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Abstract

In this paper, thermoelastic damping (TED) in free vibrating functionally graded material (FGM) micro beams with rectangular cross sections is investigated. The material properties of the micro beams are assumed to be varied continuously in the thickness direction. Based on the classical beam theory and coupled thermo-elastic dynamics, governing equations coupled with the thermal effects derived in terms of the deflection and temperature rise filed. A layer-wise homogenization method is proposed to solve the one-way coupled heat conduction equation with variable coefficients. By using the mathematical similarity between the vibration equation of the FGM beam and that of the reference homogenous beam, complex frequency of the FGM beam including TED is expressed in the terms of that of the reference homogenous beam without TED. Numerical results of TED are obtained for the specific material constituents and the power law gradient profile. The effects of the material gradient index, beam thickness, vibration modes and boundary conditions on the TED of the FGM micro beams are studied in detail.

Key words: Thermoelastic damping, functionally graded materials, micro beam resonators, inverse quality factor, layer-wise homogenization approach

1. Introduction

Thermoelastic damping (TED) has been considered as one of the dominant intrinsic energy dissipation mechanisms in micro and nano electromechanical systems (MEMS/NEMS) which originates from the irreversible flow of heat generated by the compression and decompression in the micro structures due to the thermoelastic coupling in the transversely vibration [1]. TED will increase significantly along with the miniaturization of devices and it will not be eliminated by improving the external conditions [2-5]. In the idealized external conditions TED always impose an upper limit on the quality factor of a micro resonator. Therefore, it is of great importance to quantitatively analyze TED and to understand it as one of the dominant energy dissipation mechanisms in all the micro mechanical resonators.

As early as in 1937's, Zener[2,3] was the first to realized that TED, or thermoelastic internal friction, may be a significant dissipation mechanism in mechanical resonators and developed an approximate analytical expression for it, which was called Zener's formula late, in a thin rectangular cross-section metallic beam with flexural vibration based on a linear one-way coupled theory of thermoelasticity and Euler-Bernoulli beam theory. Since the