Project report
(BSCM612)

on

"DISTURBANCE DUE TO MECHANICAL SOURCE IN A MONOCLINIC THERMOELASTIC MATERIAL"

Submitted in partial fulfilment of the requirement
for the degree of

B.Sc. (H) Mathematics

Submitted by

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CERTIFICATE

This is to Certify that Aarti Singh, Sagar Joshi and Sanskar Sharma has carried out their project work entitled:
"Disturbance due to mechanical source in a Monoclinic thermoelastic material "under the supervision of **Dr. Leena Rani**. This work is fit for submission for the award of Bachelor Degree in Mathematics.

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CANDIDATE DECLARATION

I hereby declare that the dissertation entitled **" Disturbance due to Mechanical Source in a Monoclinic Thermoelastic Material"** submitted by us in partial fulfilment for the degree of B.Sc. (Hons.) Mathematics in the Division of Mathematics, School of Basic and Applied Sciences, Galgotias University, Greater Noida, UP, India is my original work. It has not been submitted in whole or in part to this or any other university for the award of a degree.

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CONTENT

ABSTRACT

To investigate the thermal excitations of the boundary value problem, a homogeneous, thermally conductive monoclinic material is modelled as a three-phase delay system. By utilizing the Laplace and Fourier transforms, the governing equations are resolved. The discovered answer is used to particular issues involving a half-space that is subject to various forms of loads. The physical domain's determined components for displacement, stress, and temperature distribution are numerically calculated. The components in the physical domain were obtained using a numerical inversion technique.

Keywords: Laplace and Fourier transform, relaxation time, instantaneous load, generalized thermoelectricity, monoclinic material.

LITERATURE REVIEW

An exhaustive analysis of the reaction of anisotropic bodies to exposure to temperature fields, which may take place in service or during the production phases, requires the research of thermally generated disturbances in anisotropic bodies. For instance, the heat accumulation and cooling processes during the curing stages of filament-bound entities may cause thermal disturbances. These disturbances' intensity might be greater than their maximum power. The theory of thermoelectricity, which takes these thermal disturbances into account, has generated a lot of interest in the past century, but systematic study didn't begin until thermal waves—also known as the second sound—were first observed in substances like solid helium, bismuth, and sodium fluoride.

In a wide range of engineering applications, Fourier's law gives accurate approximations for description. However, this creates the contradiction of an infinite thermal pulse propagation speed and, in some real-world applications, may result in an inadequate description of heat conduction. Since the middle of the previous century, numerous hyperbolic thermoelastic models have been created to address the drawbacks of conventional thermoelectricity.

Maxwell-law, Cattane's which generalized Fourier's law and added a single relaxation time, replaces Fourier's law of heat conduction in the Lord and Shulman[1] model. The model put forth by Green and Lindsay[2] generalizes the constitutive relations for the stress tensor and entropy by taking two relaxation times into account.

The governing field equations of generalized thermoelectricity for anisotropic media were derived by Dhaliwal and Sherief[3], who also created a variational principle for these equations. In the context of linked thermoelectricity theory, Chattopadhyay, Keshri, and Bose[4] investigated the transient solution resulting from a temperature step input and zero stress at the surface boundary of a cylindrical hole in a transversely isotropic thermoelastic medium. The one-dimensional thermal shock problem with two relaxation durations was examined by Dhaliwal and Rokne[5]. Using a version of the heat transfer equation that takes into account the time needed for the heat flow to accelerate, Li[6] developed an extended theory of thermoelasticity for anisotropic media. For an anisotropic environment, a variational principle was constructed that corresponds to the fundamental equations of generalised thermoelasticity.

Green and Naghdi[7] presented the derivation of the entire set of governing equations of the linearized version of the theory for homogeneous and isotropic materials in terms of displacement and temperature fields and demonstrated the uniqueness of the solution the corresponding initial mixed boundary value problem. They proposed a new theory of thermoelasticity without energy dissipation. The fact that this theory is not an adaptation of thermal energy dissipation distinguishes it from other hypotheses in an important way.

