AN OVERVIEW OF THE ABSORPTIVE PROPERTIES OF MICROPERFORATED PANELS

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Abstract
The concept of microperforated panels as an absorptive element was first introduced in the 1970's by Maa, and was initially based on the use of metallic or acrylic plates with small thickness (1mm) and with very small perforations (of the order of 1mm). The main idea was to use such materials when fibrous absorptive materials were not adequate. The topic was further developed throughout the years, towards the implementation of feasible solutions, and commercial products of this type are now available.
The present work addresses the use of this type of solutions and presents the results of an extensive experimental analysis performed using the impedance tube method. The main objective is to test the effect of different variables in the behavior of the system, such as the thickness of the panel, the diameter and spacing of the holes, and the effect of the air-gap behind the panel; the use of an absorptive material within the air-gap is also addressed. Several specimens were produced using laser perforation, and a novel and automatized technique based on photogrammetric analysis is used to identify the main properties of each specimen (diameter, geometry and spacing of the holes). Finally, a comparison between the experimental measurements and theoretical results in terms of the acoustical absorption coefficient is performed.

Keywords: Wooden microperforated panels. Sound absorption. Impedance tube method ISO 10534-2.

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1 Introduction

In order to control reflections inside a room and increase sound absorption of its surfaces (ceilings and walls), it is usual to coat them with perforated wooden panels, leaving a cavity between them and the support surface, which can be, or not, filled with porous material.
The concept of microperforated panels as sound absorbing elements has been exploited in the 1970s by Maa [1]. The main products developed were thin plates of order 1mm thickness essentially metal or acrylic (transparent or semitransparent), with perforation size less than 1mm.
In the present work we study the possibility of using this concept of microperforation on wood panels whose thickness is no longer the typical one found in the original solutions. An experimental analysis

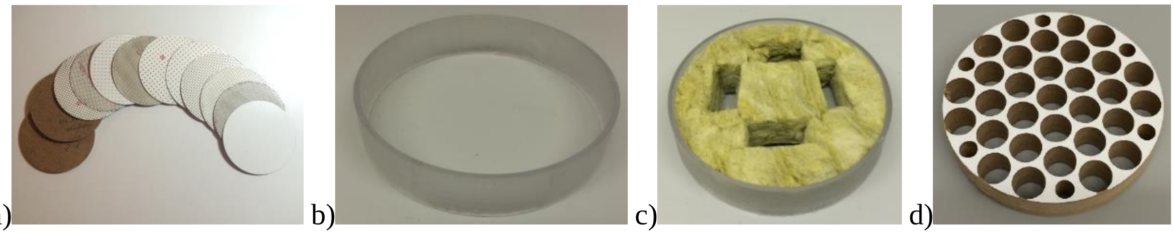
of the behavior of MDF microperforated panels is performed. The main objective is to test the efficiency of such solutions with different dimensions and hole spacings, and also to evaluate the influence of the mounting conditions and of eventually filling the air-space of the microperforated panel to the support with rock wool.
Several specimens were produced using laser perforation and a novel and automatized technique based on photogrammetric analysis is used to identify the main properties of each specimen (diameter, geometry and spacing of the holes). The experimental tests were carried out on small samples using the impedance tube method (following ISO 10534-2 standard). The results of experimental measurements are also compared to theoretical models available from the literature.

2 Analytical model for sound absorption

The model adopted in this study is based on contributions by Maa and Rayleigh [2,3], yet incorporating the corrections proposed by Ingard [4] and Morse and Ingard [5]. The model proposed by Maa [2] is based on the conversion of acoustic impedance of a single hole to an average value corresponding to the open area of the panel. Consider the microperforated panel as a set of short tubes, of thickness identical to the length of the panel, and the non-perforated part is perfectly reflective. Assume further that the wavelength of the sound which propagates is sufficiently large compared with the cross-sectional dimension of the tube (i.e., hole). This method includes the terms due to the viscosity of air, radiation and the effects of reactance air cavity behind of panel. For more details see modeling used in [6].

3 Measurements of sound absorption coefficient

A series of measurements were made with the impedance tube according to ISO 10534-2 [7]. The entire test procedure followed in this work is described in greater detail in Godinho et al [8].
The samples constituted by melamine discs (diameter of 100mm) with a thickness of 0.75mm (Fig.1a). Laser holes were made with a diameter of 0.5 mm, 075mm and 1mm. The spacing between the holes (among the axes) was 1.5mm, 2mm, 2.5mm, 3mm and 5mm. These microperforated discs were bonded to a plastic support ring (with 20mm deep) that could be empty or filled, wholly or partially, with mineral wool (Fig. 1b and 1c). For comparison, we also used a honeycomb support (MDF) with a high perforation rate, which obviously obstructed some holes of the micro-perforated disc, thereby reducing the effective open area of the sample (Fig 1d). The samples were tested in the impedance tube in order to have no air cavity on its backs (against the piston at the termination of the tube).



a) b) c) d)

Figure 1 – Samples – a) microperforated discs; b) empty plastic support ring; c) plastic support ring partially filled with mineral wool; d) MDF honeycomb support.

