Effect of mechanical force along the interface of semi-infinite semiconducting medium and thermoelastic micropolar cubic crystal

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Abstract: The present investigation deals with the two-dimensional deformation in a thermoelastic micropolar solid with cubic symmetry at the interface of the semi-infinite semiconducting medium under photothermal theory. A mechanical force is applied along the interface. The analytic expressions for the components of normal displacement, temperature distribution, normal force stress, and tangential couple stress for a thermoelastic micropolar solid with cubic symmetry have been obtained using normal mode analysis technique. The effect of anisotropy, microrotation, and thermoelasticity on the derived components have been depicted graphically.

Keywords: thermoelasticity; cubic symmetry; semiconducting; photothermal; normal mode

1. Introduction
A micropolar continuum is a collection of inter-connected particles in the form of small rigid bodies in which materials’ deformation is determined by both translational and rotational motion. In such type of motion, the force at a point of the surface element of the body is completely characterized...
by the stress vector at that point. Some examples of such materials are fiberglass, polymeric materials, wood, rocks etc. Eringen and Suhubi (1964a, 1964b) developed a nonlinear theory of microelastic solids. Later Eringen (1965, 1966, 1984) developed a theory for the special class of micro-elastic materials and named it the “linear theory of micropolar elasticity”. Under this theory, solids can undergo macro-deformations as well as micro-rotations. Thermoelasticity is the study of equilibrium of bodies, treated as thermodynamic systems, whose interactions with the surroundings are restricted to the mechanical work, heat exchange, and external forces. The change of body temperature is caused not only by the external and internal heat sources, but also by the process of deformation itself. The micropolar theory was extended to include thermal effects by Nowacki (1966), Eringen (1970), Tauchert, Claus, and Ariman (1968), Tauchert (1971), and Nowacki and Olszak (1974). One can refer to Dhaliwal and Singh (1980, 1987) for a review on the micropolar thermoelasticity, as well as to Eringen and Kafadar (1976) in “Continuum Physics” series in which the general theory of micromorphic media has been summed up.

There are two very well known generalized theories of thermoelasticity. The first one is due to Lord and Shulman (1967) in which, in comparison to the classical theory, the Fourier law of heat conduction is replaced by Maxwell–Cattaneo laws that generalizes the Fourier law and which included the time needed for acceleration of the heat flow in the heat transport equation and introduced a single relaxation time into consideration. The second generalization of the coupled theory of elasticity is known as the theory of thermoelasticity with two relaxation time or the theory of temperature-rate-dependent thermoelasticity. Muller (1971), in the review of thermodynamics of thermoelastic solids, proposed an entropy production inequality, with the help of which he considered restrictions on a class of constitutive equations. Green and Lindsay (1972) obtained another version of the constitutive equations. A generalization of this inequality was proposed by Green and Laws (1972). These equations were also obtained independently and more explicitly by Suhubi (1975). This theory contains two constants that act as relaxation times and modify all the equations of coupled theory, not only the heat equation.

In the cubic symmetry, the materials have nine planes of symmetry whose normals are on the three coordinate axes and on the coordinate planes making an angle $\pi/4$ with the coordinate axes. With the chosen coordinate system along the crystalline directions, the mechanical behavior of a cubic crystal can be determined by four independent elastic constants $A_1, A_2, A_3, A_4$. Some frequently used substances which belong to cubic crystals are Au, Si, Ni, Fe, Cu etc. Minagawa, Arakawa, and Yamada (1981) discussed dispersion curves for waves in a cubic micropolar medium for diamond. Kumar and Ailawalia (2005) used Eigenvalue approach to study the response of a micropolar cubic crystal due to various sources acting at the free surface. Kumar and Ailawalia (2006) studied the time-harmonic sources at micropolar thermoelastic medium possessing cubic symmetry with one relaxation time. Kumar and Ailawalia (2007) discussed the moving load response in micropolar thermoelastic medium without energy dissipation possessing cubic symmetry. Abbas, Kumar, and Rani (2015) studied the thermoelastic interaction in a thermally conducting cubic crystal subjected to ramp-type heating. Kumar and Partap (2010) studied the propagation of waves in micropolar thermoelastic cubic crystals. Kumar and Partap (2012) studied the axisymmetric wave motion in a micropolar cubic crystal plate. Lotfy, Yahia, and Hassan (2014) investigated a two-dimensional problem in a micropolar thermoelastic medium possesses cubic symmetry for a mode-I crack in the context of three theories of thermoelasticity. Othman, Abo-Dahab, and Alosaimi (2016) investigated the two-dimensional problem of micropolar thermoelastic rotating medium possessing cubic symmetry under the effect of inclined load in the context of Green Naghdi theory of type-III. Ailawalia, Sachdeva, and Pathania (2017) discussed the response of thermoelastic micropolar cubic crystal under Dynamic Load at an Interface.