A thermoelastic two-phase delay model was created by Tzou[8] and Chandrasekharaiah[9]. In these models, the Fourier law included two distinct delay phases, one for the temperature gradient and the other for the heat flux vector. In the context of generalised thermoelasticity theory with one relaxation time, Sherief and Helmy[10] looked into the two-dimensional generalised thermoelasticity problem for a half-space whose surface is rigidly fixed and subject to thermal shock effects. The point heat source Green's function problem was investigated by Han and Hasebe[[11]] iShen and Li[12] looked at how shear deformable laminated plates resting on a tension-free elastic base responded after buckling under mechanical and thermal pressure. In a generalised orthorhombic system, Kumar and Rani[13] studied the failures brought on by mechanical and thermal factors. Roy Choudhuri[14] planned a three-stage defer model in which the intensity conduction regulation was supplanted by a guess to a change of the Fourier regulation presenting three different stage delays for the intensity motion vector, the temperature slope and the warm drop.

1. BASIC EQUATION

Following Dhaliwal and Sherief [3], Green and Naghdi [7] and Roy Choudhuri[14] the field equations and constitutive relations for homogeneous, anisotropic thermoelasticity in the absence of body forces and heat sources are given by

$$t_{ij,j} = \rho \ddot{u}_i, \tag{1}$$

$$K_{ij}\left(\dot{T}_{,\mathrm{ij}} + \tau_T \frac{\partial}{\partial t}\dot{T}_{,\mathrm{ij}}\right) + K^*{}_{ij}\left(T_{,\mathrm{ij}} + \tau_v \dot{T}_{,\mathrm{ij}}\right) = \left(1 + \tau_q \frac{\partial}{\partial t} + \tau_q^2 \frac{\partial^2}{\partial t^2}\right)\left(\rho c_e \ddot{T} + T_o \beta_{ij} \ddot{u}_{i,j}\right) \tag{2}$$

$$t_{\mathrm{ij}} = c_{ijkl} e_{kl} - \beta_{ij} T_{,i}, \qquad (\mathrm{i,j,k,l} = 1,2,3), \tag{3}$$

where at the end list of symbols is given. Dash notation and dot notation are used for spatial derivatives and time differentiation.

2. FORMULATION AND SOLUTION OF THE PROBLEM

Consideration has been given to a homogeneous, monoclinic thermoelastic half-space in an undisturbed state at a constant temperature. On the planar surface with z=0, a rectangular Cartesian coordinate system (x, y, and z) is introduced, with the z-axis pointing vertically into the surroundings. The mechanical load, which is dependent on the time t and the spatial coordinate z $(-\infty < z < \infty)$, has an impact on the boundary of the half-space.

For a two-dimensional plane strain problem (4), we use u =(u,0,w) and T1(x, z, t) as the temperature change.

Using in equation (3) as $11 \rightarrow 1,\quad 22 \rightarrow 2,\quad 33 \rightarrow 3,\quad 23 \rightarrow 4,\quad 13 \rightarrow 5,\quad 12 \rightarrow 6$ to relate c_{ijkl} to $c_{\mathrm{pq}}$where (i,j,k,l=1,2,3, p,q=1,2…….,6).

Using equation (3) in equations (1) and (2), the field equations for such an environment in the absence of body forces and heat sources can then be rewritten in dimensionless form after the suppression of prime numbers as

$$u_{,xx} + p_{11}\mathrm{u}_{,\mathrm{zz}} + p_{12}\mathrm{w}_{,\mathrm{xz}} - T_{,x} = \ddot{u}\ , \tag{5}$$

$$p_{11}\mathrm{w}_{,\mathrm{xx}} + p_{13}\mathrm{w}_{,\mathrm{zz}} + p_{12}\mathrm{u}_{,\mathrm{xz}} - \bar{\beta}T_{,z} = \ddot{\mathrm{w}}, \tag{6}$$

$$\left(1 + \tau_T \frac{\partial}{\partial t}\right)\left(\dot{T}_{,\mathrm{xx}} + \bar{K}\dot{T}_{,\mathrm{zz}}\right) + (1/\omega^*)\left(1 + \tau_v \frac{\partial}{\partial t}\right)\left(\bar{K}_2 \mathrm{T}_{,\mathrm{xx}} + \bar{K}_1 \mathrm{T}_{,\mathrm{zz}}\right)$$
$$= \left(1 + \tau_q \frac{\partial}{\partial t} + \frac{\tau_q^2}{2}\frac{\partial^2}{\partial t^2}\right)\left\{\ddot{T} + \epsilon_1\left(\ddot{u}_{,x} + \ddot{w}_{,z}\right)\right\}, \tag{7}$$

