Dissipative heating and thermal fatigue life prediction for structures containing piezoactive layers

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A method for investigating the thermomechanical response of physically inelastic non-linear systems to dynamic loading is developed. For the case of harmonic loading, a simplified formulation is given based on a single frequency approximation and utilizing the concept of complex moduli to characterize the non-linear cyclic properties of the material. It is demonstrated that the method is a powerful tool for determining the system's responses to the mechanical and electrical excitations, as well as the elevated temperatures arising due to the dissipative heating. As an example, the forced vibrations and dissipative heating of a roller-supported beam containing piezoactive layers are considered.

The developed formalism of thermo-electro-mechanical problem can be also used for estimating the self-heating caused by the electromechanical losses in piezoactive layers and the mechanical losses in electrically passive metal layer. For this purpose, the heating temperature evolution with time is computed. It is 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. The thermal fatigue life of the considered structure is estimated assuming that the structure fails if the temperature exceeds the Curie point for piezoceramics. Using this criterion, the safe dissipative heating levels under harmonic loading are determined. The developed method is 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.