The semiconducting materials have a wide range of applications in modern engineering and sciences. The propagation of the wave in a semiconducting medium is of significant use in academics and application value. The solution for wave propagation in micropolar elastic half space was derived by Ariman (1972). The solution for wave propagation in micropolar viscoelastic generalized
thermoelastic solid was given by Kumar (2000). Ezzat and Othman (2001) discussed electromagneto thermoelastic plane waves with two relaxation times in a medium of perfect conductivity. Singh (2001) studied the reflection and refraction of plane wave at a liquid thermo-micro stretch elastic solid interface. Singh and Singh (2004) discussed the reflection of plane waves at the free surface of a fiber-reinforced elastic half space. The solution for reflection of Magneto thermo-viscoelastic waves under generalized thermo-viscoelasticity was given by Song, Zhang, Xu, and Lu (2004). Othman and Song (2006) discussed the effect of rotation on the reflection of magneto-thermoelastic waves under thermoelasticity without energy dissipation. The effect of initial hydrostatic stress on the reflection of generalized thermoelastic waves from a solid half-space was studied by Singh, Kumar, and Singh (2006). Gordon, Leite, Moore, Porto, and Whinnery (1964) gave the first photothermal method. Some problems on photothermal methods have been discussed by Tam (1983, 1989). The generalized thermoelastic vibration of optically excited semiconducting microcantilevers was studied by Song, Todorovic, Cretin, and Vairac (2010). The reflection of plane waves in a semiconducting medium under photothermal theory was discussed by (Song, Bai, and Ren (2012). Othman, Tantawi, and Eraki (2016) studied the propagation of the photothermal waves in a semiconducting medium in the context of LS theory. Lotfy (2016) investigated the effect of the internal heat source and gravitational field on the elastic wave motions for a photothermal medium of a dual-phase-lag model.

The present investigation is to determine the component of normal displacement, temperature distribution, normal force stress, and tangential couple stress for a thermoelastic micropolar solid with cubic symmetry due to the mechanical source. The solution is obtained using normal mode analysis technique and effect of anisotropy, microrotation, and thermoelasticity on the derived components have been depicted graphically.

We consider a normal force of magnitude $P_1$ acting along the interface of micropolar thermoelastic cubic crystal (medium I) occupying the region $0 \leq z \leq \infty$ and a semi-infinite semiconducting medium (medium II) in the region $-\infty \leq z \leq 0$ is shown in Figure 1.

We restrict our analysis to the plane strain parallel to $xz$ plane with displacement vector for micropolar thermoelastic solid with cubic symmetry (medium I) is given by $\vec{u}^I = (u^I_1, 0, u^I_3)$, microrotation vector as $\vec{\phi} = (0, \phi_2, 0)$ and displacement vector for semi-infinite semiconducting medium (medium II) is given by $\vec{u}^II = (u^II_1, 0, u^II_3)$.