where for spatial derivatives the comma notation is used, we have defined the quantities

$$x' = \frac{\omega_1^* x}{v_1}, \quad z' = \frac{\omega_1^* z}{v_1}, \quad u' = \frac{\rho v_1 \omega_1^*}{\beta_1 T_0} u, \quad t' = \omega_1^* t, \quad w' = \frac{\rho v_1 \omega_1^*}{\beta_1 T_0} w,$$

$$T' = \frac{T}{T_0}, \quad p_{11} = \frac{c_{55}}{c_{11}}, \quad p_{12} = \frac{c_{13} + c_{55}}{c_{11}}, \quad p_{13} = \frac{c_{33}}{c_{11}}, \quad \bar{K}_1 = \frac{K_3^*}{K_1},$$

$$\omega' = \frac{\omega}{\omega_1^*}, \quad \tau_T' = \omega_1^* \tau_T, \quad \tau_\nu' = \omega_1^* \tau_\nu, \quad t_1' = \omega_1^* t_1 \quad \tau_q' = \omega_1^* \tau_q,$$

$$\bar{\beta} = \frac{\beta_3}{\beta_1}, \varepsilon_1 = \frac{\beta_1^2 T_o}{\rho k_1 \omega_1^*}, \bar{K}_2 = \frac{K_1^*}{K_1}, \bar{K} = \frac{K_3}{K_1}. \tag{8}$$

$$\boldsymbol{t'_{zz}} = \frac{\boldsymbol{t_{zz}}}{\boldsymbol{\beta_1 T_0}}, \quad \boldsymbol{t'_{zx}} = \frac{\boldsymbol{t_{zx}}}{\boldsymbol{\beta_1 T_0}}, \quad \mathbf{h}' = \frac{\mathbf{h v_1}}{\boldsymbol{\omega_1^*}}, \tag{9}$$

and $v_1 = \left(\frac{c_{11}}{\rho}\right)^{\frac{1}{2}}$ and $\omega_1^* = \frac{c_e c_{11}}{K_1}$.

Applying the Integral transforms

$\hat{f} = \int_0^\infty f e^{-pt} \, dt$ and

$$\tilde{f} = \int_{-\infty}^{\infty} \hat{f} e^{i\xi x} \, dx. \tag{10}$$

we obtain

$$\tilde{u}_{zz} = R_{11}\tilde{u} + R_{13}\tilde{T} + R_{15}\, \tilde{w}_z, \tag{11}$$

$$\tilde{w}_{zz} = R_{22}\tilde{w} + R_{24}\tilde{u}_z \frac{d\tilde{u}}{dz} + R_{26}\tilde{T}_z, \tag{12}$$

$$\frac{d^2\tilde{T}}{dz^2} = R_{31}\tilde{u} + R_{33}\tilde{T} + R_{35}\frac{d\tilde{w}}{dz}. \tag{13}$$

where

$$R*_{11} = \frac{\xi^2 + p^2}{p_{11}}, \quad R*_{13} = \frac{-i\xi}{p_{11}}, \quad R*_{15} = \frac{i\xi c_2}{p_{11}},$$

$$R*_{22} = \frac{p_1\xi^2 + p^2}{p_{13}}, \quad R*_{26} = \frac{\bar{\beta}}{p_{13}}, \quad R*_{24} = \frac{i\xi p_2}{p_{13}},$$

$$R*_{31} = -\frac{i\xi\varepsilon_1 S_3 p^2}{(S_1 + S_2)\bar{K}_1}, R*_{33} = \frac{S_1\xi^2 + S_2\bar{K}_2 + S_3 p^2}{(S_1 + S_2)\bar{K}_1}, R*_{35} = -\frac{\bar{\beta}\varepsilon_1 S_3 p^2}{(S_1 + S_2)\bar{K}_1},$$

$$S_1 = p + \tau_T p^2, S_2 = \frac{1 + \tau_\nu p}{\omega_1^*} S_3 = 1 + \tau_q p + \tau_q^2 p^2.$$

