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Sound absorption properties of microperforated panel with membrane cell and mass blocks composite structure

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ABSTRACT

Microperforated panel (MPP) absorbers have been widely used in noise reduction and are regarded as a promising alternative to the traditional porous materials. However, the absorption bandwidth of a single-layer MPP is insufficient to compete with the porous materials. In order to improve the sound absorption ability of the single-layer MPP, membrane cell and mass blocks composite structure is introduced. Sound absorption properties of the MPP with membrane cell and mass blocks composite structure are studied by the impedance tube experiment. Results show that Membrane cell and mass blocks can change the sound absorption of MPP by introducing additional absorption peaks and valleys. To illustrate the role of membrane and mass in the sound absorption process, the acoustic properties of aluminum plate, aluminum plate with membrane, aluminum plate with membrane and mass are further investigated. When the membrane and mass are added, the sound resistance of the structure is increased and sound reactance of the structure jump abruptly near the sound absorption. This is mainly due to the local resonance of the membrane and mass. Therefore,combined with the characteristics of the sound absorption of MPP, the membrane and mass can further improve the sound absorption properties of the structure. Excellent performance of sound absorbing structure will be obtained by rational design of MPP, the size of membrane cell, the number, size and position mass blocks.

1. Introduction

In recent years, noise control has received much attention for improving living environments. A microperforated panel (MPP) absorber has become widely known as the most attractive alternative for the next generation sound absorbing material [1]. The MPP is first proposed by Maa, who has established its theoretical basis and design principle [2–4]. The MPP absorber is a thin panel or membrane less than 1 mm thick with perforation of less than 1% perforation ratio with air-back cavity and a rigid backing [5]. The fundamental absorbing mechanism of the MPP absorber, which is typically backed by an air cavity and a rigid wall, is Helmholtz-resonance absorption [6]. This type of absorption is mainly due to frictional loss in the air flow of the apertures [6]. With the rapid development of processing technologies and computational methods, MPP sound absorption theory has also been further development [7–9]. But the sound absorption bandwidth of the single-leaf MPP is usually limited to about two octaves [2–4]. In order to heighten the absorption property of MPP, Maa has proposed a double-leaf MPP backed by a rigid-back wall with an air-cavity [10]. Sakagami et al. have studied the sound absorption characteristics of a single-leaf MPP absorber backed by a porous absorbent layer and a double-leaf structure with MPP and permeable membrane [11,12]. Qian et al. have investigated the acoustical properties of MPP with ultra-micro perforations based on MEMS technology [13]. Results show that better absorption capability can be given with MPP by using an ultra-micro perforation [13]. Liu and Herrin have studied the sound attenuation performance of MPP with adjoining air cavity [14]. The resulting sound pressure fields indicated that partitioning the adjoining air cavity increase the overall sound attenuation due to the MPP by approximately 4 dB [14]. Wang and Huang have investigated the acoustic properties of parallel arrangement of multiple MPP absorbers with different cavity depths [15]. Compared with single MPP absorber, the absorber array requires lower acoustic resistance for good absorption, and the resonance frequencies shift due to inter-resonator interactions [15]. Tao et al. have studied the sound absorption of a finite MPP backed by a shunted loudspeaker [16]. The results show that the composite absorber is more effective than the traditional MPP absorbers especially at the low frequency when there is a length constraint thanks to the resonance absorption provided by the shunted loudspeaker [16]. Li et al. have studied the perforated panel sound absorber with extended tubes from the perforations [17]. On the basis of previous studies,we have studied the sound absorption of a composite MPP sound absorber with

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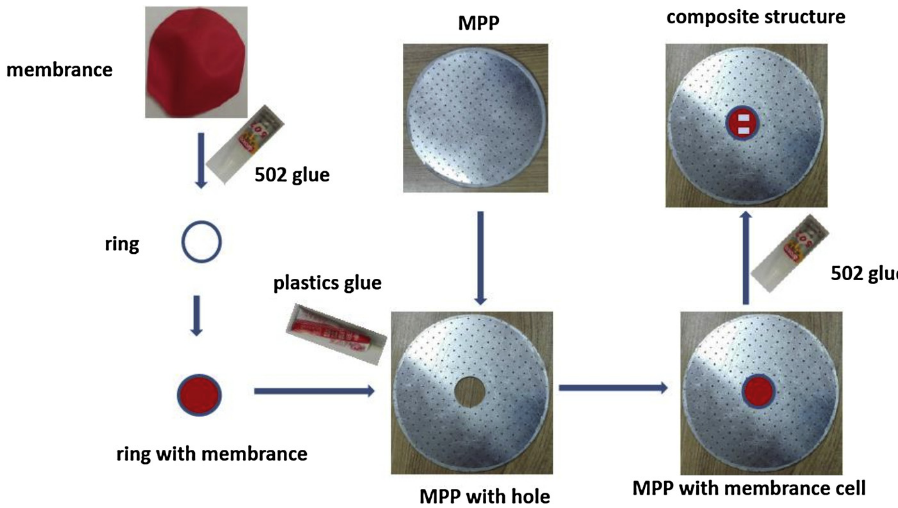

Fig. 1. Sketch of the manufacturing process of a composite structure of MPP with membrane cells and mass blocks.