The field equations and constitutive relations in the absence of body forces, body couples, and heat sources for medium I and medium II are given by,

For medium I i.e. micropolar thermoelastic medium with cubic symmetry is given by Lord and Shulman (1967), Green and Lindsay (1972), and Minagawa et al. (1981) as,
Field equations,

\begin{align}
A_1 \frac{\partial^2 u^I_1}{\partial x^2} + (A_2 + A_4) \frac{\partial^2 u^I_3}{\partial x \partial z} + A_3 \frac{\partial^2 u^I_3}{\partial z^2} - (A_3 - A_4) \frac{\partial \phi_2}{\partial z} - v_1 \frac{\partial}{\partial z} \left( 1 + \tau_1 \frac{\partial}{\partial t} \right) T_1 &= \rho_1 \frac{\partial^2 u^I_1}{\partial t^2}, \\
A_3 \frac{\partial^2 u^I_1}{\partial x^2} + (A_2 + A_4) \frac{\partial^2 u^I_3}{\partial x \partial z} + A_1 \frac{\partial^2 u^I_3}{\partial z^2} + (A_3 - A_4) \frac{\partial \phi_2}{\partial x} - v_1 \frac{\partial}{\partial x} \left( 1 + \tau_1 \frac{\partial}{\partial t} \right) T_1 &= \rho_1 \frac{\partial^2 u^I_1}{\partial t^2}, \\
B_3 \left( \frac{\partial^2 \phi_2}{\partial x^2} + \frac{\partial^2 \phi_2}{\partial z^2} \right) + (A_3 - A_4) \left( \frac{\partial u^I_1}{\partial z} - \frac{\partial u^I_3}{\partial x} \right) - 2(A_3 - A_4) \phi_2 &= \rho \frac{\partial^2 \phi_2}{\partial t^2}, \\
K_1 \left( \frac{\partial^2 T_1}{\partial x^2} + \frac{\partial^2 T_1}{\partial z^2} \right) &= \rho_1 c_1 \left( \frac{\partial T_1}{\partial t} + \tau_0 \frac{\partial^2 T_1}{\partial t^2} \right) + v_2 T_0 \left( \frac{\partial}{\partial t} + \eta_0 \frac{\partial^2}{\partial t^2} \right) + \frac{\partial u^I_4}{\partial x} + \frac{\partial u^I_4}{\partial z},
\end{align}

the constitutive relations are,

\begin{align}
\sigma^I_{zz} &= A_1 \frac{\partial u^I_3}{\partial z} + A_2 \frac{\partial u^I_1}{\partial x} - v_1 \left( 1 + \tau_1 \frac{\partial}{\partial t} \right) T_1, \\
\sigma^I_{zx} &= A_2 \frac{\partial u^I_1}{\partial z} + A_4 \frac{\partial u^I_3}{\partial x} + (A_4 - A_3) \phi_2, \\
m^I_{zy} &= B_3 \frac{\partial \phi_2}{\partial z}.
\end{align}

For medium II i.e. semi-infinite semiconducting medium under photothermal theory is given by Song et al. (2012) as:

Field equations,

\begin{align}
(\lambda_2 + 2\mu_2) \frac{\partial^2 u^I_2}{\partial x^2} + (\lambda_2 + \mu_2) \frac{\partial^2 u^I_3}{\partial x \partial z} + \mu_2 \frac{\partial^2 u^I_3}{\partial z^2} - \gamma_2 \frac{\partial T_2}{\partial x} - \delta_n \frac{\partial N}{\partial \xi} &= \rho_2 \frac{\partial^2 u^I_2}{\partial t^2}, \\
\mu_2 \frac{\partial^2 u^I_3}{\partial x^2} + (\lambda_2 + \mu_2) \frac{\partial^2 u^I_3}{\partial x \partial z} + (\lambda_2 + 2\mu_2) \frac{\partial^2 u^I_3}{\partial z^2} - \gamma_2 \frac{\partial T_2}{\partial z} - \delta_n \frac{\partial N}{\partial \xi} &= \rho_2 \frac{\partial^2 u^I_3}{\partial t^2}, \\
D_e \left( \frac{\partial^2 N}{\partial x^2} + \frac{\partial^2 N}{\partial z^2} \right) - \frac{1}{\tau} N + \kappa T_2 - \frac{\partial N}{\partial t} &= 0, \\
K_2 \left( \frac{\partial^2 T_2}{\partial x^2} + \frac{\partial^2 T_2}{\partial z^2} \right) - \frac{E_2}{\tau} N + \gamma_2 T_0 \frac{\partial}{\partial t} \left( \frac{\partial u^I_1}{\partial x} + \frac{\partial u^I_3}{\partial z} \right) - \rho_2 c_2 \frac{\partial T_2}{\partial t} &= 0.
\end{align}

