Acoustic Response of a Multilayer Panel with Viscoelastic Material

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The development of materials both rigid and light with high damping effect and acoustic insulation is possible by using a multilayer panel with viscoelastic material. The rigidity of a multilayer panel is provided by its elastic layers, and damping is provided by viscoelastic layers. Prediction of the behavior of such systems in the conception phase is very important to determine the most important parameters in a multilayer panel in the aim to maximize insulation and to properly design this panel for several applications. In this work we have developed a model based on transfer matrix method, which is an analytic method to predict behavior of infinite layer subjected to a plane wave with an oblique incidence.

Notation

v_1	Velocity in the $\boldsymbol{x}_1$ direction
v_3	Velocity in the $\boldsymbol{x}_3$ direction
G	Shear modulus
$\boldsymbol{\nu}$	Poisson's ratio
$\boldsymbol{\rho}$	Mass density
$\boldsymbol{\omega}$	Angular frequency
$\boldsymbol{k_{comp}}$	Wave number of compressional wave
k_{cis}	Wave number of shear wave
ϕ	Compressional wave potential
ψ	Shear wave potential
k_1	Wave number in the x_1 direction
$k_{\phi 3}$	Wave number of the compressional wave in the x_3 direction
$k_{\psi 3}$	Wave number of the shear wave in the x_3 direction
σ_{33}	Normal stress
σ_{31}	Shear stress
p	Pression of the fluid
$\mathbf{V}$	State vector
$\mathbf{I}_{\mathbf{f},\mathbf{s}}$, $\mathbf{J}_{\mathbf{f},\mathbf{s}}$	Interface matrix
$\mathbf{I}_{\mathbf{s},\mathbf{f}}$, $\mathbf{J}_{\mathbf{s},\mathbf{f}}$	Interface matrix
$\mathbf{T}$	Transfer matrix
Z_c	Characteristic impedance of the fluid
Z_a	Impedance at the left-hand side of the material
Z_a	Impedance at the left-hand side of the material
T	Transmission coefficient
R	Reflection coefficient
TL	Transmission loss
τ	Acoustic transparency
E^*	Complex Youngs modulus
τ, τ_u	Relaxation time of the viscoelastic material
E_∞	Modulus in high frequency
E_0	Modulus at low frequency
f_{carac}	Characteristic frequency
δ	Phase angle for the viscoelastic material
f_{coin}	Coincidence frequency
D	Flexural rigidity

1. INTRODUCTION

Multilayer panels are widely used as sound insulation in automotive industries and building acoustics. Studies of acoustic response and wave propagation through stratified material are of paramount importance for the optimum design of a multilayer panel that is both rigid and light. In order to increase acoustic insulation properties of multilayered panels, many configurations including plates, impervious screens, and layers of air and viscoelastic media have been studied. The behavior of these combinations of materials depends more or less on the dimensions and the boundary conditions at the edges. Nevertheless, interesting results can be obtained by modelling the samples as infinite plates subjected to incident plane waves. Using the transfer matrix related to each layer considerably