International Journal of Pure and Applied Mathematics
Volume 34 No. 2 2007, 229-243

THERMOELASTIC INTERACTION WITH ENERGY DISSIPATION IN AN INFINITE SOLID WITH DISTRIBUTED PERIODICALLYVARYING HEAT SOURCES

Sukla Banik[1], Sadek Hossain Mallik[2 §], M. Kanoria[3]
[1,2,3]Department of Applied Mathematics
University of Kolkata
92 A.P.C. Road, Kolkata, 700009, W.B. INDIA
[2]e-mail: sadek_mallik@yahoo.co.in
[3]e-mail: k_mri@yahoo.com

Abstract: This paper deals with the problem of thermoelastic interactions in a homogeneous isotropic unbounded medium due to the presence of periodically varying heat sources in the context of the linear theory of generalized thermoelasticity with energy dissipation (TEWED). The governing equations are expressed in Laplace-Fourier transform domain. The inversion of Fourier transform is carried out analytically while that of Laplace transform is done numerically using a method based on Fourier series expansion technique. The numerical estimates of the displacement, temperature, stress and strain are obtained and presented graphically. A comparison has been made with the results obtained earlier for thermoelasticity without energy dissipation (TEWOED).

AMS Subject Classification: 74F10, 42C20
Key Words: Green-Naghdi model type III, periodically varying heat sources

1. Introduction

Thermoelasticity theories which admit a finite speed for thermal signals (sec-

Received: October 30, 2006

§Correspondence author

ond sound) have arisen much interest in the last three decades. These theories, known as generalized theories, involve hyperbolic type heat transport equation in contrast to the classical coupled thermoelasticity theory involving parabolic type (diffusion type) heat transport equation, which predicts infinite speed of propagation of thermal signals. Among the generalized theories the extended thermoelasticity theory (ETE) proposed by Lord and Shulman [19] and the temperature rate dependent thermoelasticity (TRDTE) propsed by Green and Lindsay [12] have been the subject of recent investigations. In view of experimental evidence in support [1, 2, 3, 16, 18] of the finiteness of the speed of propagation of heat wave, generalized thermoelasticity theories are more acceptable than the conventional thermoelasticity theories in dealing with practical problems involving very short time intervals and high heat fluxes, like those occuring in laser units, energy channels and nuclear reactor, etc.

Problems using CTE concerning an infinite isotropic thermoelastic solid with distributed time-dependent heat sources have been investigated in [22]. The solutions derived in [22] consist of a wave part travelling with the speed of modified dilatational wave and a part which is diffusive in nature. Later Roychoudhuri et al [23, 24, 25] investigated the distribution of temperature, displacement, stress and strain in an infinite isotropic solid having instantaneous and continuous heat sources in the context of the ETE and generalized magneto-thermoelasticity respectively. In these works small time-solutions were achieved. Das et al [11] solved a three dimensional problem for a transversely isotropic infinite medium in presence of heat sources using several thermoelasticity theories and applying eigenvalue approach of Das et al [10].

Green and Naghdi [13] developed three models for generalized thermoelasticity of homogeneous isotropic materials which are labelled as model I, II and III. The nature of these theories are such that when the respective theories are linearized, Model I reduces to the classical heat conduction theory (based on Fourier's law). The linearized versions of model II and III permit propagation of thermal waves at finite speed. Model II, in particular, exhibits a feature that is not present in the other established thermoelastic models as it does not sustain dissipation of thermal energy [15]. In this model the constitutive equations are derived by starting with the reduced energy equation and by including the thermal displacement gradient among other constitutive variables. The Green-Naghdi's third model admits the dissipation of energy. In this model the constitutive equations are derived by starting with the reduced energy equation, where the thermal displacement gradient in addition to temperature gradient, are among the constitutive variables. Reference [15] includes the derivation of complete set of governing equations of linearized version of the theory for homogeneous and isotropic materials in terms of displacement and temperature fields and a proof of the uniqueness of solution for the corresponding initial-boundary value problem. In the context of linearized version of this theory [14, 15], theorem on uniqueness of solutions has been established in [6, 7]. Chandrasekharaiah et al [8] studied the one dimensional thermal wave propagation in a half space based on the GN model due to a sudden exposure of temperature to the boundary, using the laplace transform method. Chandrasekharaiah et al [9] studied the thermoelastic interaction caused by a continuous point heat source in a homogeneous isotropic unbounded thermoelastic body by employing linear theory of thermoelasticity without energy dissipation (TEWOED). Mallik et al [20, 21] have studied the thermoelastic interaction in an infinite rotating elastic medium in presence of heat sources in generalized thermoelasticity. The problems have been solved applying eigenvalue approach. Taheri et al [27] have employed Green-Naghdi theories of type II and type III to study the thermal and mechanical waves in an annulus domain. Roychoudhuri et al [26] studied thermoelastic interactions in an isotropic homogeneous thermoelastic solid containing time-dependent distributed heat sources which vary periodically for a finite time interval in the context of TEWOED. Bandyopadhyay et al [4] have considered one dimensional wave propagation in a homogeneous isotropic thermoelastic half space using Green-Naghdi model II under various boundary conditions and obtained short time solutions for displacement, temperature and stresses.

