Stability Analysis of Columns with Surface Bonded Piezoelectric Layers Using Meshfree Method

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Abstract
The main objective of this work is to extend the use of the Element-Free Galerkin (EFG) method for static buckling analysis of column with surface bonded piezoelectric layers. The piezoelectric layers are implemented in order to increase the buckling capacity of the column. The most significant advantageous of the meshfree method is that it requires only nodes, a description of internal and external boundaries of the model and also no element connectivity is needed. However, similar to any discretization method, acceptable solutions can only be obtained for a sufficiently refined discretization. The formulation is derived from the variational principle and solved numerically and the piezoelectric stiffness is taken into account in the model. A constant gain feedback control algorithm is used and increases Euler's critical buckling load during piezoelectric actuation. The results obtained from the meshfree buckling analysis of an axial compressed simply supported, fixed-fixed and fixed-pinned columns show that active control can be used to stabilize compressive members against buckling, allowing them to be loaded well in excess of critical buckling load of bare coulmns.
Keywords: Piezoelectric layer, Column, Buckling, Meshfree method.

1. INTRODUCTION

The mathematical solution for the buckling analysis of columns under different boundary conditions subjected to non-follower compression is well documented in the monograph by Timoshenko and Gere [1]. A non-follower force is usually referred as an axial force with its direction remaining constant during the deformation of the structure. Buckling of a column is referred as the change of its equilibrium state from one configuration to another at a critical compressive load.

The applications of the smart materials in engineering structures have drawn serious attention recently. Smart structures are systems whose geometric and structural characteristics can be beneficially modified during their operational life to meet the host's requirement. They compose the main structure and a network of sensors and actuators. Because of their self-monitoring and self-adaptive capabilities, the smart structures have recently attracted considerable attention and their numerous applications range from shape control and vibration suppression to self-diagnostic applications for the detection of cracks or defects within a structure or building. A common form of a smart structure is a thin structure equipped with sensors and actuators. Due to unique characteristics such as ease of integration into existing structures, and easily controlled by voltage and high bandwidth (allowing large range of applications), piezoelectric materials are suitable candidates to be implemented as sensors and actuators. When the piezoelectric material is subjected to a mechanical deformation, an electrical voltage is generated within that material. Likewise, if a voltage is applied across the piezoelectric material, a strain is created in the material. These two phenomena are well known as direct and converse piezoelectric effects. Such materials have been studied in varied applications such as shape control of structures, acoustic wave excitation and structural health monitoring [2,3]. Meressi and Paden showed that the buckling of a flexible beam could be postponed beyond the first critical load by means of feedback using piezoelectric actuators and strain gauges [4]. Thompson and Loughlan studied experimentally the potential to increase the load bearing strength of imperfection sensitive composite columns loaded in compression [5]. The concept is to apply a controlled voltage to the actuators to induce a reactive moment at the column centre with the aim of removing the lateral deflections and force the column to behave in a perfectly straight manner. The use of piezoelectric layers to induce tensile forces on the host column in enhancing the buckling capacity of the latter under a non-follower force has been mathematically formulated and analyzed by Wang [6].In this study, the effects of the location and size of the piezoelectric layers on the buckling enhancement are studied.

The subject of numerical simulation has been dominated by the finite element method (FEM), finite difference method (FDM) and boundary element method (BEM) for the past few decades. Having been