Response to "Comments on An analytical study of sound transmission through unbounded panels of functionally graded materials"

Changzheng Huang[1,*], Steven Nutt[1]

1. Department of Chemical Engineering and Materials Science, University of Southern California, Los Angeles, CA 90089-0241, USA

Abstract: The solution expression in Eq. (28) is clarified and corrected.

*Corresponding authors: email: changzh@usc.edu (C.Huang), nutt@usc.edu (S. Nutt)

1. Introduction

We appreciate the comments made by Norris and Shuvalov regarding the solution of an ordinary differential equation system Eq. (26) in our original paper [1]. The solution expression stated in Eq. (28) is valid for constant matrix **A**, but generally not valid if the matrix **A** has variable coefficients.

The analytical solution for Eq. (26) with variable coefficient matrix has been given, for instance, in [2] and [3]. It involves a 6×6 matricant **M**

$$\boldsymbol{\psi}(z)=\mathbf{M}(z,0)\boldsymbol{\psi}(0). \quad (1)$$

This matricant M can be evaluated by the Peano series [2] and [3]

$$\mathbf{M}(z,0)=\mathbf{I}+\int_0^z \mathbf{A}(z_1)\mathrm{d}z_1+\int_0^z\int_0^{z_1}\mathbf{A}(z_1)\mathbf{A}(z_2)\mathrm{d}z_1\,\mathrm{d}z_2+\cdots. \quad (2)$$

The transfer matrix **T** defined in Eq. (30) may be expressed by the matricant as

$$\mathbf{T}=\mathbf{M}(h,0). \quad (3)$$

Please cite this article as: Changzheng Huang, Steven Nutt, **An analytical study of sound transmission through unbounded panels of functionally gradedmaterials**, Journal of Sound and Vibration, Volume 330, Issue 6, 14 March 2011, Pages 1153-1165, ISSN 0022-460X, http://dx.doi.org/10.1016/j.jsv.2010.09.020.

Another method to estimate the transfer matrix **T** is to divide a functionally graded panel into a number of sub-layers. With this approach, the transfer matrix **T** can be written as

$$\mathbf{T}^{(\text{new})} = \mathbf{T}^{(N)}\mathbf{T}^{(N-1)} \cdots \mathbf{T}^{(2)}\mathbf{T}^{(1)} = \prod_{n=N}^{1} \exp(h_n \mathbf{A}_n). \tag{4}$$

Here $h_n = z_n - z_{n-1}$ is the thickness of the nth sub-layer and $\mathbf{A}_n$ is the coefficient matrix evaluated at the mid-plane of this sub-layer. The method used in Ref. [1] is equivalent to evaluating the transfer matrix **T** as follows:

$$\mathbf{T}^{(\text{old})} = \exp\left(\sum_{n=N}^{1} h_n \mathbf{A}_n\right). \tag{5}$$

We re-ran the computations for the examples presented in Ref. [1] and found the results from these two approaches were nearly identical. Therefore the plots in [1] will not be repeated here.

References:

1. C. Huang, S. Nutt, An analytical study of sound transmission through unbounded panels of functionally graded materials, Journal of Sound and Vibration 330 (2011) 1153–1165.
2. A. Shuvalov, O. Poncelet, M. Deschamps, General formalism for plane guided waves in transversely inhomogeneous anisotropic plates, Wave Motion 40 (2004) 413–426.
3. A.L. Shuvalov, A.A. Kutsenko, A.N. Norris, O. Poncelet, Effective Willis constitutive equations for periodically stratified anisotropic elastic media,Proceedings of the Royal Society, A (2011), doi:10.1098/rspa.2010.0389.