Broadband Acoustic Absorber Panel

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SOMMAIRE

Cet article décrit comment la largeur de bande d'absorption d'un revêtement absorbant passif, qui souvent consiste d'une couche de matériau fibreux ou poreux tel que laine de verre ou mousse, peut être étendue au domaine des basses fréquences en combinant ce dernier à un système absorbant réactif à base de résonateurs de Helmholtz. Le système réactif, qui peut être composé d'un ou de deux couches de resonateurs, est à son tour couplé à ce qu'on appelle des "plaques résonateurs" qui fournissent un autre pic de résonance dû au couplage de la rigidité de plaque à la rigidité du volume de la cavité. Par un choix judicieux des dimensions des résonateurs de Helmholtz et des plaques résonateurs, les pics de résonances sont combinés de façon à élargir la largeur de bande d'absorption et par ce faite couvrir le domaine des basses fréquences. Cependant, un couplage positif du système réactif avec le système passif est achevé grâce à un choix approprié des caractéristiques du matériau et d'une couche de lame d'air séparant les deux systèmes. Différentes combinaisons ont été testées dans un tube d'impédance et un outil de calcul prévisionnel a été développé et validé. Dans une application pratique, les panneaux absorbants seront accordés à différentes fréquences pour assurer une bonne absorption couvrant tout le domaine des fréquences souhaité. Le coefficient d'absorption moyen varirait alors de 0,8 à 1 dans la gamme des fréquences 50 Hz à 10 kHz.

INTRODUCTION

A bulk absorber panel usually consists of a single layer construction with a solid back plate and a porous face sheet. The cavity is filled with a porous or fibrous material such foam or fiberglass. This passive panel has a wide absorption bandwidth and can absorb sound effectively at all frequencies above the first quarter wave resonance. Its acoustic performance depends mainly on the material thickness and on its resistivity which is a function of the fiber or pore diameters and density of the fills. It can easily be confirmed that the low frequency absorption is poor even for a thick layer of material. This absorber type is the most commonly used and is known as a "conventional acoustic panel".

A reactive acoustic panel can be designed as a Helmholtz resonators panel. In this case, the acoustic performances depend on the physical sizes of the resonators and on their mechanical characteristics. In addition, the acoustic excitation, under which those resonators are exposed and their location inside the circuit, will also affect its performances. Moreover, a one layer resonator panel design consists of inserting partitions between perforate plate and solid back plate. This reactive system absorber is acoustically effective over the narrowest range of frequencies and must be tuned to the frequency of greatest concern. Thus, to increase the effectiveness range, a second peak of resonance can be obtained by adding another layer of resonators and/or by choosing an appropriate plate thickness. This latter resonator is known as a "plate resonator" and its peak of absorption is due to a combination of the plate stiffness and volume stiffness of the cavity.

This paper describes how the absorption bandwidth of a conventional acoustic panel can be expanded to the low frequency domain by coupling it to a reactive panel. The coupling of the two systems is accomplished by a judicious choice of the material properties, an air gap layer, and a proper dimensioning of the Helmholtz resonators (cavity dimensions, plate thickness, hole diameter) with the plate resonators (plate resonator type) [1]. The peaks of resonance are combined in order to widen the absorption bandwidth and thus cover the low frequency range. Different combinations have been tested in impedance tube and a design program has been developed and validated.

VALIDATION

Different samples consisting of single and double layer resonators have been made with different materials and have been tested in an impedance tube by the two microphone technique [2].

The calculation method of the absorption coefficient and the acoustic impedance is based on transfer impedance procedures. The impedance of the overall system is evaluated in stages. The impedance is transferred from one layer to another until the final passive layer which may have a protective skin or a perforated plate.

The "plate resonator" impedance is calculated by solving the equations for the plate motion. The firsts modes of vibrations are then determined and the impedance is calculated [3]. The impedance of the plate resonator is combined with the Helmholtz resonators impedance. The passive layer impedance is calculated using Allard's and Delany & Bazley's models [4,5] in case of a fibrous material. For an elastic porous material, a semi-empirical model is used [6].

The panel's absorption characteristics are dependent on the following:

¨ two coupled resonance given by the Helmholtz resonance and by the combination of the plate stiffness and volume stiffness of the cavity

¨ additional coupling of these two resonances by a passive layer of porous or fibrous material

¨ exact tuning of the system as influenced by the air-gap between the passive layer and the resonators which in turn depend on the material density and its thickness

The coefficients are evaluated from the mass, stiffness and internal damping of the panel, the stiffness of the cavity, the air gap and the characteristic parameters of the passive material.

CONCLUSION

The prediction scheme developed to evaluate the absorption coefficient of a layered passive/reactive absorption panel was validated by conducting impedance tube tests. An example of test results compared to the prediction of the absorption coefficient of a double layer resonator is shown in figure 1. The results show the prediction compares well with actual test data. Figure 2 shows an example of test results of a passive/reactive system absorber. Furthermore, it is important to mention that the passive system absorber can also be coupled to a plate resonator system alone. The cavity's volume of the plate resonator can be filled with porous or fibrous material to increase the absorption.

In real applications, the panels will be tuned to different frequencies to ensure a high absorption over the frequency range of concern. The proposed broadband absorber acoustic panels would present a mean absorption coefficient of 0.8 to 1 from 50 Hz to 10 kHz.

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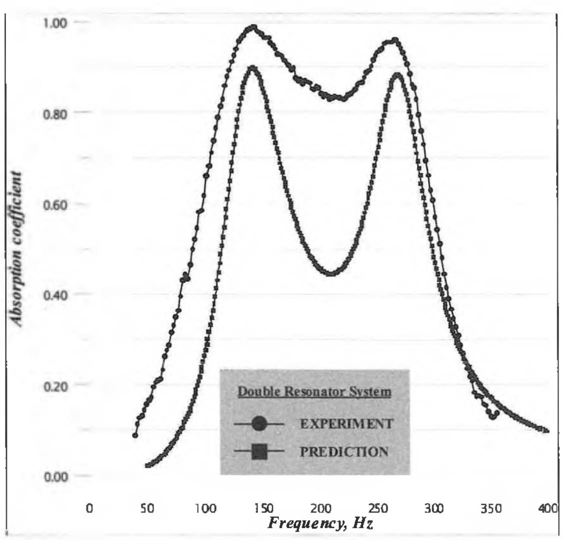
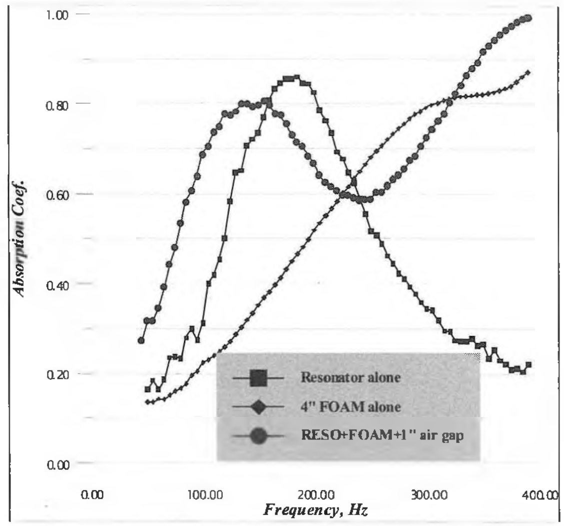


Comparison between measurement in impedance tube and prediction of a double layer Helmholtz resonator system.

Figure 2: One Helmholtz resonator combined with 4" foam.



Measured in impedance tube.