The equations (13)-(15) are as

$$\frac{d}{dz} W_1(\xi, z, p) = A_1(\xi, p) W_1(\xi, z, p), \tag{14}$$

where

$$W = \begin{bmatrix} U_1 \\ U_1{}' \end{bmatrix}, \quad A = \begin{bmatrix} O & I \\ A*_1 & A*_2 \end{bmatrix}, \quad U = \begin{bmatrix} \tilde{u} \\ \tilde{w} \\ \tilde{T} \end{bmatrix}, \quad U' = \begin{bmatrix} \tilde{u}' \\ \tilde{w}' \\ \tilde{T}' \end{bmatrix},$$

$$I = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}, \quad A*_1 = \begin{bmatrix} 0 & R*_{15} & 0 \\ R*_{24} & 0 & R*_{26} \\ 0 & R*_{35} & 0 \end{bmatrix},$$

$$A*_2 = \begin{bmatrix} R*_{11} & 0 & R*_{13} \\ 0 & R*_{22} & 0 \\ R_{31} & 0 & R*_{33} \end{bmatrix},$$

To solve the equation (14),we take

$W_1(\xi, z, p) = X1(\xi, p)\, e^{qz}$ (17)

so that

$$A1(\xi,p)W_1(\xi,z,p) = qW_1(\xi,z,p)$$

which leads to an eigenvalue problem. The characteristic equation corresponding to matrix A is given by

$$\det[A1-qI]=0 \qquad (15)$$

which on expansion leads to

$$q^6 - \lambda_1 q^4 + \lambda_2 q^2 - \lambda_3 = 0 \qquad (16)$$

Where

$\lambda_1 = R^*_{15} R^*_{24} + R^*_{33} + R^*_{22} + R^*_{11} + R^*_{26} R^*_{35}$

$\lambda_2 = R*_{15}\, R*_{24}\, R*_{33} - R*_{13}\, R*_{24}\, R*_{35} + R*_{22}\, R*_{33} + R*_{11}\, R*_{26}\, R*_{35}$
$-R*_{31}\, R*_{15}\, R*_{26} + R*_{11}\, R*_{33} - R*_{31}\, R*_{13} + R*_{11}\, R*_{22}$

$\lambda_3 = R*_{22}\,(R*_{11}\, R*_{33} - R*_{31}\, R*_{13}),$

The roots are $\pm q_\ell (\ell = 1, 2, 3)$.
The eigenvalues of the matrix A1 are roots of equation (15). The eigenvector $X(\xi, p)$ can be determined as

$$[A1-qI]\, X(\xi,p)=0 \qquad (17)$$

the X_ℓ (ξ,p), (ℓ =1,2,3,4,5,6) may be written as

$$X*_\ell\,(\xi,p) = \begin{bmatrix} X*_{\ell 1}\,(\xi,p) \\ X*_{\ell 2}\,(\xi,p) \end{bmatrix}$$

Where,

$$X*_{\ell 1}\,(\xi,p) = \begin{bmatrix} -\xi \\ a1_\ell q1_\ell \\ b1_\ell \end{bmatrix}, \qquad X*_{\ell 2}\,(\xi,p) = \begin{bmatrix} -\xi q1_\ell \\ a1_\ell q1_\ell^2 \\ b_\ell q_\ell \end{bmatrix}, \qquad q = q1_\ell, \ell = 1,2,3.$$

$$X*_{\ell_a 1}\,(\xi,p) = \begin{bmatrix} -\xi \\ -a1_\ell q1_\ell \\ b_\ell \end{bmatrix}, \qquad X*_{\ell_a 2}(\xi\,,p) = \begin{bmatrix} \xi q1_\ell \\ a1_\ell q1_\ell^2 \\ -b_\ell q_{1\ell} \end{bmatrix}, \quad \ell_a = \ell + 3, \quad q = -q1_\ell, \ell = 1,2,3.$$