The constitutive stress relations are,

\begin{align}
\sigma^I_{xx} &= (\lambda_2 + 2\mu_2) \frac{\partial u^I_1}{\partial x} + \lambda_2 \frac{\partial u^I_3}{\partial z} - (3\lambda_2 + 2\mu_2)(\alpha_1 T_2 + d_n N), \\
\sigma^I_{zz} &= (\lambda_2 + 2\mu_2) \frac{\partial u^I_3}{\partial z} + \lambda_2 \frac{\partial u^I_1}{\partial x} - (3\lambda_2 + 2\mu_2)(\alpha_1 T_2 + d_n N), \\
\sigma^I_{zx} &= \mu_2 \left( \frac{\partial u^I_1}{\partial z} + \frac{\partial u^I_3}{\partial x} \right).
\end{align}

To simplify numerical calculations, the following non-dimensional variables have been used:
\[
\begin{align*}
\dot{x} &= \omega' \xi^* x, \quad \dot{z} = \omega' \zeta^* z, \quad u_1' = \frac{\alpha' \omega' \zeta^*}{\gamma_1} u_1, \quad u_2' = \frac{\alpha' \omega' \zeta^*}{\gamma_1} u_2, \\
\dot{\varphi}_1 &= \frac{\alpha' \omega' \zeta^*}{\gamma_1} \varphi_1, \quad \varphi_2 = \frac{\alpha' \omega' \zeta^*}{\gamma_1} \varphi_2
\end{align*}
\]

where, \( c_i \) is the standard velocity given by \( c_i^2 = \frac{A_i}{\rho_i} \) and characteristics frequency \( \omega' \) of medium is given by \( \omega' = \frac{\alpha' \omega' \zeta^*}{\gamma_1} \).

Using above non-dimensional variables and dropping superscripts the Equations (1–7) becomes,

\[
\begin{align*}
&\frac{\partial^2 u_1'}{\partial x^2} + h_2 \frac{\partial^2 u_1'}{\partial x \partial z} + h_3 \frac{\partial^2 u_1'}{\partial z^2} - h_4 \frac{\partial \varphi_2'}{\partial x} - \frac{\partial}{\partial x} \left( 1 + \tau_1 \frac{\partial}{\partial t} \right) T_1 = \frac{\partial^2 u_1'}{\partial t^2}, \\
&\frac{\partial^2 u_1'}{\partial x^2} + h_2 \frac{\partial^2 u_1'}{\partial x \partial z} + h_3 \frac{\partial^2 u_1'}{\partial z^2} + h_4 \frac{\partial \varphi_2'}{\partial x} - \frac{\partial}{\partial x} \left( 1 + \tau_1 \frac{\partial}{\partial t} \right) T_1 = \frac{\partial^2 u_1'}{\partial t^2}, \\
&\frac{\partial^2 \varphi_2'}{\partial x^2} + \frac{\partial^2 \varphi_2'}{\partial z^2} - h_5 \left( \frac{\partial u_1'}{\partial x} - \frac{\partial u_1'}{\partial z} \right) - 2h_6 \varphi_2' = h_6 \frac{\partial^2 \varphi_2'}{\partial t^2}, \\
\left( \frac{\partial^2 T_1}{\partial x^2} + \frac{\partial^2 T_1}{\partial z^2} \right) - \left( \frac{\partial T_1}{\partial t} + \tau_0 \frac{\partial^2 T_1}{\partial t^2} \right) - h_7 \left( \frac{\partial}{\partial t} + n_0 \tau_0 \frac{\partial^2}{\partial t^2} \right) \left( \frac{\partial u_1'}{\partial x} + \frac{\partial u_1'}{\partial z} \right) = 0,
\end{align*}
\]