The main object of this paper is to study one dimensional thermoelastic disturbances in a homogeneous isotropic infinite elastic solid in presence of periodically distributed heat sources over a plane by employing Green-Naghdi model III (TEWED). The method of Laplace transform in time domain and Fourier transform in space domain have been applied to the governing equations and the resulting equation have been solved in Laplace-Fourier transform domain. Inversion of Fourier transform has been obtained analytically and finally Laplace inversion has been carried out numerically. The results obtained are compare with that obtained in [26] by making damping coefficient equal to zero.

2. Formulation of the Problem

We consider a homogeneous isotropic infinitely extended thermoelastic body at a uniform reference temperature θ_0 in presence of periodically varying heat sources distributed over a plane area. The governing field equations for the dynamic coupled generalized thermoelasticity based on the Green-Naghdi model III (TEWED) are written as [5]

$$\mu\nabla^2\vec{u} + (\lambda+\mu)\text{grad div}\vec{u} - \gamma\text{grad}\theta = \rho\ddot{\vec{u}}, \tag{2.1}$$

$$\rho c\ddot{\theta} + \gamma\theta_0\text{div}\ddot{\vec{u}} = K^\star\nabla^2\theta + K\nabla^2\dot{\theta} + \rho\dot{Q}, \tag{2.2}$$

where $\vec{u}$ is the displacement vector θ is the temperature increase with respect to the uniform reference temperature θ_0, ρ is the density, c is the specific heat, λ and μ are Lame's constant, $\gamma = (3\lambda+2\mu)\alpha_t$, α_t is the coefficient of linear thermal expansion, $K^\star$ is a material constant characteristic of the theory, K is the coefficient of thermal conductivity, and dot denotes derivatives with respect to time, Q is the rate of internal heat generation per unit mass. The strain and stress tensors E and T associated with $\vec{u}$ and θ are given by the following geometrical and constitutive relations respectively as

$$E = \frac{1}{2}\Big(\nabla\vec{u} + \nabla\vec{u}^T\Big), \tag{2.3}$$

$$T = \lambda(\text{div}\vec{u})I + \mu\Big(\nabla\vec{u} + \nabla\vec{u}^T\Big) - \gamma\theta I, \tag{2.4}$$

where I is a (3×3) unit matrix and the superscript T stands for the transpose of a matrix. The constants appearing in these equations satisfy the following inequalities

$$\mu > 0,\ \lambda+\mu > 0,\ \rho > 0,\ \theta_0 > 0,\ c > 0,\ \gamma > 0,\ K^\star > 0,\ K > 0.$$

We now introduce the following non dimensional variables

$$x_i^{'} = \frac{x_i}{l},\ t^{'} = \frac{vt}{l},\ \theta^{'} = \frac{\theta}{\theta_0},\ u_i^{'} = \frac{(\lambda+2\mu)u_i}{l\gamma\theta_0},\ \tau_{ij}^{'} = \frac{\tau_{ij}}{\gamma\theta_0}, \tag{2.5}$$

where l is a standard length and v is a standard speed. The equations of (2.1)-(2.4) can be written in non-dimensional form after omitting the primes as follows

$$C_S^2\nabla^2\vec{u} + (C_P^2 - C_S^2)\text{grad div}\vec{u} - C_P^2\text{grad}\theta = \ddot{\vec{u}}, \tag{2.6}$$

$$\ddot{\theta} + \epsilon\text{div}\ddot{\vec{u}} = C_T^2\nabla^2\theta + C_K^2\nabla^2\dot{\theta} + Q_0, \tag{2.7}$$

$$E = \frac{\gamma\theta_0}{(\lambda+2\mu)}(\nabla\vec{u} + \nabla\vec{u}^T), \tag{2.8}$$

$$T = \Big(1 - \frac{2C_S^2}{C_P^2}\Big)(\text{div}\vec{u})I + \frac{C_S^2}{C_P^2}\Big(\nabla\vec{u} + \nabla\vec{u}^T\Big) - \theta I, \tag{2.9}$$

where

$$C_P = \frac{1}{v}\sqrt{\frac{\lambda+2\mu}{\rho}},\ C_S = \frac{1}{v}\sqrt{\frac{\mu}{\rho}},\ C_T = \frac{1}{v}\sqrt{\frac{K^\star}{\rho c}},$$

$$C_K = \sqrt{\frac{K}{\rho c l v}},\ Q_0 = \frac{\dot{Q} l}{c\theta_0 v},\ \epsilon = \frac{\gamma^2\theta_0}{\rho c(\lambda+2\mu)}. \tag{2.10}$$

In the last expressions C_P, C_S, C_T represent non dimensional dilatational, shear and thermal wave velocities respectively and C_K is the damping co-efficient for GN model III (TEWED) and ϵ is the thermoelastic coupling constant.

