Mechanical Engineering Master's Defense

Nonlinear geometric response of structure with piezoelectric actuator by reduced order modeling using a temperature analogy

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abstract

The focus of this investigation is on the formulation and a validation of reduced order models (ROMs) for the prediction of the response of structures with embedded piezoelectric actuators. The ROMs considered here are those constructed in a nonintrusive manner from a commercial finite element software, NASTRAN is adopted here. Notwithstanding the popularity of piezoelectric materials in structural dynamics related applications such as structural health monitoring and energy harvesting, not all commercial finite element software allow directly their modeling. In such cases, e.g., with NASTRAN, one can proceed with an analogy and replace the electric actuation in the piezoelectric material by a fictitious thermal effect producing the same strain. This process recasts the determination of a ROM for a structure with embedded piezoelectric actuator into a similar ROM but for a heated structure, the framework of which has recently been developed. Yet, the temperature field resulting from the analogy would be quite different from the one considered in past effort and would excite a broad array of structural modes. Accordingly, as a preamble to considering a beam with a piezoelectric layer, a simpler plate model is considered that is subjected to a uniform temperature but a complex pressure loading that excites the entire set of modes of the plate in the broad frequency band considered. The very good match of the predictions obtained by this ROM in comparison to their full finite element counterparts provides the necessary confidence to next address a beam with embedded piezoelectic actuator. The test model considered for this validation is a built-up nano beam analyzed recently in nonlinear geometric conditions by full finite elements and by an intrusive ROM procedure under harmonic variations of the piezoelectic voltage. This structural model and its loading conditions are very different from those considered in past applications of nonintrusive ROMs, thus the excellent results obtained here provide further support of the broad generality of the nonintrusive ROM methodology, including of the appropriateness of the "dual modes" basis functions.

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