Vibroacoustic Analysis and Response Suppression of a Rectangular Sandwich Electrorheological Panel

Seyyed M. Hasheminejad, S. M. Parvasi and A. Fadavi-Ardakani

Acoustics Research Laboratory, Center of Excellence in Experimental Solid Mechanics and Dynamics, School of Mechanical Engineering, Iran University of Science and Technology, Narmak, Tehran 16844 Iran

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A modal summation method based on far-field sound intensity is used to study the average radiation efficiency and the corresponding radiation power of a point-excited, simply-supported, rectangular sandwich plate containing a tunable electrorheological fluid (ERF) core, and set in an infinite rigid baffle. In addition, a classical analytical procedure based on the Rayleigh integral equation method is adopted to investigate the sound transmission characteristics (TL) of the adaptive plate insonified by plane pressure waves at an arbitrary angle of incidence, or excited by a perfectly diffuse sound field with a Gaussian directional distribution of energy. Numerical results reveal the imperative influence of an applied electric field strength (0–3.5 kV/mm) on controlling acoustic radiation from (or sound transmission through) the smart panel in a wide frequency range. In addition, an effort is made to find the optimal electric field which yields improved sound radiation and transmission characteristics for each excitation frequency. Limiting cases are considered and good agreements with the solutions available in the literature used in this study are obtained.

1. INTRODUCTION

Plates are one of the most extensively used structural components in industrial applications. Many civil, industrial, and modern aerospace and aeronautical structures (*e.g.*, walls and floors, ship hulls, machine elements, and aircraft sidewalls) can be practically modelled, to a first approximation, as a finite baffled panel. Throughout the past few decades, vibroacoustic problems involving acoustic radiation from (or sound transmission through) finitely bounded isolated panel structures have been subject to intense research. In particular, numerous efforts have been concentrated on studying the sound radiation and transmission characteristics of rectangular plates with various complications since early 1960s.[1] Maidanik[2] was the first to apply the concept of power flow and statistical energy analysis to derive several approximate asymptotic expressions for calculating the modal radiation resistance in different wavenumber regions for a simply-supported, rectangular isotropic plate placed in an otherwise rigid co-planar baffle. Wallace[3] subsequently used the Rayleigh integral to derive analytical expressions for the modal radiation efficiency of a simply-supported baffled rectangular panel. Leppington, *et al.*[4] provided a detailed mathematical analysis of the modal radiation from a simply-supported panel, and used the assumption of high modal densities to revise some of Maidanik's results for large acoustic wavenumbers, especially in the ranges close to the critical frequency.

Roussos[5] developed an analytical procedure for an efficient solution of sound transmission through a rectangular, simply-supported, isotropic or symmetrically laminated composite plate in an infinite rigid baffle and under arbitrary plane wave incidence. Panneton and Atalla[6] used a three-dimensional finite element model coupled with a boundary element approach to predict the sound transmission loss through multi-layer structures made of elastic, acoustic, and poroelastic (Biot) media. Lee and Kondo[7] presented analytical and experimental studies of noise transmission loss of a three-layered simply-supported baffled rectangular plate with a viscoelastic core. Foin, *et al.*[8] proposed a variational model to analyse the vibroacoustic behaviour of a rectangular, baffled, simply-supported plate covered by a free or a constrained viscoelastic layer and immersed in either a light or a heavy fluid. Foin, et al.[9] investigated the vibroacoustic behaviour of an elastic, simply-supported rectangular plate covered by a locally reacting decoupling layer immersed in water and subjected to a point force disturbance. Sgard, *et al.*[10] employed the finite element method to predict sound-transmission loss across finite- sized, double-panel sound barrier with poroelastic linings. Berry, *et al.*[11] investigated the vibroacoustic response of a finite, simply-supported rectangular plate covered by a thick layer of decoupling material and immersed in a heavy fluid. Park, *et al.*[12] used the Rayleigh-Ritz method to investigate the effects of the support properties (stiffness and damping) on the forced vibration response and the associated radiated sound of viscoelastically supported rectangular plates.

Chiello, *et al.*[13] used a free-interface component mode synthesis technique associated with the finite element method to study the vibroaocoustic behaviour of an elastically-supported baffled plate excited by a plane wave or a diffuse field. Xie, *et al.*[14] used results from a modal summation method based on the farfield sound intensity to investigate the average radiation efficiency of point-excited baffled rectangular plates, including those with a very large aspect ratio (strips). Au and Wang[15] investigated sound radiation from forced vibration of rectangular orthotropic plates with general boundary conditions traversed by moving loads. Park and Mongeau[16] used the Mindlin plate theory and the Rayleigh-Ritz method to investigate the vibroacoustic characteristics of sandwich panels with viscoelastic supports. Assaf and Guerich[17] used a finite element formulation coupled to a boundary element method to predict noise transmission loss (TL) through viscoelastically-damped sandwich rectangular plates subjected to an acoustic plane wave or