4 Geometric characterization of samples

The geometric characterization of the holes' shape in the microperforated discs was made using digital image processing techniques, which made it possible to have an accurate characterization efficiently performed in feasible time. For each sample, an image with 9559×9557 pixels was captured through HP Officejet 6700 Premium scanner. Each pixel represents an area of 0.011×0.011 mm^2 of the sample. A Matlab script was developed by one of the authors [9] allowing to detect and count the holes in each RGB image, to compute the perforated area of the discs, and to determine the area, the diameter and the coordinates of the centroid of each hole. This analysis involved the following main steps: 1) Convert each RGB image to a binary image based on a threshold that allowed distinguishing between the holes and the surrounding sample; 2) Compute the filled area of each object and remove the objects not corresponding to holes (*i.e.*, that have a filled area larger than 2 mm^2 or lower than 0.1 mm^2); 3) Fit an ellipse to the edge of each object and remove objects that do not have an elliptical shape; 4) Count the number of remaining objects (holes) and compute the length of the major and minor axes of the fitted ellipse; 5) Save data and plot the results in the original RGB image (see Figure 2).

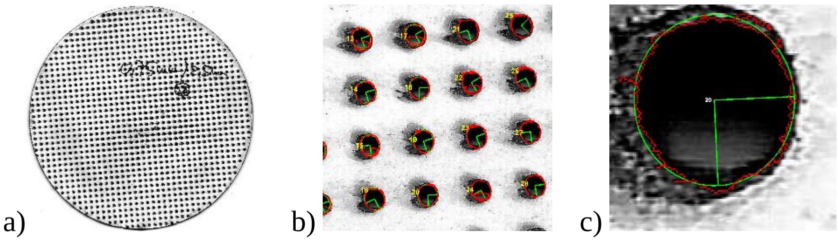
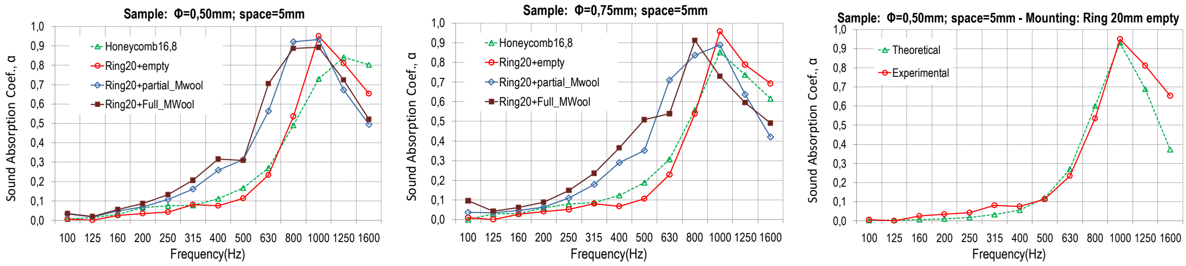


Figure 2 – Exemplification of image processing process: (a) original RGB image; (b) detected holes plotted in an extract of the original image; (c) zoom in of a detected hole (boundary of a hole represented in red and the approximated ellipse and their axis in green).

5 Results

It should be noted that the samples tested with the honeycomb support have some of the holes covered ("blind holes"), thereby reducing the actual perforation rate (thus decreasing the resonance frequency). On the other hand, its thickness is slightly lower than the support in plastic ring, respectively, 16.8mm vs 20mm (whose effect is to increase the resonance frequency). Indeed, with the use of the honeycomb support it was observed, in general, that an increased sound absorption occurs at lower frequencies, although the maximum sound absorption decreases slightly, in comparison with the empty case with plastic support (Figure 3a and b). Filling the air cavity with rock wool originated an increased maximum sound absorption and a larger bandwidth where sound absorption is high; for the same case, the resonance frequency seems to be moved to lower frequencies (Figure 3a and b). No significant change in sound absorption seems to occur when the air cavity was partially filled.

Finally, comparison between experimental results and numerical modeling results was also performed. A sample result is displayed in Fig. 3c, revealing a good agreement between both approaches, and indicating the possibility of using the analytical models for the prediction of the sound absorption of microperfotared wooden panels.



a) b) c)

Figure 3 – Results: a) and b) Experimental results; c) Comparison with theoretical prediction.

6 Conclusions

The microperforated solutions studied in this work have, as expected, a good sound absorption in the low / mid frequencies. Since they are intended to be adopted as acoustic opaque linnig solutions, the use of rock wool inside the air cavity significantly improves the sound absorption, especially for panels with higher drilling rates. It is also important to note that the absorber system has a maximum thickness of 20mm and is, therefore, possible to develop a compact and tuned system with a perforation practically invisible. The only downside is the cost of production. The theoretical model proved to be a good tool to support the development of such solutions. The results of this study are consistent with those presented by the aythors in previous congresses [10].

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