Absorption of a rigid frame porous layer with periodic circular inclusions and backed by a periodic grating.

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This abstract is derived from an article recently published[1].

This work was initially motivated by a design problem connected to the determination of the optimal profile of a discontinuous spatial distribution of porous materials and geometric properties for the absorption of sound. When compared to their efficiency at higher frequencies, porous materials (foams) suffer from a lack of absorption at low frequencies. The purpose of this presentation is to investigate an alternative to multilayering by combining the effects of embedding periodic rigid inclusions inside the porous sheet and of periodic irregularities of the rigid backing on which the structure porous panel is glued.

The first effect was previously investigated by use of the multipole method whereby a periodic set of rigid circular cylindrical inclusions was embedded in a macroscopically homogeneous rigid frame porous sheet. The radius of the inclusions were comparable to the wavelength in the plate. When the porous sheet is not backed, the addition of the heterogeneities leads either to an increase of the absorption coefficient, mainly due to a decrease of the transmission coefficient in the case of one grating of inclusions, or to band-gaps with total absorption peak in the case of a sonic crystal (multi-layered grating). The influence on the absorption was explained by mode excitation of the configuration, which was enabled by the periodic inclusions. The structure of this mode is close to one of the modes of the porous sheet and leads to energy entrapment. When the porous sheet is backed by a flat rigid plate and when one grating is embedded, a complex trapped mode can be excited. This results in a quasi-total absorption peak at a frequency below the quarter-wavelength resonance frequency.

The second effect was previously investigated by use of the multi-modal method, by considering periodic rectangular air-filled irregularities of the rigid plate on which porous sheets are often attached. This leads, in the case of one irregularity per spatial period, to a total absorption peak associated with the excitation of the fundamental modified mode of the backed layer. This mode is excited thanks to the surface grating.

Local resonance and trapped modes are other methods to localize the field and to trap the energy. In this presentation, the combined effects of embedding periodic circular inclusions inside a porous sheet and of an irregular rigid backing glued to the structure is investigated theoretically and numerically. The effect of the Bragg interference is clearly visible on the absorption curve, while large absorption peaks are obtained for frequencies close to or below the quarter-wavelength resonance of the backed porous sheet. The latter peaks are associated with the fundamental modified mode of the layer, with a complex trapped mode linked to the arrangement of the cylinders, and with a trapped mode, whose structure is close to the one of the fundamental mode of the irregularity. Each of these modes interferes mutually.

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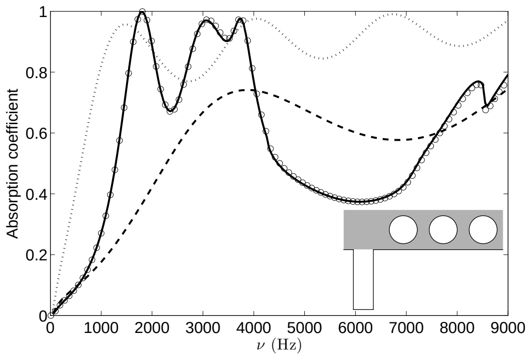

Figure 1: Absorption coefficient of a porous sheet of Fireflex backed by a rigid flat plate, when the thickness is $H = 2$ cm $(- - -)$ and when the thickness is $H + b = 5$ cm $(\cdots)$ without inclusion embedded and (—) with three $R = 75$ mm radius circular cylinders embedded per spatial period $d = 8$ cm, with an irregularity of the rigid backing. The Finite Element result is plotted with (o).

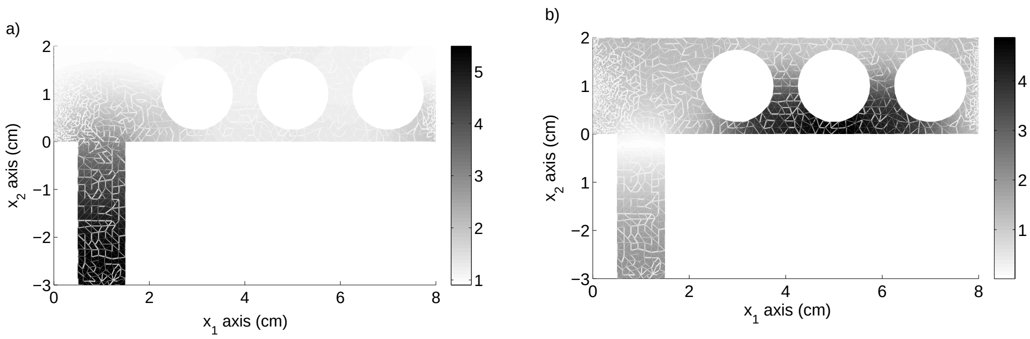

Figure 2: Snapshots of the pressure field in the porous sheet and the irregularity of the unit cell a) at $\nu_t^{(i)} = 1810$ Hz and b) $\nu_t^{(c)} = 3070$ Hz.

As an example Figure 1 depicts the absorption coefficient of a configuration composed of a porous sheet of thickness $H = 2$ cm, with three $R = 75$ mm radius circular cylinders embedded per spatial period $d = 8$ cm, with an irregularity of the rigid backing $b \times w = 3$ cm $\times 1$ cm (with b the height and w the width of the irregularity) when solicited at normal incidence. The numerical validation was performed by matching the absorption coefficient, as calculated with the multi-modal method together with the multipole method, with the one as calculated with a Finite Element method. The snapshots of the pressure field inside the porous sheet and the irregularity are depicted in Figure 2. From this figure it becomes clear that both absorption peaks at $\nu_t^{(i)}$ and $\nu_t^{(c)}$ are related to trapped mode excitation of the irregularity and three cylinders set, respectively.

References

1. J.-P. Groby, A. Duclos, O. Dazel, L. Boeckx, and W. Lauriks. Absorption of a rigid frame porous layer with periodic circular inclusions backed by a periodic grating. *J. Acoust. Soc. Am.*, 129:3035–3046, 2011.