

# Effect of Contamination on Acoustic Performance of Microperforated Panels

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## ABSTRACT

Microperforated panel (MPP) absorbers are rugged, non-combustible, and do not deteriorate over time. That being the case, they are especially suitable for long term use in harsh environments. However, the acoustic performance is modified when contaminated by dust, dirt, or fluids (i.e. oil, water). This paper examines that effect experimentally and correlates the absorption performance with Maa's theory for micro-perforated panels. Transfer impedance and absorption coefficient are measured for different levels of aluminum oxide and carbon dust accumulation. The amount of dust contamination is quantified by measuring the luminance difference between clean and dirty panels with a light meter. The porosity and hole diameter in Maa's equation are modified to account for dust obstruction. The effect of coating the MPP with oil, water, and other appropriate viscous fluids was also measured. This effect was simulated by modifying the viscous factor in Maa's equation.

## INTRODUCTION

Micro-perforated panel (MPP) absorbers are attractive because they provide effective sound absorption in environments where fibrous or porous materials deteriorate. For ordinary perforated panels, pore diameters or slit dimensions are on the order of millimeters or even centimeters. MPP absorbers have pore diameters sub-millimeter in size. Due to the small holes, MPP absorbers provide acoustic resistance, which enhances the sound attenuation. Compared to traditional sound absorbing materials, MPP absorbers are unique because they are sustainable and reclaimable, non-combustible, rugged, fiber free, and aesthetically pleasing. Due to these benefits, MPP absorbers have been successfully used in the German parliament building [1] and are commercially used in outdoor

noise barriers, building interiors, engine enclosures and mufflers [2].

Another advantage of MPP absorbers is that they are tunable and can provide broadband sound absorption at low frequencies. Maa [3,4,5,6], Atalla and Sgard [7], Lee et al. [8], and Takahashi [9] developed models for predicting the acoustic properties of MPP absorbers. The models are similar and each characterizes the MPP absorber as a function of the pore diameter, porosity, thickness, and backing cavity depth.

MPP absorbers are a very attractive option for long-term use in harsh and corrosive environments. For example, MPP absorbers have been used in noise barriers on mining sites [10], in engine enclosures as an acoustical heat shield [11], and inside mufflers [12]. However, after being exposed to these hostile environments for a certain amount of time, the MPP absorber openings are very likely to be filled with different types of contamination. Contamination can be either dust, dirt or fluid (i.e. oil, water). To our knowledge, there have been no prior studies to assess MPP performance when contaminated. Naturally, this effect will be important for engine enclosures, sound barriers and other industrial applications. By understanding this effect and the mechanism behind it, cleaning protocols can be established or absorbers can be designed to function well for known levels of contaminant accumulation.

In order to study the contamination effect, we need to choose acoustic parameters that can represent the performance of MPP absorbers and reflect the influence of contamination. Consider a MPP absorber with thickness  $t$ , hole diameter  $d$ , and air cavity depth  $D$  as illustrated in Figure 1. Let  $p_1$  and  $p_2$  denote the sound pressures, and  $v_1$  and  $v_2$  denote the particle velocities in front and back of the panel.

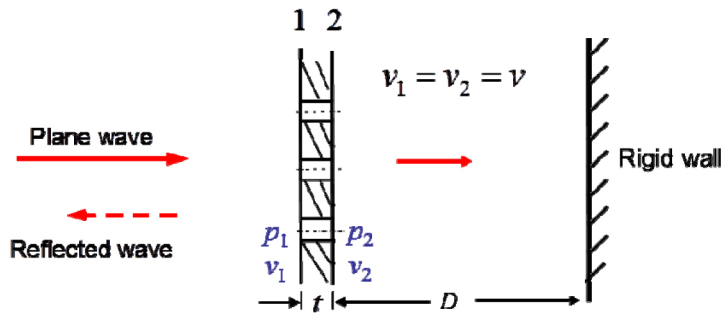


Figure 1. Schematic illustrating transfer impedance.