Now we consider one dimensional disturbance of the medium so that the displacement vector $\vec{u}$ can be taken in the following form

$$\begin{aligned} &\vec{u} = (u(x,t),0,0), \\ &\theta = \theta(x,t). \end{aligned} \tag{2.11}$$

Also we assume that the medium is initially at rest and undisturbed and maintained at a uniform reference temperature. Then we have

$$u(x,0) = \dot{u}(x,0) = \theta(x,0) = \dot{\theta}(x,0) = 0. \tag{2.12}$$

In the present case equations (2.6)-(2.9) reduce to

$$C_P^2\Big(\frac{\partial^2 u}{\partial x^2} - \frac{\partial\theta}{\partial x}\Big) = \frac{\partial^2 u}{\partial t^2}, \tag{2.13}$$

$$\frac{\partial^2\theta}{\partial t^2} + \epsilon\frac{\partial^3 u}{\partial t^2\partial x} = C_T^2\frac{\partial^2\theta}{\partial x^2} + C_K^2\frac{\partial^3\theta}{\partial t\partial x^2} + Q_0, \tag{2.14}$$

$$e_{xx} = \frac{\gamma\theta_0}{\lambda+2\mu}\frac{\partial u}{\partial x} = M_1\frac{\partial u}{\partial x}, \tag{2.15}$$

$$\tau_{xx} = \frac{\partial u}{\partial x} - \theta, \tag{2.16}$$

where $M_1 = \frac{\gamma\theta_0}{\lambda+2\mu}$.

Now let us assume that heat sources are distributed over the plane $x = 0$ in the following form

$$Q_0 = \begin{cases} Q_0^\star\delta(x)\sin(\frac{\pi t}{\tau}), & \text{for } 0 \le t \le \tau\,, \\ 0\,, & \text{for } t > \tau\,. \end{cases} \tag{2.17}$$

We now define Laplace-Fourier double integral transform of a function $f(x,t)$ by

$$\begin{aligned} \bar{f}(x,p) &= \int_0^\infty e^{-pt} f(x,t)dt, \quad \mathrm{Re}\,(p) > 0 \\ \text{and} \quad \hat{\bar{f}}(\xi,p) &= \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} e^{i\xi x} \bar{f}(x,p)dx. \end{aligned} \tag{2.18}$$

Now taking Laplace and Fourier transform of the equations (2.13)-(2.16) consecutively and using equation (2.12) we obtain

$$\hat{\bar{u}}(\xi,p) = \frac{i\xi C_P^2}{C_P^2\xi^2 + p^2} \hat{\bar{\theta}}(\xi,p), \tag{2.19}$$

$$(p^2 + C_T^2\xi^2 + pC_K^2\xi^2)\hat{\bar{\theta}}(\xi,p) - i\epsilon p^2 \xi \hat{\bar{u}}(\xi,p) = \frac{Q_0^*\pi\tau(1+e^{-p\tau})}{\sqrt{2\pi}(\pi^2 + p^2\tau^2)}, \tag{2.20}$$

$$\hat{\bar{e}}_{xx} = -i\xi M_1 \hat{\bar{u}}, \tag{2.21}$$

$$\hat{\bar{\tau}}_{xx} = -i\xi\hat{\bar{u}} - \hat{\bar{\theta}}. \tag{2.22}$$

Solving equations (2.19) and (2.20) for $\hat{\bar{u}}$ and $\hat{\bar{\theta}}$ we obtain

$$\hat{\bar{u}} = \frac{i\xi C_P^2 Q_0^* \pi\tau(1+e^{-p\tau})}{\sqrt{2\pi}(\pi^2 + p^2\tau^2)M^\star}, \tag{2.23}$$

$$\hat{\bar{\theta}} = \frac{Q_0^*\pi\tau(1+e^{-p\tau})(\xi^2 C_P^2 + p^2)}{\sqrt{2\pi}(\pi^2 + p^2\tau^2)M^\star}, \tag{2.24}$$

where

$$\begin{aligned} M^\star &= C_P^2(pC_K^2 + C_T^2)\xi^4 + [pC_K^2 + C_T^2 + (1+\epsilon)C_P^2]p^2\xi^2 + p^4 \\ &= C_P^2(pC_K^2 + C_T^2)(\xi^2 - k_1^2)(\xi^2 - k_2^2) \end{aligned} \tag{2.25}$$

and k_1^2, k_2^2 are the roots of the equation

$$\xi^4 + \frac{[pC_K^2 + C_T^2 + (1+\epsilon)C_P^2]p^2}{C_P^2(pC_K^2 + C_T^2)}\xi^2 + \frac{p^4}{C_P^2(pC_K^2 + C_T^2)} = 0. \tag{2.26}$$

