Achieving Excellent Sound Absorption with Reduced Weight in Fibrous Materials

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Abstract: Fibrous materials are crucial for enhancing acoustic environments in construction and automotive settings. Despite extensive research on their acoustic properties, which covers both natural and synthetic fibers, much of the focus has been on experimental methods. Despite the availability of precise numerical and semi-phenomenological models, there has been limited attention given to developing reliable and straightforward strategies for optimizing these properties and guiding the material preparation process, including weight reduction considerations.

Keywords: *sound absorption, weight reduction, fibrous material, optimization, semi-phenomenological model,*

The Johnson-Champoux-Allard-Lafarge (JCAL) model is a prominent choice among semi-phenomenological models, widely recognized and utilized in acoustic research [1-3]. Five out of the six non-acoustical parameters encompassed within the JCAL model are intricately linked to the porosity and fiber diameter of fibrous materials. Several models have been developed to estimate these non-acoustical parameters utilizing porosity and diameter as key inputs [4]. The originally complex JCAL model can be streamlined into a more simplified one-parameter model, focusing solely on porosity. For the multilayer structure, it is feasible to use various layers that including porous layer and air layer to reduce weight but maintain the excellent sound absorption.

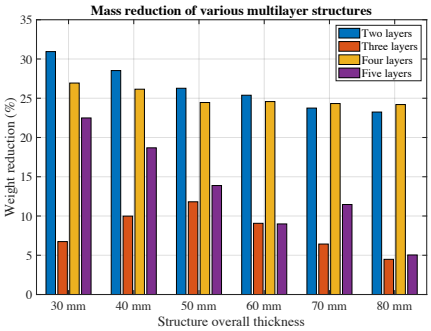

Figure 1 Weight reduction of various thickness (i.e., 30, 40, 50,60, 70 and 80 mm) structures.

The weight reduction for two to five layers structures with the overall thickness from 30 mm to 80 mm is shown in Figure 1. It is possible to achieve a maximum weight reduction of approximately 31%.
Two layers structures, containing one porous layer and one air layer, with 30 to 60 mm thickness and four layers configurations with 70 to 80 mm thickness have been validated to achieve significant weight reduction while maintaining excellent sound absorption properties.

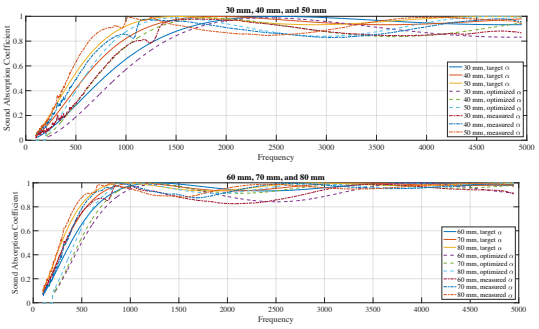

Figure 2 Comparison between target, optimized and measured sound absorption of multilayer structure.

The comparison is demonstrated in Figure 5. Although the measured sound absorption is little bit lower than the target values in mid or high frequencies, the measured sound absorption shown better sound absorption at low frequencies (i.e., < 1000 Hz). It can be concluded that the simplified JCAL model is applicable for multilayer structure. The successful validation of the simplified JCAL model highlights its potential to advance the practical applicability of sound absorption analysis in fibrous materials. This simplified approach not only enhances the understanding of sound absorption phenomena but also accelerates research and development efforts in sound absorption materials and acoustic design methodologies.

Acknowledgement*: This project has received funding from the European Union's Horizon Europe research and innovation programme under the Marie Skłodowska-Curie grant agreement No. 101063867.*

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