And,

$$a_\ell = \frac{\{(\bar\beta - p_2)\xi^2 + p^2\bar\beta - p_1\bar\beta q1_\ell^2\}}{\Delta_\ell},$$

$$b_\ell = \frac{\{c_1 q1_\ell^2\xi - (\xi^2+p^2)\xi\}\{(p_1\xi^2+p^2) - q1_\ell^2(p_3 - p_2\bar\beta)\} - q1_\ell^2 p_2 \xi \quad \{(\xi^2+p^2) - p_1 q_\ell^2\}\bar\beta - p_2\xi^2\}}{\xi\Delta_\ell},$$

$$\Delta_\ell = i\{(p_1\xi^2 + p^2) - (p_3 - p_2\bar\beta)q_\ell^2\}, \qquad \ell = 1,2,3.$$

The solution of equation (20) is given by

$$W = \sum_{\ell=1}^{3}[B1_\ell X1_\ell\ exp(\,q_\ell z) + B1_{\ell+3} X1_{\ell+3}\ exp(-q_\ell z)], \qquad (18)$$

where$B1_\ell(\ell = 1,2,3,4,5,6)$
Equation (18) therefore shows a solution to a problem. The Displacements and temperature distributions that satisfy the regularity conditions as

$$\tilde u = \ -\xi(B1_4\, e^{-q_1 z} + B1_5\, e^{-q_2 z} + B1_6\, e^{-q_3 z}), \qquad (19)$$

$$\tilde w = \ -(a_1 q_1 B_{14}\, e^{-q_1 z} + a_2 q_2 B1_5\, e^{-q_2 z} + a_3 q_3 B1_6\, e^{-q_3 z}), \qquad (20)$$

$$\tilde T = \ (b_1 B1_4\, e^{-q_1 z} + b_2 B1_5\, e^{-q_2 z} + b_3 B1_6\, e^{-q_3 z}), \qquad (21)$$

1. APPLICATION

Limiting Conditions are given as

$$t_{zz} = r(x,t), \quad t_{zx} = 0, \qquad \text{at } z = 0$$

$$\frac{\partial T}{\partial z} = 0$$

$$or$$

$$T = 0 \tag{22}$$

where r(x,t)=$\eta(x)F(t)$

Using of Eqs. (3), (8)-(12),(19)- (22), we obtain the expressions for displacement components, stresses and temperature distribution as

$$\tilde{u} = -r(\xi,p)\frac{\xi\sum_{m=1}^{3}\Delta''_m e^{-q_m z}}{T_0\Delta_2^*},\ \tilde{w} = -r(\xi,p)\frac{\sum_{m=1}^{3} a_m q_m \Delta''_m e^{-q_m z}}{T_0\Delta_2^*},\tilde{t}_{zx} = r(\xi,p)\frac{\sum_{m=1}^{3} s_m\Delta''_m e^{-q_m z}}{T_0\Delta_2^*},$$

$$\tilde{t}_{zz} = r(\xi,p)\frac{\sum_{m=1}^{3} p_m \Delta''_m e^{-q_m z}}{T_0\Delta_2^*},\tilde{T} = -r(\xi,p)\frac{\sum_{m=1}^{3} b_m\Delta''_m e^{-q_m z}}{T_0\Delta_2^*}. \tag{23}$$

where

$$\Delta = \Delta_1^* + \Delta_2^*,$$

$$\Delta_1^* = p_1(s_3q_2b_2 - s_2q_3b_3) + p_2(s_3q_3b_3 - s_3q_1b_1) + p_3(s_2q_2b_1 - s_1q_2b_2),$$

$$\Delta_2^* = p_1(s_2b_3 - s_3b_2) + p_2(s_3b_1 - s_1b_3) + p_3(s_1b_2 - s_2b_1),$$

$$\Delta''_1 = p_2s_3 - s_2p_3, \Delta''_2 = p_2s_3 - s_1p_3, \Delta''_3 = p_1s_2 - s_1p_2,$$

$$s_m = \frac{\xi k_\ell(1 + ia_\ell)}{c_{11}}, \qquad p_\ell = \frac{i\xi c_{13} + a_\ell q_\ell^2 c_{33} - \bar{\beta} b_\ell}{c_{11}}, \quad \ell = 1,2,3.$$

we set $\eta(x) = \begin{cases} 1 & \text{if } |x| \le a, \\ 0 & \text{if } |x| > a, \end{cases}$

in equation (25).Applying integral transform we get

$$\{\eta(\xi)\} = \left[2\,sin\left(\frac{\xi c_2 a}{\omega_1^*}\right)/\xi\right],\ \xi \neq 0.$$

Case 1: Instantaneous **strip loading:**

Let $F(t)$=$F_0\delta(t)$

With $\tilde{F}(p) = F_0$,

whereF_0 is a constant.

