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Active Control and Microperforated Panels

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One of the current applications of Active Noise Control Techniques is the improvement of noise absorption in the low frequency range in combination with an absorptive material. Some published works show examples where those materials need to be designed as thick layers in order to obtain the required passive absorption. This paper presents an alternative use of microperforated panels and/or non-waven textile sheets allowing the ease and adaptability of this kind of materials for this purpose.

1. INTRODUCTION

In a great number of cases of absorbent acoustic devices the total space occupied by such devices plays an important role, which is the case of aircraft or automobile cabins. The acoustic noise bands centred in mid and high frequency range can be absorbed using thin layers of porous materials as passive absorbers (as mineral wools, etc.). On the other hand, sufficient acoustic absorption in the low frequency range needs bulky absorption devices made with adequate absorbing porous materials. In these latter situations, the application of active noise control techniques (ANCT) allows higher acoustic absorption in the low frequency range with reduced thicknesses of the absorbing implemented devices.

In this paper, the development of new hybrid passive – active absorbing devices, in which the thicknesses are even more reduced, are proposed. The new designs are based on the use of microperforated panels or screens as absorptive elements that should be combined with ANCT in order to implement the desired device. Theoretical and experimental results are compared together with its pros and cons.

2. PASSIVE ABSORPTIVE MATERIALS

2.1 Microperforated panel

Perforated panels have been used for several years [2] but its use was restricted to act as cover of absorptive porous materials, mainly fibrous and open foam type. At the end of 1960's, two researchers [3, 5] studied independently the use and application of microperforated panels as robust sound absorbers acting as wide-band resonator absorbers.

The absorption mechanism was based in the acoustic resistance of submilimetric holes (0.1mm to 1mm) practised in a thin plate. In that way its acoustic mass reactance was low enough to act as a wide-band sound absorber, without the need of additional porous material between the plate and the rigid back surface, necessary to implement the acoustic resonator.

Nowadays the most cited papers about this type of absorbers are those of Maa [3,6], but analogous explanations and final results can be found in Cremer's book [5].

Following Maa [6], the specific impedance of a microperforated panel (MPP) normalised to the specific acoustic impedance of the air, can be expressed as:

$$Z = \frac{Z_1}{\sigma \rho_0 c} = r + j\omega m = \frac{32\eta t}{\sigma \rho_0 c d^2}\left(\sqrt{1+\frac{k^2}{32}} + \frac{\sqrt{2}}{32}k\frac{d}{t}\right) + \mathrm{j}\frac{\omega t}{\sigma c}\left(1+\frac{1}{\sqrt{1+\frac{k^2}{2}}} + 0.85\frac{d}{t}\right), \quad (1)$$

where, ρ_0=1.21Kg/m^3, c=343m/s, σ is the perforation coefficient, d is the diameter of holes, t is the thickness of panel, ω is the circular frequency, η is the viscosity coefficient, and $k=d(\omega\rho_0/4\eta)^{1/2}$

An easy way to check the absorption of a designed and constructed MPP is to measure its absorption coefficient as a function of the frequency in a standing wave tube in which the test probe is placed perpendicular to the incident acoustic wave. In this work a two-microphone arrangement tube is used, employing pseudorandom white noise and FFT algorithms. In order to get a MPP absorber it is necessary to place it in front of a solid surface (backing) separated from it by an air cavity of deep D. Therefore the surface impedance is given by:

$$Z_S = r + j\omega m - j\cot\left(\frac{\omega D}{c}\right), \quad (2)$$

and the acoustic absorption coefficient is calculated following traditional formulation.

2.2 Sheet absorber

The second alternative can be implemented using tissues with adjusted air flow resistance. For this kind of materials their structural impedance can be expressed as [7]:

$$Z = \rho_0 c R + j\omega t(1+G)/c, \quad (3)$$

where R is the air flow resistance expressed in MKS Rayls and G the induced mass factor per unit length of the sheet. The magnitude of the second term in Eq. (3) has a great dependence of the way that the screen is mounted. Usually, in order to get the best absorption capabilities of the device, the values of R should be near to one.

As the MPP the sheet or membrane absorbers, MA, are also of the resonant type, which means they need an air space behind them and the backing surface. In this way, the surface impedance of this kind of absorbers can be expressed adding the *cot(ωD/c)* term.