\[
\begin{align*}
\sigma_{zz}' &= h_1 \frac{\partial u_1'}{\partial z} + h_8 \frac{\partial u_1'}{\partial x} - \left( 1 + \tau_1 \frac{\partial}{\partial t} \right) T_1, \\
\sigma_{zz}' &= h_1 \frac{\partial u_1'}{\partial z} + h_8 \frac{\partial u_1'}{\partial x} - h_4 \varphi_2', \\
m_{xy} &= h_{10} \frac{\partial \varphi_2'}{\partial z},
\end{align*}
\]

where,

\[
\begin{align*}
&h_1 = \frac{A_1}{\rho_1 c_1^2}, \quad h_2 = \frac{A_1 + A_2}{\rho_1 c_1^2}, \quad h_3 = \frac{A_1}{\rho_1 c_1^2}, \quad h_4 = \frac{A_1 - A_2}{\rho_1 c_1^2}, \quad h_5 = \frac{\delta_1 - \delta_2}{B_{ij} c_j^2}, \quad h_6 = \frac{\delta_2}{B_1}, \\
h_7 = \frac{\delta_1}{B_{ij} c_j^2}, \quad h_8 = \frac{A_1}{\rho_1 c_1^2}, \quad h_9 = \frac{A_1}{\rho_1 c_1^2}, \quad h_{10} = \frac{B_{ij} c_j^2}{\rho_1 c_1^2}.
\end{align*}
\]

2. Solution of the problem

The solution of the considered physical variables can be decomposed in terms of normal mode and can be considered in the following form,

\[
\begin{align*}
\hat{u}_i'(x, z, t) &= (\alpha_i', \tilde{T}_i, \varphi_2, \sigma_{ij}', m_{ij}, \bar{u}_{ij}'(z), \bar{a}_{ij}', \bar{m}_{ij}, \bar{a}_{ij}'', \bar{N}(z)) e^{i(\omega t + kx)} 
\end{align*}
\]

where \( \omega \) is complex frequency, \( a \) is wave number in the x-direction, and \( \bar{u}_{ij}'(z), \bar{T}_i(z), \varphi_2(z), \bar{a}_{ij}'', \bar{N}(z) \) are the amplitudes of field quantities.

Using (***) in (15–18), we get

\[
\begin{align*}
(h_1 D^2 - h_{11}) \bar{u}_{ij}' + h_{12} D \bar{u}_{ij}' - h_{13} \bar{T}_i &= 0, \\
(h_2 D^2 - h_{22}) \bar{u}_{ij}' + h_{23} \bar{T}_i &= 0, \\
(h_3 D^2 - h_{33}) \bar{u}_{ij}' &= 0, \\
(h_3 D^2 - h_{33}) \bar{u}_{ij}' + (h_2 D^2 - h_{22}) \bar{u}_{ij}' &= 0,
\end{align*}
\]

\[
\begin{align*}
(h_4 D^2 - h_{44}) \bar{u}_{ij}' &= 0, \\
(h_5 D^2 - h_{55}) \bar{u}_{ij}' &= 0, \\
(h_6 D^2 - h_{66}) \bar{u}_{ij}' &= 0,
\end{align*}
\]

