A robust computational method for coupled processes in inelastic materials under active damping regimes

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Abstract

A robust computational method for investigating the thermomechanical response of physically inelastic non-linear systems to dynamic loading was developed. A non-linear dynamic problem of thermo-electromechanics for layered beams was formulated using the Kirchhoff–Love hypotheses. For the case of harmonic loading, a simplified formulation was given based on a single frequency approximation and utilizing the concept of complex moduli to characterize the non-linear cyclic properties of the material. As an example, the forced vibrations and dissipative heating of a roller-supported beam were considered. The developed formalism of thermo-electro-mechanical problem was used for estimating the self-heating caused by the electromechanical losses in piezoactive layers and the mechanical losses in electrically passive metal layer. The heating temperature evolution with time was computed. It was shown that even very small temperature increases due to the dissipation of electromechanical energy over the single vibration cycles may lead to a significant temperature rise for the multi-cycle processes. Following (1-3), the cyclic behaviour of PZT was considered to be a viscoelastic one with relatively small loss moduli. Complex moduli for this material were assumed to be independent of the frequency, temperature, and strain intensity. To avoid dangerous overheating, safe vibration regimes were found. For this purpose, the thermal fatigue life characteristic was introduced. It corresponds to the classical fatigue life, but with the Curie temperature taken as the failure criterion. To prevent overheating, active suppression of the vibration can be used. This was illustrated by numerical examples. The developed method was also successfully used for describing the thermal state under active damping regimes for other thin wall structures with piezoelectric layers for the case of small to moderate inelastic strains in the metal layer.

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