Using (2.23) and (2.24) in equations (2.21) and (2.22) we get

$$\hat{\bar{e}}_{xx} = \frac{\xi^2 M_1 C_P^2 \pi\tau(1+e^{-p\tau})}{\sqrt{2\pi}(\pi^2 + p^2\tau^2)M^\star}, \tag{2.27}$$

$$\hat{\bar{\tau}}_{xx} = \frac{-Q_0^\star \pi\tau(1+e^{-p\tau})p^2}{\sqrt{2\pi}(\pi^2+p^2\tau^2)M^\star}. \tag{2.28}$$

Now inverse Fourier transforms of the equations (2.23), (2.24), (2.27), (2.28) give the following solutions for displacement, temperature, strain and stress in Laplace transform domain as follows

$$\bar{u} = -\frac{C_P^2 Q_0^\star \pi\tau(1+e^{-p\tau})\Big(e^{ik_1x}-e^{ik_2x}\Big)}{2C_P^2(\pi^2+p^2\tau^2)(C_T^2+pC_K^2)(k_1^2-k_2^2)}, \text{ for } \quad x \geq 0\,, \tag{2.29}$$

$$\bar{\theta} = \frac{iQ_0^\star \pi\tau(1+e^{-p\tau})\Big[\Big(k_1C_P^2+\dfrac{p^2}{k_1}\Big)e^{ik_1x}-\Big(k_2C_P^2+\dfrac{p^2}{k_2}\Big)e^{ik_2x}\Big]}{2C_P^2(\pi^2+p^2\tau^2)(C_T^2+pC_K^2)(k_1^2-k_2^2)}, \quad \text{for } \quad x \geq 0\,, \tag{2.30}$$

$$\bar{e}_{xx} = \frac{iQ_0^\star \pi\tau M_1(1+e^{-p\tau})\Big(k_1e^{ik_1x}-k_2e^{ik_2x}\Big)}{2C_P^2(\pi^2+p^2\tau^2)(C_T^2+pC_K^2)(k_1^2-k_2^2)}, \text{ for } \quad x \geq 0\,, \tag{2.31}$$

$$\bar{\tau}_{xx} = \frac{iQ_0^\star \pi\tau p^2(1+e^{-p\tau})\Big(\dfrac{e^{ik_1x}}{k_1}-\dfrac{e^{ik_2x}}{k_2}\Big)}{2C_P^2(\pi^2+p^2\tau^2)(C_T^2+pC_K^2)(k_1^2-k_2^2)}, \text{ for } \quad x \geq 0\,, \tag{2.32}$$

where $\mathrm{Im}(k_1) > 0$ and $\mathrm{Im}(k_2) > 0$.

The corresponding solutions in Laplace transform domain for displacement, temperature, strain and stress for the region $x < 0$ are given as follows

$$\bar{u} = \frac{C_P^2 Q_0^\star \pi\tau(1+e^{-p\tau})\Big(e^{-ik_1x}-e^{-ik_2x}\Big)}{2C_P^2(\pi^2+p^2\tau^2)(C_T^2+pC_K^2)(k_1^2-k_2^2)}, \text{ for } \quad x < 0\,, \tag{2.33}$$

$$\bar{\theta} = \frac{iQ_0^\star \pi\tau(1+e^{-p\tau})\Big[\Big(k_1C_P^2+\dfrac{p^2}{k_1}\Big)e^{-ik_1x}-\Big(k_2C_P^2+\dfrac{p^2}{k_2}\Big)e^{-ik_2x}\Big]}{2C_P^2(\pi^2+p^2\tau^2)(C_T^2+pC_K^2)(k_1^2-k_2^2)}, \quad \text{for } \quad x < 0\,, \tag{2.34}$$

$$\bar{e}_{xx} = \frac{iQ_0^\star \pi\tau M_1(1+e^{-p\tau})\Big(k_1e^{-ik_1x}-k_2e^{-ik_2x}\Big)}{2C_P^2(\pi^2+p^2\tau^2)(C_T^2+pC_K^2)(k_1^2-k_2^2)}, \text{ for } \quad x < 0\,, \tag{2.35}$$

