70/73

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A PREDICTION OF OBLIQUE INCIDENCE BEHAVIOUR OF POROUS, FIBROUS ABSORBENTS.

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INTRODUCTION

Acoustic absorbents have often been considered to be locally reacting.[1-3] Further, in several theories of their oblique incidence behaviour, where extended reaction has been allowed, the models used are isotropic.[4-7] However, a considerable body of experimental evidence has been accumulated for porous absorbents of the fibrous type indicating both extended reaction[6-11] and anisotropy.[11,12]

Several theories[2-4] are simple extensions of classical normal incidence treatments and thus are based on general models whose microstructure is not specified. Frequency-dependent "gross" parameters are introduced which have involved meaning and are not readily measurable in actual materials. Other theories[7,11] relate to bulk acoustical variables with straightforward interpretation but therefore, require a minimum of either three acoustical measurements [11] or two mechanical and one acoustical,[7] to derive surface impedance as a function of angle.

THE FIBRE MODEL

A model which exhibits a relevant anisotropy[2,7(b),12] and which has been found appropriate for the prediction of normal incidence acoustic behaviour of glass-fibre quilt[13,14] is one of an array of parallel elastic (or inelastic) fibres in air. The "fibre reinforced air" treatments require knowledge of basic structural parameters only e.g. average fibre dimensions, concentration, etc. That of Kawasima[13] is based essentially on a homogeneous material or continuum approach, and thus is similar to classical treatments, requiring prediction simply of normal incidence values of propagation constant (k_{bn}) and characteristic impedance ($\rho_{bn}c_{bn}$) for extension to oblique incidence. However, that of the author [14] necessarily takes into account the discrete discontinuities of the model, as it is based on a scattering approach. The resulting prediction of oblique incidence behaviour is thus different from that of previous work.

THE SCATTERING THEORY

The theory involves computation of the scattering coefficients (zero'th and first order) of the expansion, in cylindrical harmonics, of the dilational wave scattered by a single fibre. These values are then used to evaluate the far-field scattering amplitudes necessary for application of a multiple scattering analysis based on Twersky.[15]

Clearly the scattering amplitudes differ according to whether incidence is normal to the fibre axes or at some angle. This reflects the anisotropy of the model.

PREDICTION OF BULK PARAMETERS

A - Normal Incidence

The field at any point inside a slab region of fibre scatterers on which is normally incident a plane dilatational wave, will consist of contributions from the incident wave and waves scattered and rescattered (i) backwards from fibres beyond and (ii) forwards from fibres in front of, the point considered. If this situation is compared with that for a continuum slab i.e. a single forward and backward wave, it is possible to derive an expression which represents an effective bulk propagation constant (k_{bn}). Similarly it is possible to discern in comparison of expressions for surface impedance, an expression which may be termed an effective bulk characteristic impedance ratio ($\rho_{bn}c_{bn}/\rho_o c_o$).

B - Oblique Incidence

When the incident wave is inclined to the surface at some angle θ these expressions become functions of θ, differing between incidence in the plane normal to the fibre axes and incidence in the plane parallel to the fibre axes. The "effective" bulk propagation constant expression represents, in fact, a value (k_b) in the direction normal to the surface. For an anisotropic model this clearly would be expected to depend on the angle of refraction, even without discontinuities.[11] However, the angular dependence of k_b, as predicted by the scattering theory is more involved.

CONCLUDING REMARKS

When the discontinuous nature of fibrous materials is brought into account, the feasibility of defining acoustical "constants" valid at oblique incidence is brought into question. It is possible however, to predict their behaviour entirely in terms of basic structural properties, using a fibre model and a scattering analysis.

RESULTS

Fig.1 shows the form of extended reaction predicted by the scattering theory. Figs.2-3, show the angular variation of expressions representing $k_m = (k_b^2+k_D^{f2}\sin^2\theta)^{\frac{1}{2}}$ i.e. the propagation constant in the direction of the "refracted" wave, for incidence both normal to the fibre axes and at some angle to them.

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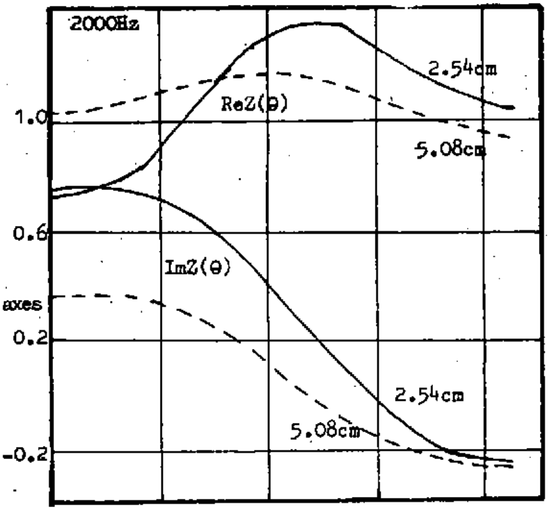

Fig.1

Layer impedance
Z(θ)

Normal to Fibre axes

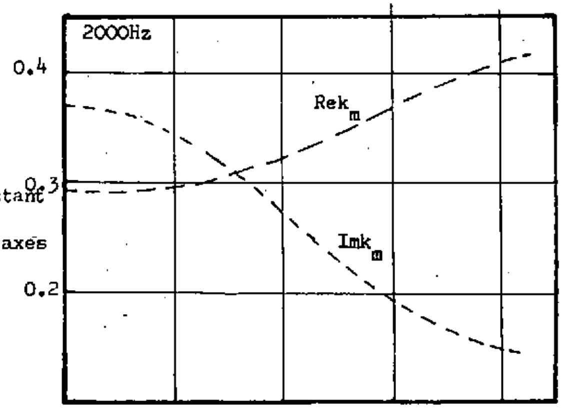

Fig.2

Propagation constant

Normal to Fibre axes

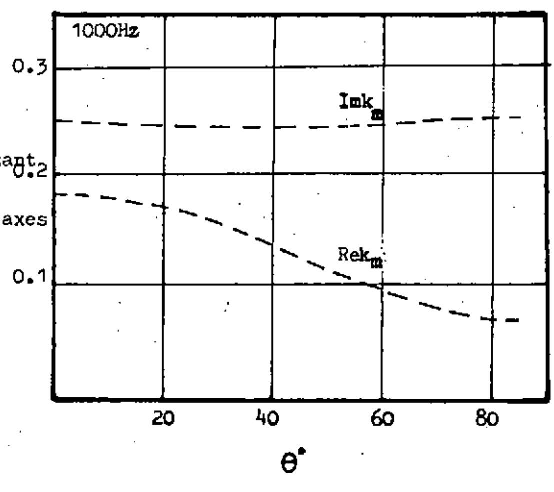

Fig.3

Propagation constant

Oblique to Fibre axes