The structure of these absorbers is very simple and their absorption characteristics are exactly predictable. Normally this kind of sheet absorbers is made of textiles, non-woven textiles, pressed cellulose fibres, cotton and even mineral wools. Due to this kind of intrinsic constitution, it is no possible to calculate their resistive and reactive terms, being necessary to start from experimental measurements of these characteristics.

This kind of absorbers shows a wider absorption frequency band in comparison with those of the MPP type, for the same mounting conditions.

3. DESIGN OF PASSIVE BULK SIZE ABSORBER

The interest in this work resides in the development of low frequency absorbers as light and thin as possible. Cobo et al. [8] show the possibility and the way to build an actively controlled absorber with reduced bulk size, capable of good absorption characteristics in a very low frequency band. The low frequency absorption was limited by the longitudinal size of the standing wave tube and the frequency resonance of the used control loudspeaker (≅ 100 Hz), and in the high frequency range by the tube diameter (10 cm) and the electronic performance and capabilities of the control condition, which impose a maximum cut–off frequency of 1 kHz. The paper shows that under those conditions, using a layer of selected porous material and an air cavity, the pressure release condition discussed by Beyene and Burdisso [1] can give good results in the frequency range of 50 – 1000Hz with a device made of 7 cm of melamine foam and an air cavity of 3 cm, backed by the control loudspeaker. This means a bulk thickness of 10 cm. (It is worth to notice that the length of a wedge made from glass wool, capable of absorb such frequencies, should be at least of 120 cm).

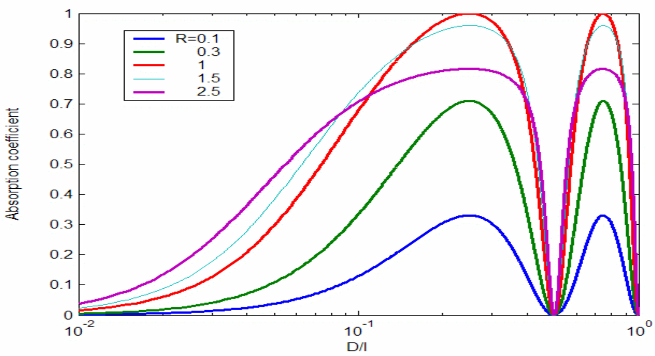

Figure 1. *Absorption curves of a MA absorber for normalised R values: 0.1<R<3.*

With the aim to reduce the total thickness of the bulk absorbers, MPP or MA absorbers can be employed with excellent results and lower thickness that of the previous ones. Figure 1 plots the evolution of the absorbing curves of an MA for different normalised R values (0.1<R<10) in function on the D/λ ratio in order to universalise the results. The induced mass reactive term has not been considered due to its little influence in comparison with the reactive air cavity term. It can be checked that the best *R-values* are those near to *R =1*.

The behaviour of these curves are analogous to those found for MPP (figure 3 of [Maa, 6]), meaning that for lower maxima α values the absorption bandwidth increases and the resonant frequency displaces to lower values.

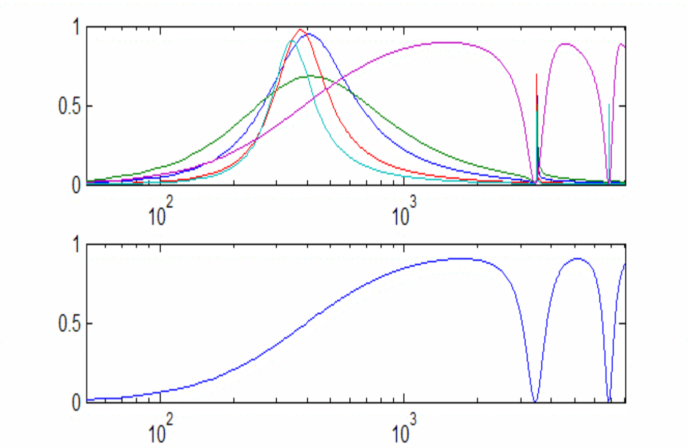

Figure 2. *Comparison between a MPP and a MA absorber.*

For MA absorbers the resonance absorption curves are asymmetrical, showing the same behaviour as those of the MPP when the factor *k* (eq. 5) is high enough. For small *k* values the MPP absorption curves show symmetrical figures centred at the resonance frequency of the system (Figure 2, upper). In the presented figures there is not discontinuity between MPP and MA absorbers. Figure 2 shows in its upper part the evolution of the absorption of the MPP in function of *f* for a microperforated rigid plate (d=0.5, 0.3, 1, 1.5mm and 60µm; t=1mm; σ=0.5%; D=50mm), and in the lower one the absorption curve for an MA with *r = 1.9* and D=50mm.

