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HAMILTONIAN MECHANICS FORMULATION & FINITE ELEMENT SIMULATION OF ADAPTIVE SMART AXISYMMETRIC TELESCOPIC STRUCTURES

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ABSTRACT

In this research, an analytical formulation and a numerical finite element modeling of a smart laminated composite tubular space structure are presented. It is equipped with concentric internal and external tubes of piezoelectric layers for actuation/ sensation around the host tube structure. The smart space structure consists of a tubular or box section of either steel or aluminum elastic core covered between two interior and exterior elastopiezoelectric outer and inner layers sandwiching the core. This geometric setup works together as a telescopic section. This model plays the role of both the load carrying system and the actuator/ sensor mechanisms. It is assumed that the geometry, material behaviors, boundary conditions, and electrodynamic loadings including inertia effects of earthquake excitation have all axial symmetry. This hypothesis permits the use of two-dimensional axisymmetric solid elements to be used in finite element modeling instead of shell elements. The actuation mechanism under axisymmetric loadings is conjectured to be only in the extensional-mode mechanism. The actuating mechanism activates the elastic core layer sandwiched between two transversely polarized active outer and inner surface-bonded tubular piezolayers in which the polarization vector is parallel to the applied electric field intensity vector both of them parallel to the radial directions. For more simplifications of the constructed mathematical theory, some implementable special boundary conditions have been incorporated into the model for the structural connection of the piezoelectric layers to the foundation of the integrated tube. The mechanical and electrical field variables of the continuum are developed theoretically by the extended principle of Hamiltonian electrodynamics. The corresponding finite element modeling is coded and calculated using the commercial stress analysis multiphysics ANSYS® and numerical/graphical MATLAB® softwares. In this paper, as a parametric study, the effects of actuator locations and control voltage magnitudes on the axisymmetric static and electrostatic responses, natural frequency/ mode shape analysis, and dynamic and electrodynamic responses to multi-harmonics sinusoidal and pulse excitations are calculated and compared. Also, the maximum allowable value of the voltage applied to the actuator is calculated based on the dielectric strength of piezoelectric materials and their Von-Mises yield stress criterion.

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