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Finite Volume Method for Buckling Analysis of Columns with Piezoelectric Layers

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ABSTRACT

The main objective of this study is to develop a finite volume based formulation for the instability analysis of columns with piezoelectric patches bonded on their faces. The piezoelectric layers are implemented in order to increase the buckling capacity of the column. For the columns with piezoelectric Layers and different boundary conditions, the variation of the buckling capacity is discussed through the numerical simulations. The mathematical formulation is presented and solved numerically based on the cell-centered finite volume method, in which the shear effects are taken into account. A constant gain feedback control algorithm is used which increases the critical buckling load over the piezoelectric actuation period. In this way, the equilibrium equations of control volumes are expressed and used with the boundary conditions to obtain the eigenvalue equation in the standard format. Then, the buckling loads of columns are obtained by solving the eigenvalue equations. The formulation is tested on a number of benchmark problems.
The results obtained from the finite volume 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 columns.

Key Words: Piezoelectric layer, Composite column, Buckling, Finite volume 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]. 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. 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. 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 [2]. Thompson and Loughlan studied experimentally the potential to increase the load bearing strength of imperfection sensitive composite columns loaded in compression [3]. 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