Design of Microscopic Perforated Absorber Considering Manufacturability and Application to Road Noise Control

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This study describes a method for designing sound absorbers that improve the noise performance of automobiles. As vehicle power sources become quieter due to electrification and improved ICE, the noise contribution of road noise has increased. This noise can be roughly classified into tire cavity resonance at low frequencies and noise in a wide mid-frequency band due to tire pattern noise. Existing noise countermeasure methods, such as Helmholtz resonators and porous sound absorption materials, have problems in terms of volume and weight.

Micro Perforated Plate(MPPs) with sub-millimeter pore diameters exhibit high sound absorption characteristics over a wide range of frequencies in several octaves. However, there are various limitations to manufacturing pores of 1.0 mm or less. For example, there are cost and thickness limitations of plates and shape flexibility. This study examines a design method for MPPs using plastic injection molding to solve these problems. Since it is difficult to mold pores 1.0mm or smaller by injection molding, optimization calculations are performed by arranging MPPs with pores of about 2.0 mm in parallel. By making the back air cavity independent, interactions with each back cavity are eliminated (Fig.1). This method obtains the MPPs design parameters that exhibit good broadband sound absorption characteristics in the mid-frequency range.

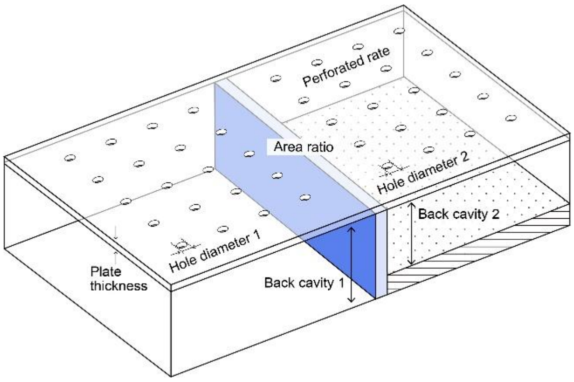

Fig. 1 Schematic diagrams of the MPP absorbers. The parallel arrangement of multiple MPPs exhibits a sound absorption effect over a wide frequency range. The uncertainty in the MPP parameters is evaluated to find a robust structure.

Furthermore, since the manufacturing tolerance of the pore size during manufacturing strongly affects the sound absorption properties, we present a method for quantitatively calculating the uncertainty in the pore size. Assuming the existence of manufacturing tolerances with a Gaussian distribution of pore size variation, the sound absorption characteristics also exhibit a Gaussian probability distribution. The probability distribution of this sound absorption property is obtained by quantitatively evaluating the uncertainty with Monte Carlo simulation. Using this uncertainty as an evaluation function, the design parameters of MPPs that exhibit robust acoustic properties against manufacturing variation were determined by optimization calculations. Fig.2 compares the uncertainty in the sound absorption coefficient of simply parameter-optimized MPPs and the MPPs optimized to account for manufacturing variation. Simply optimizing the MPPs design parameters to maximize the sound absorption coefficient resulted in a good sound absorption coefficient over a range of 900-1500 Hz. However, the sound absorption coefficient fluctuates significantly in the frequency range of 1000-1250 Hz due to pore size variation. On the other hand, when optimized with uncertainty, the frequency range of good sound absorption is slightly narrower, but the fluctuations are robust to variations in manufacturing. Therefore, by optimizing the MPPs parameters using the proposed method, it was possible to design an MPPs that exhibits high sound absorption characteristics while considering manufacturability in resin injection molding.

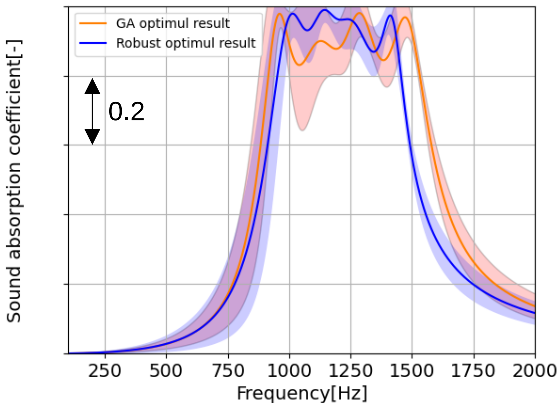

Fig. 2 Comparison of simple parameter optimization using Genetic algorithm and results considering uncertainty. Orange: optimization results with Genetic algorithm, Blue: optimization results with the uncertainty of micro hole of MPP. Filled areas indicate expexted value ± 3σ value.

The above-designed MPPs was protptyped and attached to the inner liner of the wheel house. We installed a speaker on the ground surface of the right front tire to verify the effect of the MPP on road noise. Sound pressure levels were measured at 1.0 m from the center of the wheel and 1/3-octave analysis was performed. As a result, a noise reduction effect of 1.3 dB was confirmed in the 200-2000 Hz target frequency range.