6. NUMERICAL INVERSION

To obtain a solution to the problem in the physical domain, the follows the technique applied by Kumar and Rani (2004).

Conclusion

1. 1. For the quasi-static and static thermoelastic instances, Laplace and Fourier techniques were utilised to get the formulas for the stress, displacement, and temperature distribution components.
2. 2. A graphic representation of the effects of the two forces SSL and ISL on the monoclinic three-phase-lag thermo-elastic model for magnesium crystal-like material has been provided.
3. Variation trend of field variables in the quasi-static case is observed to be the dynamic case with a difference in magnitude.

Nomenclature

$v = (p, q, r)$ – vector of displacement

T(x,y,z,t)-temperature change

c_{ijkl} - isothermal elastic parameters,

t- time variable

t_{ij} - stress

e_{ij} - strain

T_0 - uniform temperature

□ - density

$\square_T$, □□ *and* □ q - thermal relaxation time

□ kl - linear thermal expansion tensor.

K^*_{ij} □ $\frac{c_e c_{11}}{4}$ --the theory's physical characteristic constant.

K_{ij}= temperature conductivity

References

[1] LORD H.W. and SHULMAN Y. Generalized dynamic theory of thermoelasticity. J. Mech. Phys. Solids, 15, 299-309, (1967)

[2] GREEN AND LINDSAY. Generalized thermoelasticity for anisotropic media. Quart. of Applied Mathematics, 38,1-8, (1980)

[3] DHALIWAL AND SHERIEF Thermoelasticity without energy loss. J. Elasticity, 31, 189-208, (1993)

[4] KESHRI AND BOSE. On a thermoelastic three-phase model. J. Thermal Stresses, 30, 231-238, (2007)

[5] DHALIWAL AND ROKNE, U. A method for the numerical inversion of the Laplace transform, Journal of Computational and Applied Mathematics, 10,113-132,(1984)

[6] Li., Numerical Recipes,p.134, Cambridge University Press, Cambridge, 1986.

[7] GREEN, A.E. and NAGHDI, P.M. Thermoelasticity without energy dissipation. J. Elasticity,31, 189-208, (1993).

[8] Tzou D. Y. A Unified Field Approach for Heat Conduction from Macro to Micro-Scales. ASME J. Heat Transf., 117, 8–16, (1995)

[9] CHANDRASEKHARAIAH D.S. Hyperbolic Thermoelasticity: A Review of Recent Literature, Appl. Mech. Rev., 51, 705–729,(1998).

[10] SHEIEF, H.H and HELMY, K.A. A two-dimensional generalized thermoelastic problem for a half-space. J. Thermal Stresses, 22, 897-910, (1999)

[11] HAN, JIAN-JUN and HASEBE, N. Green's functions of point heat source in various thermoelastic boundary value problems. J. Thermal Stresses, 25,153-167, (2002)

[12] SHEN HUI-SHENA, and LI Q. S, Postbuckling of shear deformable laminated plates resting on a tensionless foundation subjected to mechanical or thermal loading. Int. J. Solids and Structures, 41, 4769-4785, (2004)

[13] KUMAR, R. and RANI, L. Deformation due to mechanical and thermal sources in generalized orthorhombic thermoelastic material. Sadhana, 29, 429-447, (2004)

[14] Roy CHOUDHURY,S.K. On a thermoelastic three-phase-lag Model. J.Thermal Stresses, 30, 231-238, (2007).

[15] "Response of Generalized Thermoelastic half-space with voids due to Mechanical and Thermal Sources" Meccanica, ITALY, Springer, vol.39, pp.563-584, 2004