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INTERVAL ANALYSIS METHODOLOGY IN THE VIBRATION CONTROL OF A SMART STRUCTURE WITH LAMINATED COMPOSITE UNCERTAINTIES

Marcos Daniel De Freitas Awruch, Herbert Martins Gomes

UFRGS, Brazil
marcos.dfa@gmail.com, herbert@mecanica.ufrgs.br

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Summary: In the past few years, substantial attention has been paid to active vibration control of smart and lightly damped flexible structures in several fields of civil, mechanical and aerospace engineering, in applications such as tower structures, motion control of robotic systems, satellite solar panels, and many others. In order to satisfy precision control and lightweight requirements, smart materials such as piezoelectric and shape memory alloys are frequently integrated into laminated composite structures as sensors or actuators. The usage of piezoceramic material is a field with ongoing investigation and application and its advantages include low-power consumption, fast response time, wide variety of shapes and sizes, and easy implementation.
Laminated composite structures are known for its challenges to deal with some uncertain properties that can arise from its manufacturing process as well as material defects such as interlaminar voids, fiber misalignment, residual stresses, variation in ply thickness, and others. Furthermore, the angle-ply configurations modifications could induce bending–stretching and bending-twisting coupling effects since the symmetry of the laminate might change.
To deal with the uncertainty in a project, it is possible to use a probabilistic approach, but in that case it is necessary to have enough and reliable information on the random variables, such as its mean value, moments and type of distribution. Usually, in many engineering applications, there are not enough measurements or knowledge about the uncertain parameters, or even they were measured with insufficient accuracy. When statistical data cannot be obtained or the information is imprecise, the possibilistic approach is preferable. Possibilistic methods deal with the extreme scenarios, or the problem output boundaries, giving no information about their probabilistic distribution.
This works applies an interval analysis methodology associated with a heuristic optimization algorithm to search for the output boundaries of the given example, quantifying its uncertainty. In this work the PSO (Particle Swarm Optimization) algorithm is used as the tool for the minimum and maximum boundary search. Herein we work with a laminated composite plate with embedded piezoelectric actuators controlled through Linear Quadratic Regulator (LQR) and the output performance parameter analyzed is the integral over time of the kinetic and potential energy of the beam. The uncertainties are considered present in the material properties, ply angles and ply thickness.
In view of a practical application, this interval analysis method is not intrusive and may well adapt to several existing codes and software, allowing dealing with a wide range of problems. Material property uncertainties are a reality and may cause significant modifications in the dynamic behavior of the structure. Therefore it is advisable to investigate the design performance under uncertain parameters. Some comparisons related to structural displacements and control forces in the frequency domain for each analyzed case are presented and depicted, highlighting the role and main features of the uncertain parameters.