\[
\begin{align*}
(h_7 D^2 - h_{77}) \bar{u}_{ij}' &= 0, \\
(h_8 D^2 - h_{88}) \bar{u}_{ij}' &= 0,
\end{align*}
\]
where \( D \equiv \frac{d}{dx} \), \( h_{11} = \sigma^2 h_1 + \omega^2 \), \( h_{12} = i\alpha h_2 \), \( h_{13} = i\alpha(1 + \tau_1 \omega) \), \( h_{14} = \sigma^2 h_1 + \omega^2 \), \( h_{15} = i\alpha h_2 \), \( h_{16} = i\alpha h_2 \), \( h_{17} = (1 + \tau_1 \omega) \), \( h_{18} = i\alpha h_2 \), \( h_{19} = \sigma^2 + 2h_2 + h_2 \omega^2 \), \( h_{20} = -i\alpha(1 + \tau_1 \omega) \), \( h_{21} = h_2(1 + n_0 \tau_0 \omega) \), \( h_{22} = \sigma^2 + \omega(1 + \tau_0 \omega) \).

The constitutive relations (19–21) become,

\[
\bar{\sigma}_{zz}^j = i\alpha h \bar{u}_{11}^j + h_1 \bar{D} \bar{u}_{11}^j - h_{11} \bar{f}_1, \tag{26}
\]

\[
\bar{\sigma}_{zz}^j = h_1 \bar{D} \bar{u}_{11}^j + i\alpha h \bar{u}_{11}^j - h_1 \bar{f}_2, \tag{27}
\]

\[
\bar{m}_{yz} = h_1 \bar{D} \bar{f}_2. \tag{28}
\]

Eliminating \( \bar{u}_{11}^j(z) \), \( \bar{f}_2(z) \), and \( \bar{T}_1(z) \) from Equations (22–25), we obtain differential equation for \( \bar{u}_{11}^j(z) \) as

\[
(D^8 + PD^6 + QD^4 + RD^2 + S)\bar{u}_{11}^j(z) = 0, \tag{29}
\]

where

\[
P = \frac{1}{h_1 h_3} [-h_3 h_{11} h_{12} - h_3 (h_1 h_{15} + h_{16}) - h_1 (h_1 h_{11} + h_3 h_{22}) - h_1 h_{15} + h_1 h_{11} h_3],
\]

\[
Q = \frac{1}{h_1 h_3} [h_1 (h_1 h_{17} - h_1 h_{13} - h_2 h_1 h_{21}) + h_21 (h_1 h_{17} + h_1 h_{13}) + h_1 h_{11} h_3 h_{21} + h_2 (h_1 h_{14} - h_1 h_{18}) - h_1 h_3 h_22 h_{15} + h_1 h_3 h_{19} + h_1 h_3 h_{16} h_{18}],
\]

\[
R = \frac{1}{h_1 h_3} [h_1 h_{20} h_1 h_{21} + h_1 h_{15} + h_1 h_{19} + h_1 h_1 h_{16} - h_1 h_{15} h_{19} + h_1 h_{16} h_{18} - h_1 h_{15} + h_1 h_{16} h_{18} - h_1 h_{15} h_{19} + h_1 h_{16} h_{18}],
\]

\[
S = \frac{1}{h_1 h_3} [h_{13} h_{16} h_{18} h_{20} - h_{13} h_{14} h_{19} + h_{11} h_{22} h_{14} h_{19} + h_{16} h_{18}].
\]

Similarly, \( \bar{u}_{11}^j(z) \), \( \bar{f}_2(z) \), \( \bar{T}_1(z) \) satisfies the equation,

\[
(D^8 + PD^6 + QD^4 + RD^2 + S)\bar{u}_{11}^j(z), \bar{f}_2(z), \bar{T}_1(z)) = 0, \tag{30}
\]

which can be factorized as,

\[
(D^2 - l_1^j)(D^2 - l_2^j)(D^2 - l_3^j)(D^2 - l_4^j)\bar{u}_{11}^j(z) = 0, \tag{31}
\]

where \( l_n^j \) \((n = 1, 2, 3, 4)\) are roots of Equation (31).