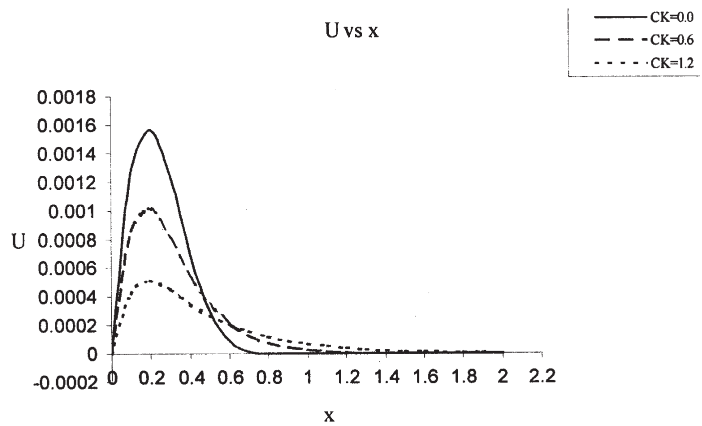

Figure 1: Variation of displacement U with distance x for $t = 0.4$

$$\bar{\tau}_{xx} = \frac{iQ_0^\star \pi\tau p^2(1+e^{-p\tau})\Big(\dfrac{e^{-ik_1x}}{k_1} - \dfrac{e^{-ik_2x}}{k_2}\Big)}{2C_P^2(\pi^2+p^2\tau^2)(C_T^2+pC_K^2)(k_1^2-k_2^2)}, \text{ for } \quad x<0\,, \tag{2.36}$$

where $\mathrm{Im}(k_1) > 0$ and $\mathrm{Im}(k_2) > 0$.

3. Inversion of Laplace Transform

In order to invert the Laplace transform we adopt a numerical method based on a Fourier series expansion, see [17].

By this method the inverse $f(t)$ of the Laplace transform $\bar{f}(s)$ is approximated by

$$f(t) = \frac{e^{dt}}{t_1}\Big[\frac{1}{2}\bar{f}(d) + \mathrm{Re}\sum_{k=1}^{N}\bar{f}(d+\frac{ik\pi}{t_1}e^{\frac{ik\pi t}{t_1}})\Big], \quad 0<t_1<2t\,, \tag{3.1}$$

where N is a sufficiently large positive integer representing the number of terms in the truncated Fourier series, chosen such that

$$e^{dt}\mathrm{Re}\Big[\bar{f}(d+\frac{iN\pi}{t_1}e^{\frac{iN\pi t}{t_1}})\Big] \le \epsilon_1\,, \tag{3.2}$$

where ϵ_1 is a prescribed small positive number that corresponds to the degree of accuracy required. The parameter d is a positive free parameter that must be greater than the real part of all the singularities of $\bar{f}(s)$. The optimal choice of d was obtained according to the criterion described in [17].