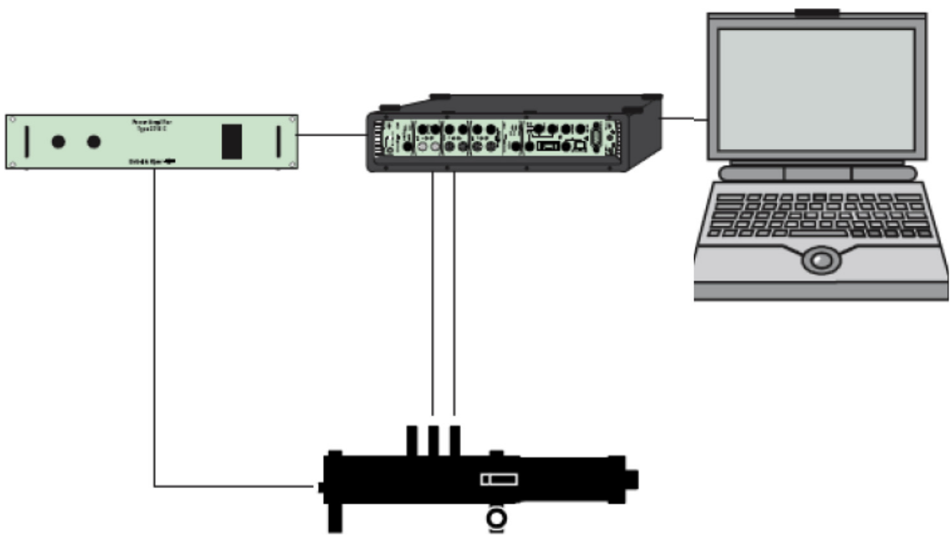

Fig. 2. The test system of impedance.

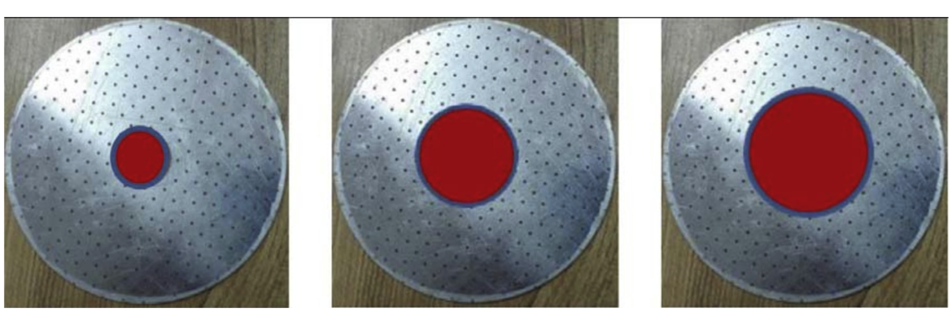

Fig. 3. MPP with membrane cell of diameter of membrane are 15 mm, 30 mm and 40 mm.

membrane cells [18]. Experimental results show that the MPP with membrane cell can provide more absorption than the single-leaf MPP absorber. Mei et al. have presented thin-film, comprising an elastic membrane decorated with asymmetric rigid platelets can reach almost unity absorption at frequencies where the relevant sound wavelength in air is three orders of magnitude larger than the membrane thickness [19]. Then, We have also investigated the transmission loss of the membrane with coaxial ring masses using the finite element method. The results show that the transmission loss peak and resonance frequencies of the membrane with coaxial ring masses depends on mass, distribution of coaxial ring masses, and the contacting area of coaxial ring masses with the membrane [20].

In this study, comprehensively considered the characteristics of MPP, membrane cells and mass blocks, composite structure of MPP with membrane cells and mass blocks is proposed. Structure of this paper will be arranged as follows: In Section 2, sample of the MPP with membrane cells and mass blocks (MPPMM) will be shown. In Section 3, the sound absorption performance of MPPMM will be studied. Finally, the conclusions will be given in Section 4.