Since the panel is very thin, a single particle velocity  $v$  is assumed across the panel thickness, i.e.  $v_1 = v_2 = v$ . Maa [3,4,5,6] showed that a MPP absorber can be modeled as transfer impedance. The transfer impedance can be expressed as

$$Z_{tr} = \frac{p_1 - p_2}{v} \quad (1)$$

Equation (1) also suggests that transfer impedance is essentially the difference between the impedances in front ( $Z_1$ ) and in back of the panel ( $Z_2$ ) [13, 14].  $Z_1$  is the impedance of the combined panel and back cavity, which can be measured using the two-microphone method [15].  $Z_2$ , which is the impedance of the back cavity, can be calculated theoretically.

The normal incident absorption coefficient of the MPP and backing air cavity can be calculated from  $Z_1$ . Transfer impedances and absorption coefficients of MPP absorbers with and without contamination were measured and compared to determine the effect of contamination on performance. This was followed by simulation to explain the effect of contamination.

## DUST CONTAMINATION

In order to allow the powder to accumulate evenly in an MPP slit, an airbrush was used to blow the powder into a spray booth. The MPP was mounted in a direction normal to the flow. The flow speed was adjusted so that it would accumulate while not dislodging standing dust in the slit. The setup for this accumulating process is shown as Figure 2. After a certain amount of time of accumulating, the panel was taken out of the booth and excess dust on the surface was carefully brushed off.

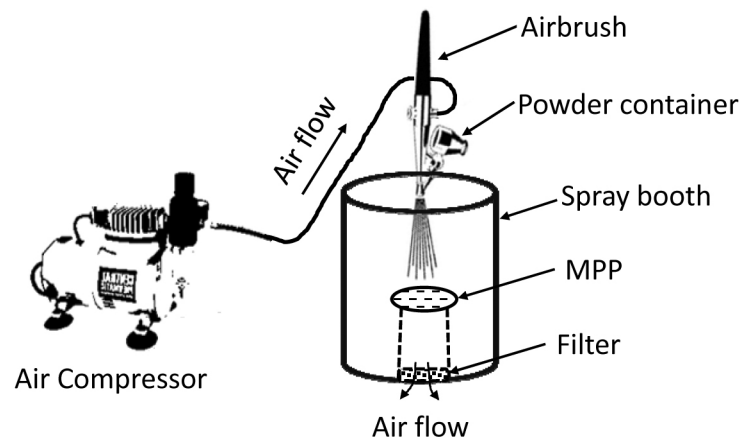


Figure 2. Setup for accumulating dust on the MPP.

Dust accumulation was quantified by placing a panel in between a luminance meter and a light pad, and measuring the light intensity through the panel. The panel porosity was calculated as the ratio of the light intensities with and without panel. The dust contamination in the slit is represented by the corresponding porosity. The lower the porosity is, the more the contamination in the slit. Though this process is prone to error, porosity measurements using lumination can be used to quantify different accumulation levels in a relative sense. After porosity measurement, the absorption coefficient and transfer impedance of the panel can be measured in the impedance tube. Normally, the impedance tube is placed horizontally on a flat surface. However, we hung the impedance tube vertically so that the accumulated dust in the slit was undisturbed during the measurement. Figure 3 shows MPP samples having different levels of dust accumulation.

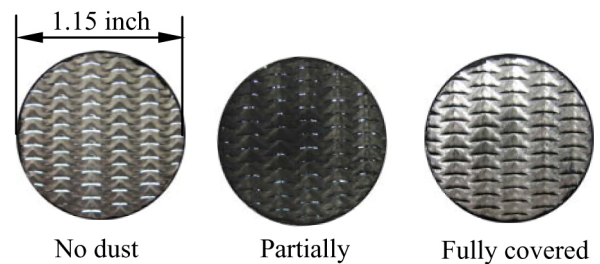


Figure 3. MPP samples with different levels of dust contamination.