bulky to attenuate this low-frequency noise.[8] Resonant absorbers such as Helmholtz resonators (HRs)[9–11] and microperforated panels (MPPs)[12–14] are widely used as alternatives to traditional sound absorbers for low-frequency applications. However, a tradeoff for this low-frequency sound abatement is the requirement of long cavities; hence, alterations to the conventional resonant absorbers are essential. In this regard, Sakagami *et al.*[15] combined MPPs of different absorption characteristics to extend the absorption spectrum to the low-frequency regime. Later, Li *et al.*[16] suggested a parallel arrangement of perforated panels to absorb low-frequency sound. Moreover, the modifications of cavity shape[17] and arranging MPPs of different cavity depths[18] are found to be effective. Meanwhile, tailoring the geometry of conventional Helmholtz resonators proved to be effective for low-frequency sound absorption with minimized thickness.[19–23] Recently, Guo *et al.*[24] achieved quasi-perfect sound absorption in an absorber comprising a parallel array