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Acoustic properties of micro-perforated panel absorbers backed by Helmholtz resonators for the improvement of low-frequency sound absorption

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ABSTRACT

Micro-perforated panel absorbers backed by Helmholtz resonators are introduced to improve sound absorption in the low-frequency region where conventional micro-perforated panel absorbers cannot provide sufficient absorption. The neck of the backing resonator is designed to be extended into its cavity to reduce the total thickness of the proposed absorber. The acoustic impedance of the proposed sound absorber is investigated by using the transfer matrix method. It is shown that the absorber has two peak frequencies a few percent lower and higher than the uncoupled resonant frequencies of the resonator and the micro-perforated panel absorber. One anti-resonant frequency in the absorption coefficient curve is related to the coupled frequency of the two separate absorbers. The nonlinear acoustic impedance is also addressed in order to apply the proposed absorber to the mitigation of acoustic loads of launcher fairings. The proposed theory is verified by comparing the estimated normal incidence absorption coefficients with the measured ones both in low and high sound pressure environments. The applicability of the proposed absorber is demonstrated by numerical examples of noise reduction in a shallow rectangular cavity and a launcher fairing.

1. Introduction

Non-porous sound absorbers are more desirable than conventional porous ones to mitigate acoustic loadings inside launcher fairings because they do not raise particles of dust and maintain the strict cleanness of interior space. In this regard, the micro-perforated panel absorbers (MPPA) can be a good candidate for the reduction of noise inside launcher fairings [1]. In order to increase the sound absorption bandwidth, some improved arrangement methods, for example, the double layer of MPPA [2–4] and the array of MPPAs with different cavity depth [5] have been proposed.

However, MPPAs and their improvements have an inherent disadvantage in suppressing the low-frequency noise around 100 Hz-band where the internal acoustic loading of payload fairings is usually very high. The conventional method is to use an array of Helmholtz resonators (HRs) to reduce this low-frequency noise [6–11]. Fahy and Schofield [6] showed that there is an optimal location as well as the optimal geometric parameters of the resonators. In general, the optimal location of the sound absorber is where the target eigen-mode has its maximum value. This implies that one could obtain the best reduction by placing a wide-band sound absorber at this location. When the application area for the noise control treatment

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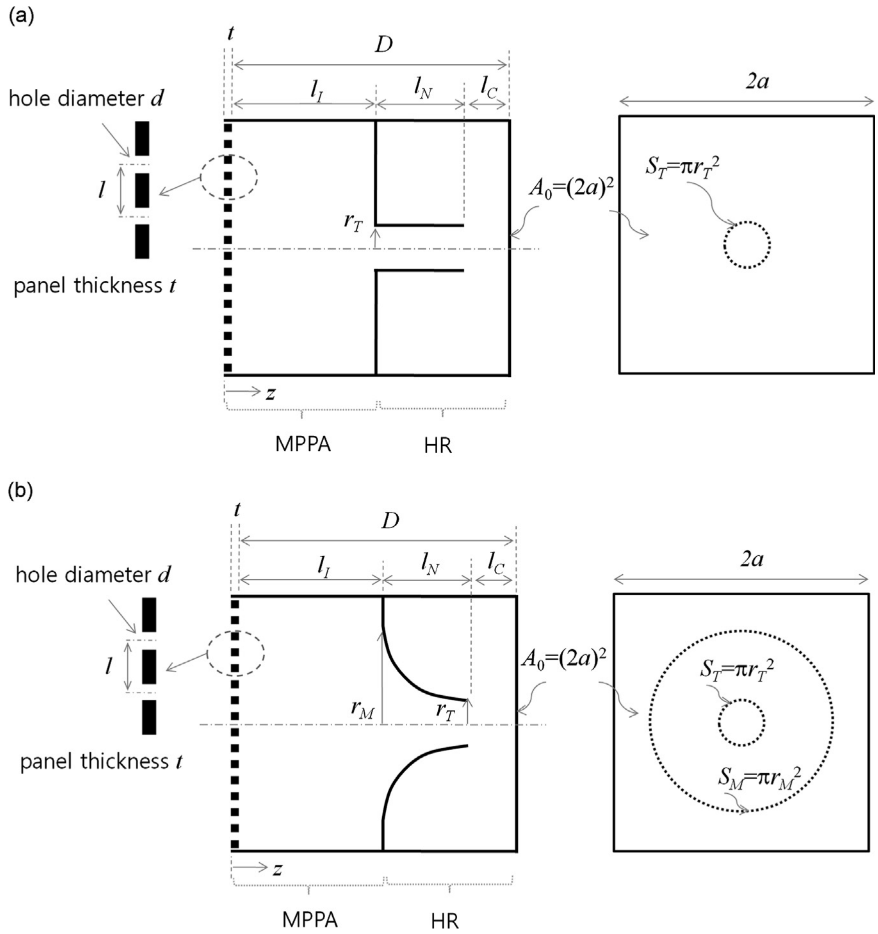

Fig. 1. Schematic diagrams of micro-perforated panel absorbers backed by Helmholtz resonators (MPPHR): (a) MPPHR with a straight neck and (b) MPPHR with a hyperbolic neck.

is limited, wide-band sound absorbers are also preferable. In launcher fairing applications, the best sound absorber would be one that can reduce low-frequency noise (near 100 Hz) as well as mid- to high-frequency noise (200–800 Hz). One of promising candidates can be the serial connection of a micro-perforated panel absorber and a Helmholtz resonator.

In this paper, we investigate the acoustic properties of the proposed sound absorber, named as the micro-perforated panel absorber backed by Helmholtz resonator (MPPHR). The schematic diagrams of possible geometry are shown in Fig. 1. The backing resonator is designed to have the extended neck into its cavity [12] for the reduction of total thickness of the absorber. As the neck of the HR, a hyperbolic tube is also considered. It increases the stiffness of the resonator panel so that it enables one to avoid the coupling of the panel vibration and the acoustic resonance of the HR. The acoustic impedance of the MPPHR is derived by using the transfer matrix method [13]. The absorption characteristics of the proposed absorber are investigated by using the derived acoustic impedance. An empirical nonlinear acoustic impedance is suggested for the application of launcher fairings. The measured absorption coefficients and estimated ones show good agreement both in low and high pressure environments. A shallow rectangular cavity example demonstrates that the proposed absorber at the optimal position could reduce 5.5 dB overall sound pressure level (OASPL) by treating only 2 percent of the interior surface. A launcher fairing example indicates that the array of MPPHRs can be an alternative acoustic protection system to mitigate the acoustic loadings inside fairing.

2. Acoustic properties of the micro-perforated panel absorber backed by Helmholtz resonator

2.1. Derivation of acoustic impedance

Fig. 1 shows the schematic diagram of micro-perforated panel absorbers backed by Helmholtz resonators (MPPHR). A micro-perforated panel (MPP) is connected to an acoustic resonator in series by a spacer whose length is l_I. The spacer provides an acoustic compliance for the micro-perforated panel so that the combination of the MPP and the acoustic cavity formed by the spacer works as a micro-perforated panel absorber. The neck of the acoustic resonator is designed to be