Application of Micro Perforated and Impervious Membranes for Noise Barriers

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Abstract

Membrane materials have been commonly used for decades in buildings. When acoustic environments are concerned, the acoustic properties of these membrane structures are of special interest.

This thesis aims to investigate acoustic properties of micro perforated membranes (MPMs) and impervious membranes and enhance the sound insulation of double layer impervious membranes by combining these with MPMs, thereby increasing the internal loss mechanisms of what is essentially a reactive wall. This thesis firstly develops a new model of an impervious membrane, taking into consideration the tension and the internal damping due to the membrane curvature.

The sound absorption of MPMs inserted between the impervious layers has been studied by introducing a new boundary condition where the particle velocity at the hole wall boundary is assumed to be equal to the membrane vibration velocity. The comparison between the predicted and measured results demonstrates that MPM 1 to 3 can be considered impervious due to their sufficiently small perforation radii, and MPM 4 is sound absorbing due to its larger perforations.

Non-linear sound absorption of MPM 4 has been observed in the experiments. It was found that the non-linear sound absorption coefficient is strongly dependent on both the magnitude of the SPLs and the waveform of the excitation. Two analytical models were developed for the non-linear acoustic impedance of MPMs. In the first model, the non-linear impedance of MPMs is considered to be the sum of the linear impedance, and the non-linear acoustic impedance dependent on the particle velocity within the perforations. The second analytical model presented is inspired by the air motion equation and the mass continuity equation considering the density variation in the time and spatial domains, and provides the most accurate predicted results among the models considered in this study.

The analytical models have been developed to predict the STL of double layer impervious membranes separated by a finite-sized air cavity, taking into consideration the fluid-structure coupling on each membrane surface. Comparing the predicted results to the measured STLs, it is found that considering the sound absorbing boundaries of the cavity can enhance the accuracy of the models.

STL measurements of double layer impervious membranes with four types of MPMs have been conducted in a diffuse field to quantify the effectiveness of the MPM insertion. The experimental results indicate that the MPM insertion can enhance the STL of the double layer impervious membranes significantly at frequencies above the first resonance frequency of the air cavity. MPMs 1 to 3 have similar main impacts on the STLs, however, MPM 4 has a different effect because of its larger perforations.

The normal incidence and diffuse field models for the double layer impervious membranes with inserted MPMs 1 to 3 were developed and the predicted results were compared with the experimental results. The models with MPM 4 were developed by taking into consideration the acoustic impedance of the MPM 4 due to its perforations. These developed models can be used as tools for design of membrane structures.

Statement of Originality

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

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η	Damping ratio	11
ξ	Membrane vibration displacement	11
t	Time variable	11
T	Tension per unit length	11
T_0	Real static tension	11
x	Position coordinate in x-axis	13
y	Position coordinate in y-axis	13
ρ_s	Surface density of membrane	13
ω	Angular frequency	14
∇^2	Two dimensional Laplace operator	14
R	Radial position in the polar coordinate system	14
η	Internal damping ratio	16
ρ_{string}	Mass per unit length of the string	16
R_0	Radius of a circular membrane	20
p_i	Incident sound pressure	20
p_r	Reflected sound pressure	20
p_t	Transmitted sound pressure	20
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c_0	Speed of sound	26
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Im	Imaginary part of impedance, reactance	26
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