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Propagation of a thermoelastic wave in a half-space of a homogeneous isotropic material subjected to the effect of gravity field

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ABSTRACT

The propagation of thermoelastic waves in a homogeneous, isotropic elastic semi-infinite space is subjected to a gravitational field, which is at temperature T_0 initially, and whose boundary surface is subjected to heat source and load moving with finite velocity. Temperature and stress distribution occurring due to heating or cooling and have been determined using certain boundary conditions. Numerical results have been given and illustrated graphically in each case considered. The results indicate that the effect of gravity field is very pronounced. Comparison is made with the results predicted by the theory of thermoelasticity in the absence of gravity. The results indicate that the effect of the gravity is very pronounced.

1. Introduction

The subject of generalized thermoelasticity has drawn the attention of researchers due to its relevance in many practical applications. The generalized thermoelasticity theories involve hyperbolic-type governing equations and admit the finite speed of thermal signals. In contrast to the conventional theories based on parabolic-type heat equation, these theories are referred to as generalized theories. Because of the experimental evidence in support of the finiteness of the speed of propagation of a heat wave, generalized thermoelasticity theories are more realistic than conventional thermoelasticity theories in dealing with practical problems involving very short time intervals and high heat fluxes such as those occurring in laser units, energy channels, nuclear reactors, etc. The phenomenon of coupling between the thermomechanical behavior of materials and magnetic behavior of materials have been studied since the19th. On a generalized thermoelastic problem in an infinite cylinder under initial stress was studied by El-Naggar and Abd-Alla [1]. Abd-Alla and Ahmed [2] studied Rayleigh waves in an orthotropic thermoelastic medium under gravity field and initial stress. Generalized thermoelastic medium with temperature-dependent properties for different theories under the effect of gravity field discussed by Othman et al. [3]. Rotation and gravitational field effect on two-temperature thermoplastic material with voids and temperature dependent property

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type III studied by Othman and Hilal [4]. Abd-Alla et al. [5] discussed the propagation of Rayleigh waves in a rotating orthotropic material elastic half-space under initial stress and gravity. Othman et al. [6] described the gravitational effect and initial stress on generalized magneto-thermo-microstretch elastic solid for the different theories. Abd-Alla et al. [7] investigated the problem of transient coupled thermoelasticity of an annular fin. Influence of gravity on the propagation of waves in granular medium was given by Ahmed [8]. On generalized magneto-thermoelastic Rayleigh waves in a granular medium under influence of the gravity field and initial stress have been studied by Abd-Alla et al. [9]. Abd-Alla and Mahmoud [10] investigated the magneto-thermoelastic problem in rotating non-homogeneous orthotropic hollow cylinder under the hyperbolic heat conduction model. Propagation of Rayleigh waves in magneto-thermo-elastic half-space of a homogeneous orthotropic material under the effect of the rotation, initial stress and gravity field was studied by Abd-Alla et al. [11]. Abd-Alla and Ahmed [12] have discussed Stoneley and Rayleigh waves in a non-homogeneous orthotropic elastic medium under the influence of gravity. Abd-Alla et al. [13] discussed the propagation of S-wave in a non-homogeneous anisotropic incompressible and initially stressed medium underinfluence of gravity field. Abd-Alla et al. [14] has studied the propagation of Rayleigh waves in generalized magneto-thermoelastic orthotropic material underinitial stress and gravity field. Abouelregal [15] has presented Rayleigh waves in a thermoelastic solid half space using dual-phase-lag model. A reflection of a plane magneto-thermoelastic wave at the boundary of a solid half-space in presence of initial stress was studied by Singh and Chakraborty [16]. Kakar [17] studied the effect of initial stress and gravity on Rayleigh wave propagation in non-homogeneous isotropic elastic media. Wang et al. [18] proposed the analytical solutions for elastic fields caused by eigenstrains in two joined and perfectly bounded half-spaces and related problems. Propagation of waves in transversely isotropic micropolar generalized thermoelastic half space was studied by Kumar and Gupta [19]. Sarkar and Lahiri [20] discussed the three-dimensional thermoelastic problem for a half-space without energy dissipation. Sherief and Saleh [21] investigated the half-space problem in the theory of generalized thermoelastic diffusion. Singh [22] investigated the wave propagation in an initially stressed transversely isotropic thermoelastic solid half-space. Ezzat and Youssef [23] proposed the three-dimensional thermal shock problem of generalized thermoelastic half-space. Plane waves at an imperfectly bonded interface of two orthotropic generalized thermoelastic rotating half-spaces with two relaxation times was studied by Kumar and Singh [24]. Xia et al. [25] studied the dynamic response of two-dimensional generalized thermoelastic coupling problem subjected to a moving heat source. Rossikhin [26] investigated the propagation of plane waves in an anisotropic thermoelastic half-space. Said [27] investigated the influence of gravity on generalized magneto-thermoelastic medium for three-phase-lag model. Stoneley waves in a non-homogeneous orthotropic granular medium under the influence of gravity studied by Ahmed [28]. Kumar and Chawla [29] proposed the wave propagation at the imperfect boundary between transversely isotropic thermodiffusive elastic layer and half-space. Othman and Atwa [30] investigated the Thermoelastic plane waves for an elastic solid half-space under the hydrostatic initial stress of type III. Kumar and Singh [31] studied the propagation of plane waves in thermoelastic cubic crystal material with two relaxation times. Ailawalia and Narah [33] investigated the effect of rotation in generalized thermoelastic solid under the influence of gravity with an overlying infinite thermoelastic fluid. Vishwakarma and Gupta [34] studied Rayleigh wave propagation: A case wise study in a layer over a half space under the effect of rigid boundary.

