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ORIGINAL PAPER

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A GN model for thermoelastic interaction in a microscale beam subjected to a moving heat source

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Abstract In this study, the problem of thermoelastic interaction in a microscale beam subjected to a moving heat source in the context of Green and Naghdi theory type III is investigated. The both ends of the microscale beam are clamped and thermally isolated. The basic equations have been written in the form of a vector-matrix differential equation in the Laplace transform domain, which is then solved by an eigenvalue approach. The analytical solution in the Laplace domain is obtained for lateral deflection, displacement, temperature, and stress. The effects of moving heat source speed are analyzed. The resulting quantities are depicted graphically.

1 Introduction

Biot [1] introduced the theory of coupled thermoelasticity to overcome the first shortcoming in the classical uncoupled theory of thermoelasticity where it predicts two phenomena not compatible with physical observations. The theory of coupled thermoelasticity was extended by Lord and Shulman [2] and Green and Lindsay [3] by including the thermal relaxation time in constitutive relations. In the decade of the 1990s, Green and Naghdi [4–6] proposed three new thermoelastic theories based on an entropy equality rather than the usual entropy inequality. During the second half of the twentieth century, non-isothermal problems of the theory of elasticity became increasingly important. The counterparts of our problem in the contexts of the thermoelasticity theories have been considered by using analytical and numerical methods [7–21]

Microscale mechanical resonators have high sensitivity as well as fast response and are widely used as sensors and modulators. Nanoelectromechanical systems, or NEMS, attain extremely high fundamental frequencies of operation given by their reduced size and small force constants. At high energy density, a thin surface layer of the solid material melts, followed by an ablation process whereby particles fly off the surface, thus giving rise to forces that generate ultrasonic waves. Thermally induced vibrations of beams have many important applications in space vehicles, turbines, mechanical signal processing, reactor vessels, etc.

Many authors have studied the vibration and heat transfer process of beams taking into account the theories of thermoelasticity. Nayfeh and Younis [22–24] derived analytical expressions for the quality factor of microplates of general shapes due to thermoelastic damping. Yasumura et al. [25] observed thermoelastic damping in single-crystal silicon and silicon nitrid microresonators at room temperature. Honsten et al. [26]

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