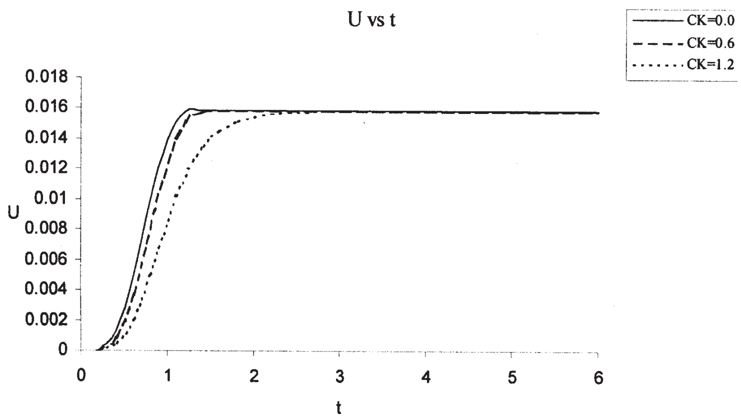

Figure 2: Variation of displacement U with distance t for $x = 0.3$

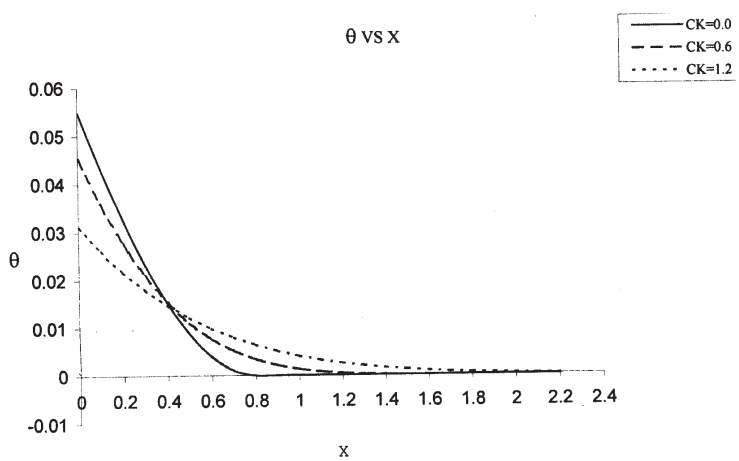

Figure 3: Variation of temperature θ with x for $t = 0.4$

4. Numerical Results and Discussions

To get the solution for thermal displacement, temperature, stress and strain in the space time domain we have to apply Laplace inversion formula to the equations (2.29)-(2.32) respectively, which have been done numerically using the method based on Fourier series expansion technique mentioned above (in the previous article). To get the roots of the polynomial equation (2.26) in complex domain we have used Laguerre's method. The numerical code has been prepared using *Fortran 77* programming language. For computational

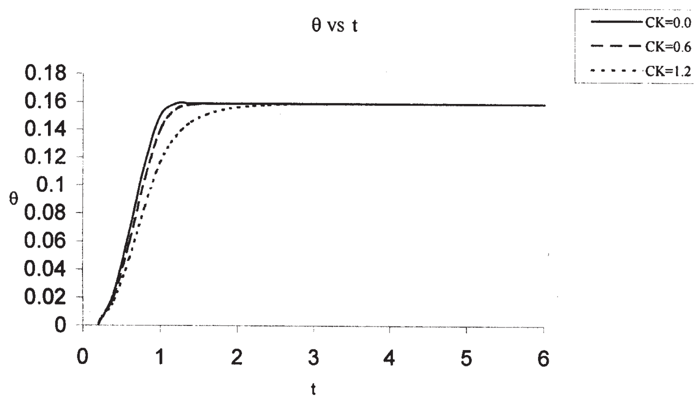

Figure 4: Variation of temperature θ with t for $x = 0.3$

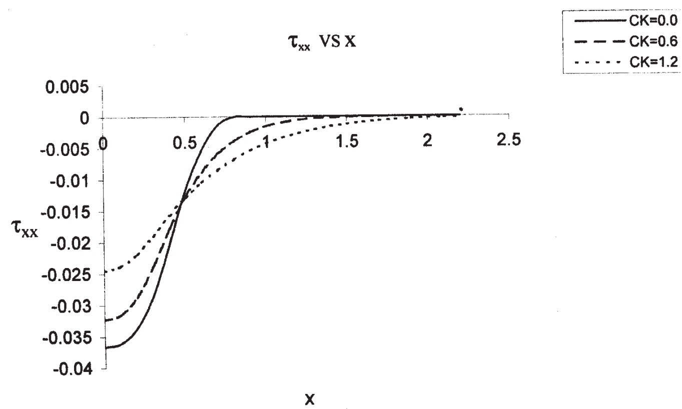

Figure 5: Variation of strass τ_{xx} with x for $t = 0.4$

purpose copper like material has been taken into consideration. The value of the material constants are taken as follows, see [26]

$$\epsilon = 0.0168, \;\lambda = 1.387 \times 10^{12} dynes/cm^2,$$

$$\mu = 0.448 \times 10^{12} dynes/cm^2, \;\alpha_t = 1.67 \times 10^{-8}/^0c$$

Also we have taken $Q_0^\star = 1, \tau = 1, \theta_0 = 1, C_P = 1, C_T = 2$, so the faster wave is the thermal wave. We now present our results in the form of graphs (Figures 1-8) to compare the thermal displacement, temperature, thermal stress and strain in the case of TEWOED and TEWED models. Figure 1 depicts variation of thermal displacement versus distance x for time $t = 0.4$ and damping coefficient

