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FORMULATION OF SMART LAMINATED BENDING PLATES

Mahmoud Miri [1], Yaser Sadeghi [2], Hadi Enferadi [3]

1- Assistant Professor, Department of civil engineering, University of Sistan and Baluchestan

2,3- Ph.D student, Department of civil engineering, University of Sistan and Baluchestan

Yaser_sadeghi_83@yahoo.com

Abstract

The structures with mounted or embedded sensors and actuators, that have the capability to sense and take corrective action are referred to as smart structures. In the present paper, the characteristics of composite and piezoelectric materials are discussed. Furthermore, a review of smart structures formulation is presented. A new element and finite element formulation is suggest for smart composite plates. A program, based on the new formulation, is written for analysis of smart laminate plates.

Keywords: Laminated plate, Piezoelectric, Composite material, Sensor, Actuator

1. INTRODUCTION

Due to the prominent role of plates in civil, aerospace and mechanical structures, extensive research has been conducted on their behavior and their analytical formulation during the last decades. With the advancement of technology, new kinds of material have been introduced into construction. For example, composite materials are now used in the production of multi-layered bending plates.

Structural members such as beams, plates, shells and laminated elements, which constitute the active material, create a class of structures known as smart structures. Various definitions of this kind of structures exist. By Newnham's description, smart structures are ones that actuators and sensors, with the ability of sensing and taking corrective action, have been implemented inside or on the surface of the structure [1]. The process of designing a piezoelectric laminated plate, with a number of sensors and actuators distributed on its surface, is developed by Lee [2]. Lee also obtained the interactive relations between a laminated plate and the smart material. Experimental research has been carried out by Lazarus on smart structures with plate elements subjected to strain excitations [3]. In 1991, a piezoelectric brick element with three degrees of freedom was proposed by Tzou et al [4]. Ha et al. proposed an 8-node hybrid brick element [5]. They investigated the response of laminated composite structures composed of piezoelectric ceramics under mechanical and electrical loading. In 1993, a 4-node flexural plate element with twelve electrical degrees of freedom was developed by Park et al [6]. Detwiler used the finite element method to analyze laminated composite structures with sensors and actuators distributed on their surface [7]. Wang et al. developed the governing equilibrium equations of smart structures comprised of piezoelectric sensors and actuators [8]. Based on classic analytical methods, they formulated a 4-node bending plate element with a single electrical degree of freedom on each node.

The construction of smart composite structures is expanding due to the articles published to this day Therefore, researchers are in need of new elements for their analyses. In this paper, a 12-node triangular element is developed for the analysis of composite plates. The authors state the assumptions and explain the formulation in detail during the process and also elaborate on the stress-strain relation of multi-layered structures. The characteristics of composite and piezoelectric materials are given afterwards. Concluding this, the suggested finite element formulation is presented for smart composite plate structures. In this process, Mindlin's first-order shear deformation theory is utilized. The proposed formulation is capable of analyzing both thin and thick plates. Finally, the competence of this new element is examined via numerical analyses.

2. PIEZOELECTRIC MATERIAL EQUATIONS

A laminated composite plate with integrated sensors and actuators is shown in Fig. 1.