Inspite of all these investigations, no attempt has been made yet to study propagation of a thermoelastic wave in a half-space of a homogeneous isotropic material under the effect of gravity field and in contact with change coordinate system moving with input by shifting origin to the position of the input. The components of displacement, normal stress, tangential stress and temperature subjected to heat source and load moving with finite velocity are obtained by Lame's potential method. Numerical computation is performed by using a numerical technique and the resulting quantities are shown graphically.

The current manuscript is devoted to investigate the propagation of wave in a homogeneous orthotropic, thermoelastic medium under the effect of the gravity field. The temperature, displacement components, stresses components is obtained in the physical domain using Lame's potential method. The results obtained in this investigation are more general in the sense that some earlier published results are obtained from our result as special cases. Numerical results for temperature, displacement and stress distributions have been obtained for a stainless steel like material and presented graphically.

2. Formulation of the problem

Let us consider a half space $y \geq 0$, initially at the temperature T_0 and in the stress free state. A variation in temperature, displacement and stress fields will occur due to actions of external loadings. Assuming that the displacement will be along x-axis, y-axis function of space coordinates x, y and time.

If g is the acceleration due to the gravity, then the components of body forces are, $X = 0$, $Y = -g$, and we shall assume that the initial stress due to gravity is hydrostatic. In practice this is a good assumption. The initial stress in this case is produced by a slow process of creep where all shear stresses tend to become small or vanish after long periods time. The state of initial stress τ_{ij} are given as [35]

$$\tau_{xx} = \tau_{yy} = \tau, \quad \tau_{xy} = 0 \tag{1}$$

where τ is a function of depth. The equilibrium equations of the initial stress is in the form

$$\frac{\partial \tau}{\partial x} = 0, \quad \frac{\partial \tau}{\partial y} - \rho g = 0. \tag{2}$$

The generalized equation of heat conduction is given by

$$K\nabla^2 T = \rho c_e\left(\frac{\partial T}{\partial t} + \tau_0\frac{\partial^2 T}{\partial t^2}\right) + (3\lambda + 2\mu)\alpha_t T_0\left(\frac{\partial}{\partial t} + \tau_0\frac{\partial^2}{\partial t^2}\right)\underline{\nabla}\cdot\vec{u}. \tag{3}$$