3.1 Pros and cons of both designs.

Under engineering purposes each type of design has its handicaps and advantages. The MPP absorber can be made of any material: sheet metal, plastic, plywood, cardboard, etc.; having a finishing termination, colour, roughness, etc. useful for interiors. The main counterpart of MPP would be the need of precision technology in order to make the minute holes required by calculus.

On the contrary, MA absorbers are very cheap, lightweight and easy to develop, having in general better acoustic absorption performances, but normally they need a perforated protective cover in order to protect the fine tissue from external agents.

Cavity requirements are similar for both devices, but they have the additional advantage as compared with the traditional, made with porous foams or fibrous materials, that the total thickness of the design decreases.

4. PUTTING ALL TOGETHER

For the two ANCT conditions, pressure release or impedance matching, in order to implement a hybrid passive–active absorbing device, the proposed passive absorbers, MPP and MA are well adapted to the first procedure, with excellent theoretical capabilities. Undoubtedly it is an advantage due to the easier implementation of the pressure release active control condition, in which the acoustic pressure inside the cavity between the passive absorber and the control loudspeaker picked-up by the error (control) microphone is minimized.

In order to illustrate the results that can be reached thorough both types of absorbers Figure 3 shows the absorption curves corresponding to an MPP with the following characteristics: d=60μm, t=1mm, σ=0.5%, cavity depth=4cm. In red colour the passive absorbing curves are represented: theoretical (continuous line), experimental (dotted line), and in green the obtained absorption after the active adjustment of the system. The controller used filters IIR for both the identification and the control algorithms. The random noise driving the primary source was also used as reference signal. It can be observed the increased absorption that can be reached in the low frequency range. A double layer of MPP separated by an air space allows increasing the frequency band of the system, affording absorption at higher frequencies.

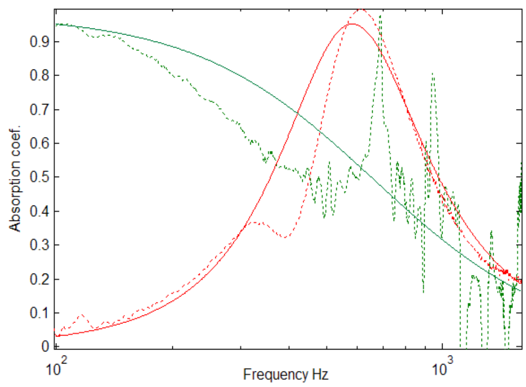

Figure 3. *Passive and hybrid absorption of a MPP.*

Figure 4 shows analogous results for a MA absorber, made with a sheet of cellulose fibres with a resistive air flow normalized to air impedance R=1.3 (surface density 15gr/m^2). Analogous colours and line types of figure 3 are used. In order to have an idea of the frequency behaviour of the absorption curve, the reader should compare the results of figure 4, restricted in the range of 100 – 1600Hz, with the curve of figure 2 (lower part), that shows a broader frequency range.

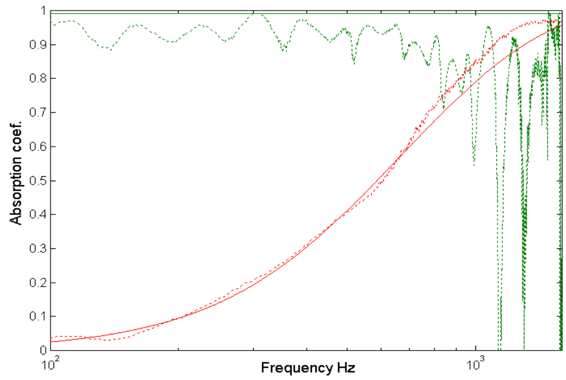

Figure 4. *Passive and hybrid absorption of a MA.*

5. CONCLUSIONS

This paper shows the potential application of MPP and MA absorbers in the development of hybrid active-passive absorbers. The principal advantages of this type of absorbers are their light weight, the capability of reduced cavities and, in the case of microperforated panels made of any kind of material, its aesthetic can be adapted to multiple architectural and decorative applications.

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