The series solution of (31) can be expressed as,

\[
\bar{u}_{11}^j(z) = \sum_{n=1}^{4} [L_n(a, \omega) e^{-l_n^j z}], \tag{32}
\]

\[
\bar{u}_{11}^j(z) = \sum_{n=1}^{6} [L_n(a, \omega) e^{-l_n^j z}], \tag{33}
\]
Using (32)-(35) in (22)-(25), we get

\[ L_n'(a, \omega) = R_{2n} L_n(a, \omega), \]
\[ L_n''(a, \omega) = R_{3n} L_n(a, \omega), \]
\[ L_n'''(a, \omega) = R_{4n} L_n(a, \omega). \]

Using (36-38) in (33-35) and (26-28) we get,

\[ \tilde{\phi}_n(z) = \sum_{n=1}^{\ddot{n}} \left[ R_{1n} L_n(a, \omega) e^{-l\cdot z} \right], \]
\[ \tilde{T}_n(z) = \sum_{n=1}^{\ddot{n}} \left[ R_{2n} L_n(a, \omega) e^{-l\cdot z} \right], \]
\[ \tilde{\Omega}_n(z) = \sum_{n=1}^{\ddot{n}} \left[ R_{3n} L_n(a, \omega) e^{-l\cdot z} \right], \]
\[ \tilde{\sigma}_n(z) = \sum_{n=1}^{\ddot{n}} \left[ R_{4n} L_n(a, \omega) e^{-l\cdot z} \right], \]
\[ \tilde{\sigma}_n(z) = \sum_{n=1}^{\ddot{n}} \left[ R_{sn} L_n(a, \omega) e^{-l\cdot z} \right], \]
\[ \tilde{m}_n(z) = \sum_{n=1}^{\ddot{n}} \left[ R_{5n} L_n(a, \omega) e^{-l\cdot z} \right], \]

where

\[ R_{1n} = \frac{[-h_1 h_2 h_3 h_4 h_5 h_6 h_7 h_8 + h_3 h_4 h_5 h_6 h_7 h_8 h_9 + h_3 h_4 h_5 h_6 h_7 h_8 h_9 + h_3 h_4 h_5 h_6 h_7 h_8 h_9)]}{(h_3 h_4 h_5 h_6 h_7 h_8 h_9)}, \]
\[ R_{2n} = \frac{[h_1 h_2 h_3 h_4 h_5 h_6 h_7 h_8 + h_3 h_4 h_5 h_6 h_7 h_8 h_9 + h_3 h_4 h_5 h_6 h_7 h_8 h_9)]}{(h_3 h_4 h_5 h_6 h_7 h_8 h_9)}, \]
\[ R_{3n} = \frac{[h_1 h_2 h_3 h_4 h_5 h_6 h_7 h_8 + h_3 h_4 h_5 h_6 h_7 h_8 h_9 + h_3 h_4 h_5 h_6 h_7 h_8 h_9)]}{(h_3 h_4 h_5 h_6 h_7 h_8 h_9)}, \]
\[ R_{4n} = \frac{[h_1 h_2 h_3 h_4 h_5 h_6 h_7 h_8 + h_3 h_4 h_5 h_6 h_7 h_8 h_9 + h_3 h_4 h_5 h_6 h_7 h_8 h_9)]}{(h_3 h_4 h_5 h_6 h_7 h_8 h_9)}, \]
\[ R_{5n} = \frac{[h_1 h_2 h_3 h_4 h_5 h_6 h_7 h_8 + h_3 h_4 h_5 h_6 h_7 h_8 h_9 + h_3 h_4 h_5 h_6 h_7 h_8 h_9)]}{(h_3 h_4 h_5 h_6 h_7 h_8 h_9)}. \]