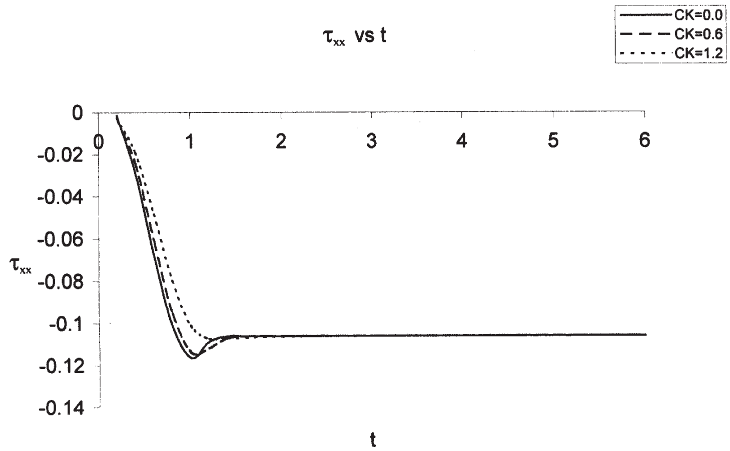

Figure 6: Variation of strass τ_{xx} with t for $x = 0.4$

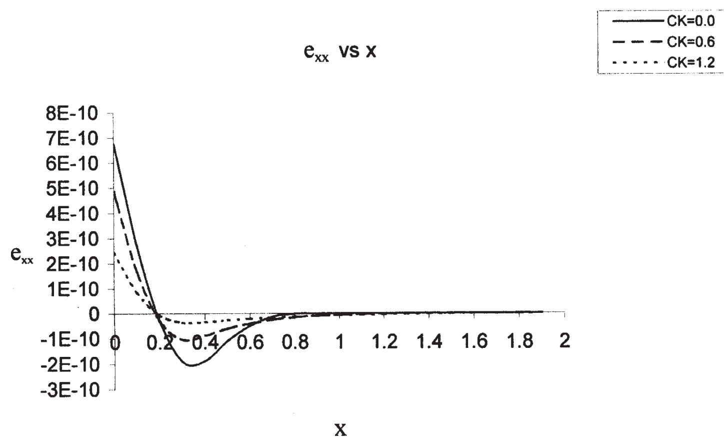

Figure 7: Variation of strain e_{xx} with x for $t = 0.4$

$C_K = 0, 0.6, 1.2$ (in the figure C_K is written as CK). It is observed that as value of the damping coefficient is increased the peak of the thermal displacement decreases and the rate of decay becomes slow. Figure 2 shows the variation of thermal displacement versus time for $x = 0.3$ and $C_K = 0, 0.6, 1.2$. It is seen that with the increase of the value of C_K, the time to reach steady state also increases which supports the physical fact.

Figure 3 is plotted to show the variation of temperature θ with distance x for $t = 0.4$. It is seen from this figure that by increasing C_K damping of

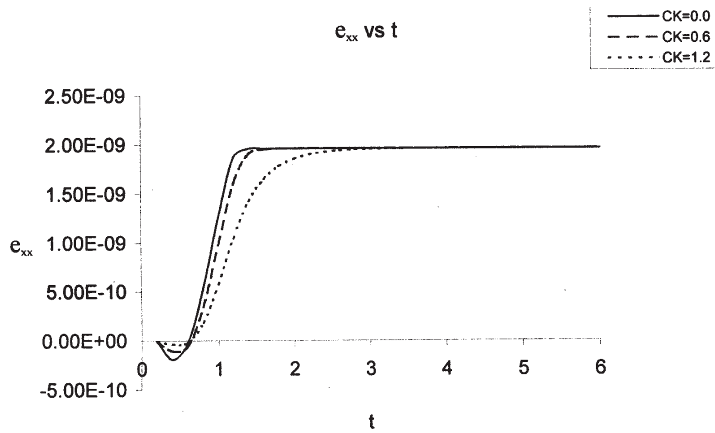

Figure 8: Variation of strain e_{xx} with t for $x = 0.3$

temperature also increases and ultimately θ approaches to zero value (this is because heat source varies periodically with the time for short duration). Figure 4 is for temperature versus time for $x = 0.3$. It is seen from this figure that by increasing C_K damping of temperature is also increasing, until θ reaches a constant value.

Figure 5 and Figure 6 are for thermal stress versus x and t respectively. Here the stress shows negative values. The same is seen in [9].

Figure 7 and Figure 8 are for variation of thermal strain against distance x and time t respectively. Figure 7 shows that the strain takes positive values in the range $0 \leq x \leq 0.2$, then negative value and then finally diminishes to zero. This is also in conformity with the fact that strain should decreases with increasing distance x from the plane $x = 0$, where heat source is active for a very short duration.

In all figures when the damping coefficient $C_K = 0$ the results tally in magnitude with the corresponding results of S.K. Roychaudhuri [26].

Acknowledgments

We are grateful to Professor S.C. Bose of the Department of Applied Mathematics, University of Calcutta, for his kind help and guidance in preparation of the paper. S.H. Mallik is grateful to the Council of Scientific and Industrial Research (CSIR), New Delhi, India for the award of a fellowship.

References

[1] C.C. Ackerman, B. Bertman, H.A. Fairbank, R.A. Guyer, Second Sound in solid helium, *Phys. Rev. Lett.*, **16** (1967), 789-309.

[2] C.C. Ackerman, R.A. Guyer, Temperature pulses in dialectic solids, *Annals. Phys.*, **50** (1968), 128-185.

[3] C.C. Ackerman, W.C. Overton Jr., Second sound in solid helium-3, *Phys. Rev. Lett.*, **22** (1969), 764-766.

