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SOUND ABSORPTION PROPERTIES OF A PERFORATED PLATE AND MEMBRANE CEILING ELEMENT

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INTRODUCTION

A standard type of sound absorbing ceiling elements manufactured by DAMPA, Denmark, is constructed of a perforated metal plate, a thin plastic membrane, and a layer of mineral wool. Tests made by the manufacturer indicated that although the mineral wool was removed, the sound absorption of the elements was preserved to a certain extent. In order to investigate the sound absorbing properties of this new type of element the absorption coefficients for a large number of test specimens were measured in an impedance tube. Based on the measurement results a simple theoretical model describing the sound absorbing properties was developed.

MODEL

The perforated plate and membrane construction is shown in Fig.1. In the figure three sections I, II, and III are indicated. These sections are limited by the perforated plate, the membrane, and the wall or ceiling to which the construction is mounted. The plate is perforated with identical circular holes. The holes are equidistant. An elastic membrane is mounted directly to or very close to the perforated plate. The distance between plate and membrane is greatly exaggerated in Fig.1. The plate and membrane are approximately located in the same plane at $y = 0$. The distance between membrane and wall is d. In the coordinate system indicated in the figure the wall is located at $y = -d$. A plane sound wave is incident on the perforated plate.

In section I in the figure the pressure is composed of incident and reflected plane waves. The total pressure on the plate is forcing the displacement of the entrapped air volumes in the perforations and of the membrane. A set of differential equations describing the pressure fields in the three sections and the motion of membrane and entrapped air volumes can be formulated as described in [1]. Based on these equations the absorption coefficient for a structure can be calculated as function of geometrical and material parameters, frequency and the losses in the structure.

LOSSES

The total loss factor depends on the losses in each hole, in the cavity between membrane and wall and in the membrane itself and on the losses induced by the motion of air in between the plate and membrane. These last-mentioned losses are of the greatest importance for the performance of the absorbent. These losses result from the wave motion in the thin boundary layers close to the membrane and plate. When the distance between membrane and plate is larger than a fraction of a millimetre, the boundary layer effect becomes insignificant. In the model only losses induced in the holes and in between plate and membrane are included. The other losses are comparatively small and therefore neglected.

MEASUREMENTS

A large number of measurements of the absorption coefficients for some small test specimens have been carried out according to the standing wave method in an impedance tube. In these measurement series the main construction parameters such as perforation ratio, hole diameter, membrane thickness, and distance between membrane and plate as well as distance between membrane and wall have been varied.

In the expressions which determine the absorption coefficients there are certain parameters which cannot be calculated directly. These parameters are proportional to the frictional or viscous losses between plate and membrane and in the holes. These unknown parameters are determined from measurements on two test specimens. The parameters so obtained are inserted in the prediction formula and used for all other configurations for both normal and diffuse incident sound fields. Some results are shown in Figs. 2 and 3 (normal incidence) and 4 (diffuse incidence). In Fig.5 the absorption coefficient is shown for a construction where the distance between membrane and plate is 0.25 mm. This distance is large enough to ensure that the losses in the boundary layers no longer determine the total losses. The absorption coefficient is consequently drastically reduced.

CONCLUSIONS

The agreement between predicted and measured absorption coefficients is satisfactory. The following observations can be made:

I The absorption for the construction is mainly due to viscous losses in between plate and membrane.

II When the distance between plate and membrane exceeds a fraction of a millimetre, then the absorption is drastically reduced.

III The frequency for which the absorption has a maximum is increased if the mass of the membrane or the distance between membrane and wall is decreased or if either the perforation ration or the tension in the membrane is increased.

ACKNOWLEDGEMENT

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REFERENCE

[1] A. Nilsson and B. Rasmussen, "Absorption Properties of a Perforated Plate and Membrane Construction". Report No. 104, Danish Acoustical Institute 1983.

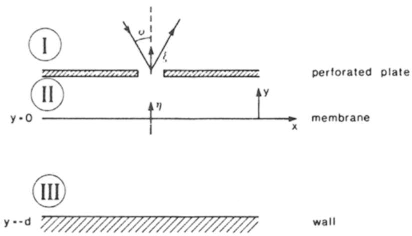

Fig.1 Model

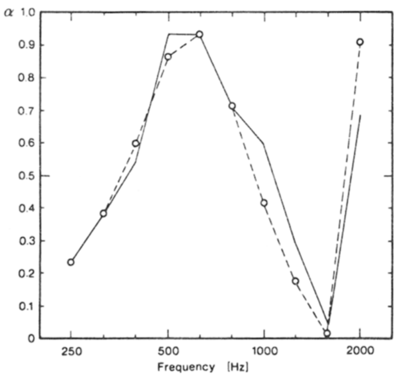

Fig.2 Measured (—) and predicted (---) absorption coefficients for normal incidence. Perforation ratio 0.11, hole diameter 1.3 mm, plate thickness 0.45 mm, distance d 0.1 m, mass of membrane 40 g/m^2.

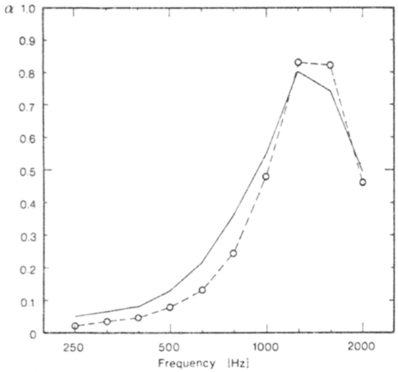

Fig.3 Measured (—) and predicted (---) absorption coefficients for normal incidence. Perforation ratio 0.27, hole diameter 1.1 mm, plate thickness 0.45 mm, distance d 0.03 m, mass of membrane 40 g/m^2.

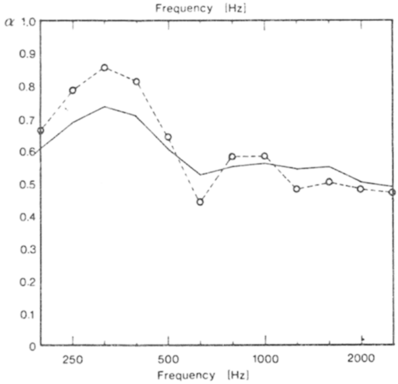

Fig.4 Measured (—) and predicted (---) absorption coefficients for diffuse incidence. Perforation ration 0.27, hole diameter 1.1 mm, plate thickness 0.45 mm, distance d 0.3 m, mass of membrane 25 g/m^2.

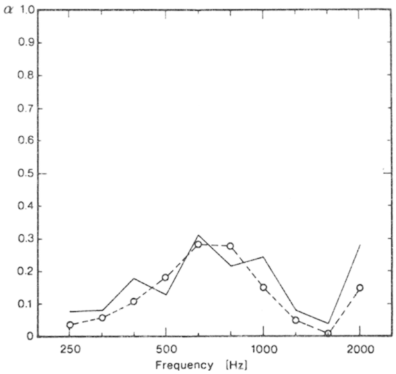

Fig.5 Measured (—) and predicted (---) absorption coefficients for normal incidence. The distance between plate and membrane is 0.25 mm, perforation ratio 0.27, hole diameter 1.1 mm, plate thickness 0.45 mm, distance d 0.1 m, mass of membrane 20 g/m^2.