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Transient coupled magnetothermoelastic problem of multilayered hollow cylinder subjected to magnetic and vapor fields ☆

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Abstract

This paper deals three-dimensional axisymmetric quasistatic-coupled magnetothermoelastic problems for time-dependent boundary condition. The water vapor temperature and pressure relation is assumed for the inner boundary. The water vapor temperature and pressure data were obtained from a thermodynamic steam table. Laplace transform and finite difference methods are used to analyze problems. The solution is obtained by using the matrix similarity transformation and inverse Laplace transform. We obtain solutions for the temperature and thermal deformation distributions in a transient and steady state. Moreover, the computational procedures established in this thesis, can solve the generalized magnetothermoelasticity problem for multilayered hollow cylinder with nonhomogeneous materials.

Keywords: Multilayered; Magnetothermoelastic; Laplace transform

1. Introduction

The classical uncoupled theory of thermoelasticity predicts two phenomena not compatible with physical observations. First, the equation of heat conduction of this theory does not contain any elastic terms, contrary to the fact that elastic changes produce heat effects. Second, the heat equation is of a parabolic type, predicting infinite speeds of propagation for heat waves. Jane and Lee [1] introduced the theory of coupled thermoelasticity to overcome the first shortcoming. The cylinder is composed of multilayers with different materials. There is no limit of number of annular layers of the cylinder in the computational procedures.

Two generalizations to the coupled theory were introduced. The first is due to Lord and Shulmann [2], who obtained a wave-type heat equation by postulating a new law of heat conduction to replace the classical Fourier's law. This new law contains the heat flux vector as well as its time derivative. It also contains a new constant that acts as a relaxation time. Since the heat equation of this theory is of the wave type, it automatically ensures finite speeds of propagation for heat and elastic waves. The remaining governing equations for this theory, namely, the equations of motions and constitutive relations, remain the same as those for the coupled and the uncoupled theories. This theory was extended by Dhaliwal and Sherief [3] to generalize an isotropic media in the presence of heat sources. Recently, Chen et al. [4,5] discussed the transient response

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Nomenclature

r	non-dimensional radial coordinate
λ	Lame's constant
ρ	density
C_v	specific heat
Θ_0	reference temperature
L	z-direction length
$v_{\theta r}$, $v_{r\theta}$	Poisson's ratio
f_1, f_2	inner and outer surrounding temperatures
Θ, T	dimensional and non-dimensional temperatures
U_r, u_r	dimensional and non-dimensional displacements
τ, t	dimensional and non-dimensional times
r, θ, z	cylindrical coordinates
k_r, k_θ, k_z	thermal conductivities
α_r, α_θ, α_z	linear thermal expansion coefficients
E_r, E_θ, E_z	Young's moduli
σ_r^*, σ_θ^*, σ_z^*	dimensional stresses
σ_r, σ_θ, σ_z	non-dimensional stresses
C_{ij}	the stiffness coefficients
μ_0	magnetic permeability
H_0	initial constant magnetic field vector

of one-dimensional quasi-static coupled and uncoupled thermoelasticity problems of multilayered hollow cylinder. Laplace transform and finite difference methods are used to analyze problems. We obtained solutions for the temperature and thermal stress distributions in a transient state. Sherief and Ezzat [6] obtained the fundamental solution for this theory that is valid for all times. The second generalization to the coupled theory of elasticity is what is known as the theory of thermoelasticity with two relaxation times or the theory of temperature-rate-dependent thermoelasticity.

Increasing attention is being devoted to the interaction between magnetic fields and strain in a thermoelastic solid due to its many applications in the fields of geophysics, plasma physics, and related topics. In the nuclear field, the extremely high temperatures and temperature gradients as well as the magnetic fields originating inside nuclear reactors influence their design and operations. This is the domain of the theory of magnetothermoelasticity. A comprehensive review of the earlier contributions to the subject can be found in Paria [7]. Among the authors who considered the generalized magnetothermoelastic equations are Nayfeh and Nasser [8], who studied the

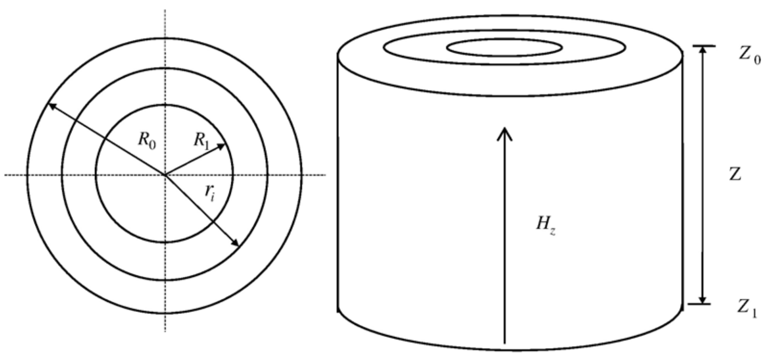

Fig. 1. Physical model and system coordinates of multilayers hollow cylinder.