[4] N. Bandyopadhyay, S.K. Roychoudhuri, Thermoelastic wave propagation without energy dissipation in an elastic half space, *Bull. Cal. Math. Soc.*, **97**, No. 6 (2005), 489-502.

[5] D.S. Chandrasekharaiah, Hyperbolic thermoelasticity, a review of recent literature, *Appl. Mech. Rev.*, 51(1998), 705-729.

[6] D.S. Candrasekharaiah, A note on the uniqueness of solution in the linear theory of thermoelasticity without energy dissipation, *J. Elasticity*, **43** (1996), 279-283.

[7] D.S. Chandrasekharaiah, A uniqueness theorem in the theory of thermoelasticity without energy dissipation, *J. Thermal Stresses*, **19** (1996), 267-272.

[8] D.S. Chandrasekharaiah, One dimensional wave propagation in the linear theory of thermoelasticity, *J. Thermal Stresses*, **19** (1996), 695-710.

[9] D.S. Chandrasekharaiah, K.S. Srinath, Thermoelastic interactions without energy dissipation due to a point heat sources, *J. Elasticity*, **50** (1998), 97-108.

[10] N.C. Das, S.N. Das, B. Das, Eigenvalue approach to thermoelasticity, *J. Thermal Stresses*, **6** (1983), 35-43.

[11] N.C. Das, A. Lahiri, P.K. Sen, Eigenvalue approach to three dimensional generalized thermoelasticity, *Bull. Cal. Math. Soc.*, **98**, No. 4, (2006), 305-318.

[12] A.E. Green, K.A. Lindsay, Thermoelasticity, *J. Elasticity*, **2** (1972), 1-7.

[13] A.E. Green, P.M. Naghdi, A re-examination of the basic results of thermomechanics, *Proc. Roy. Soc. London. Ser. A*, **432** (1991), 171-194.

[14] A.E. Green, P.M. Naghdi, On undamped heat waves in an elastic solid, *J. Thermal Stresses*, **15** (1992), 252-264.

[15] A.E. Green, P.M. Naghdi, Thermoelasticity without energy dissipation, *J. Elasticity*, **31** (1993), 189-208.

[16] R.J. Von Gutfeld, A.H. Nethercot Jr., Temperature dependent of heat pulse propagation in sapphire, *Phys. Rev. Lett.*, **17** (1966), 868-871.

[17] G. Honig, U. Hirdes, A method for the numerical inversion of the Laplace transform, *J. Comp. Appl. Math.*, **10** (1984), 113-132.

[18] H.F. Jackson, C.T. Walker, Thermal conductivity, second sound and phonon-phonon interactions in NaF, *Phys. Rev. B*, **3** (1971), 1428-1439.

[19] H. Lord, Y. Shulman, A generalized dynamical theory of thermoelasticity, *J. Mech. Phys. Solids*, **15** (1967), 299-309.

[20] S.H. Mallik, M. Kanoria, Effect of rotation on thermoelastic interaction with and without energy dissipation in an unbounded medium due to heat sources – An eigen value approach, *Far East J. Appl. Math.*, **23**, No. 2, (2006), 147-167.

[21] S.H. Mallik, M. Kanoria, A two dimensional problem in generalized thermoelasticity for a rotating orthotropic infinite medium with heat sources, *Indian Journal of Mathematics*, To Appear.

[22] G. Paria, Instantaneous heat sources in an infinite elastic solid, *Indian J. Mech. Math.*, Pt. 2, Special Issue (1969) 41-50.

[23] S.K. Roychoudhuri, N. Bhatta, Thermoelastic interactions in an infinite elastic solid with thetmal relaxation, In: *Proceeding of National Academy of Sciences*, India, 47-A, Pt-A, Physical Sciences, **4** (1981), 499-510.

[24] S.K. Roychoudhuri, G.D. Sain, Instantaneous heat sources in an infinite elastic solid with thermal relaxation, *Indian. J. Pure. Appl. Math.*, **13** (1982), 1340-1353.

[25] S.K. Roychoudhuri, G.D. Sain, N. Bhatta, Magneto-thermoelastic interaction in an infinite conducting elastic solid due to heat sources with thermal relaxation, *Proceeding of National Academy of Sciences*, India, **49** (1983), 602-621.

[26] S.K. Roychoudhuri, Partha Sharathi Dutta, thermoelastic interaction without energy dissipation in an infinite solid with distributed periodically varying heat sources, *Int. J. Solids and Structutes*, **42** (2005), 4192-4203.

[27] H. Taheri, S.J. Fariborz, M.R. Eslami, Thermoelastic analysis of an annulus using the Green-Naghdi model, *J. Thermal Stresses*, **28** (2005), 911-927.