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A regular variational boundary model for free vibrations of magneto-electro-elastic structures

G. Davì, A. Milazzo *

Dipartimento di Ingegneria Strutturale, Aerospaziale e Geotecnica, Università di Palermo, Viale delle Scienze 90128 Palermo, Italy

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ABSTRACT

In this paper a regular variational boundary element formulation for dynamic analysis of two-dimensional magneto-electro-elastic domains is presented. The method is based on a hybrid variational principle expressed in terms of generalized magneto-electro-elastic variables. The domain variables are approximated by using a superposition of weighted regular fundamental solutions of the static magneto-electro-elastic problem, whereas the boundary variables are expressed in terms of nodal values. The variational principle coupled with the proposed discretization scheme leads to the calculation of frequency-independent and symmetric generalized stiffness and mass matrices. The generalized stiffness matrix is computed in terms of boundary integrals of regular kernels only. On the other hand, to achieve meaningful computational advantages, the domain integral defining the generalized mass matrix is reduced to the boundary through the use of the dual reciprocity method, although this implies the loss of symmetry. A purely boundary model is then obtained for the computation of the structural operators. The model can be directly used into standard assembly procedures for the analysis of non-homogeneous and layered structures. Additionally, the proposed approach presents some features that place it in the framework of the weak form meshless methods. Indeed, only a set of scattered points is actually needed for the variable interpolation, while a global background boundary mesh is only used for the integration of the influence coefficients. The results obtained show good agreement with those available in the literature proving the effectiveness of the proposed approach.

1. Introduction

The use of magneto-electro-elastic materials has recently emerged in the field of smart structural devices such as sensors, actuators and transducers. These media convert energy into three different forms: magnetic, electric and mechanic. This peculiar feature arises as magneto-electro-elastic media are particulate or laminate composite materials having among their constituents piezoelectric and piezomagnetic phases. Magneto-electric coupling is the by-product property of magneto–mechanic and electro–mechanic coupling and this characteristic seems to make these multi-field composites potentially superior to other materials for application in smart structures [1]. The properties of these materials allow employing electrically or magnetically induced strains to control the mechanical behaviour of a structure and, on the other hand, the use of strain-induced electric and magnetic signals as a feedback driver in control systems. At its more evolved application this approach leads to the concept of highly integrated intelligent structures which are capable of reacting to external stimula by means of a distributed network of sensors and actuators [2–4]. This goal can be achieved by layers of magneto-electro-elastic material being either attached to or embedded in the host structure to be controlled and actuated by a system of suitably arranged electrodes and poles. Among other technological applications, great interest is devoted to structural vibrations control through the use of active or passive damping systems based on magneto-electro-elastic materials as just proposed with piezoelectrics [5–8] and piezomagnetics [9–11].

The effective design of magneto-electro-elastic devices relies on the capability of correctly modelling the system's response taking into account the mutual effects between mechanical, electric and magnetic fields. Analytical solutions to problems concerning magneto-electro-elastic solids are rare due to the complexity of the governing equations. Recently, some formulations have been developed for the dynamic analysis of single-layer and laminated electro-elastic [12–18] and magneto-electro-elastic solids [19–25]. These models are generally based on energy principles and are classified on the basis of the assumptions made to approximate the electromechanical variables in the thickness direction of the laminate. They are analytically solved for simple cases, whereas the extensive use of the finite element method allows the treatment of more general problems.

* Corresponding author. Tel.: +39 91 23896748; fax +39 91 485439.
E-mail address: alberto.milazzo@unipa.it (A. Milazzo).

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