Adopting the same methodology, we obtain the solutions for medium II as,

\[ \tilde{u}_n(z) = \sum_{m=1}^{\ddot{m}} \left[ M_m(a, \omega) e^{l\cdot z} \right] \]
\[ \tilde{U}_2^m(z) = \sum_{m=1}^{4} |H_m M_m(a, \omega)\epsilon^{m/2} |, \]  

\[ \tilde{T}_2(z) = \sum_{m=1}^{4} |H_{2m} M_m(a, \omega)\epsilon^{m/2} |, \]  

\[ \tilde{N}(z) = \sum_{m=1}^{4} |H_{3m} M_m(a, \omega)\epsilon^{m/2} |, \]  

\[ \tilde{s}_{ax}^{II}(z) = \sum_{m=1}^{4} |H_{4m} M_m(a, \omega)\epsilon^{m/2} |, \]  

\[ \tilde{s}_{x2}^{II}(z) = \sum_{m=1}^{4} |H_{5m} M_m(a, \omega)\epsilon^{m/2} |, \]  

\[ \tilde{s}_{x2}(z) = \sum_{m=1}^{4} |H_{6m} M_m(a, \omega)\epsilon^{m/2} |, \]  

where \( r_m^2 \) (\( m = 1, 2, 3, 4 \)) are the roots of the equation, 

\[ (D^8 + AD^6 + BD^4 + CD^2 + E)\tilde{U}_2(z) = 0. \]  

and 

\[ A = \frac{1}{d_5 d_6 d_{11}} \left[ d_4 d_5 d_{11} d_{17} - d_4 d_{11} d_6 d_28 + d_5 d_{24} + d_{25} - d_5 d_7 (d_{30} d_{11} + d_{23} d_5) \right], \]  

\[ B = -\frac{1}{d_5 d_6 d_{11}} \left[ d_4 d_7 d_{13} d_{17} - d_4 d_{13} d_6 d_2 + d_7 d_{11} (d_6 d_{25} - d_{25} d_{26}) + d_{11} d_7 (d_6 d_{24} + d_{26} d_{26}) + d_7 d_{13} d_6 d_{25} - (d_{30} d_{11} + d_{29} d_5) (d_6 d_{28} + d_5 d_{24} + d_5 d_{25} - d_5 d_7 d_9 d_{30}) \right], \]  

\[ C = -\frac{1}{d_5 d_6 d_{11}} \left[ d_4 d_{13} d_{21} (d_6 d_{25} - d_{25} d_{26}) - d_4 d_{13} (d_6 d_{24} + d_{26} d_{26}) + d_{13} d_6 d_{25} - d_4 (d_{28} d_{23} + d_{29} d_5) + d_6 d_7 d_{24} + d_{26} d_{28} d_{29} d_{30} \right], \]  

\[ E = \frac{1}{d_5 d_6 d_{11}} \left[ d_4 d_{13} d_{21} d_{28} + d_6 d_{13} d_6 d_{24} + d_{13} d_{28} d_{23} + d_{25} d_{28} d_{29} d_{30} \right], \]  

where \( D \equiv \frac{d_4}{d_5} \), \( d_1 = (\lambda_2 + 2 \mu_2) \), \( d_2 = (\lambda_2 + \mu_2) \), \( d_4 = (3 \lambda_2 + 2 \mu_2) \), \( d_5 = \frac{d_4 d_7}{d_9} \), \( d_6 = \frac{d_4 d_7}{d_9} \), \( d_7 = \frac{d_4 d_7}{d_9} \), \( d_8 = \frac{d_4 d_7}{d_9} \), \( d_9 = \frac{d_4 d_7}{d_9} \), \( d_{10} = \frac{d_4 d_7}{d_9} \), \( d_{11} = \frac{d_4 d_7}{d_9} \), \( d_{12} = \frac{d_4 d_7}{d_9} \), \( d_{13} = \frac{d_4 d_7}{d_9} \), \( d_{14} = \frac{d_4 d_7}{d_9} \), \( d_{15} = \frac{d_4 d_7}{d_9} \), \( d_{16} = \frac{d_4 d_7}{d_9} \), \( d_{17} = \frac{d_4 d_7}{d_9} \), \( d_{18} = \frac{d_4 d_7}{d_9} \), \( d_{19} = \frac{d_4 d_7}{d_9} \), \( d_{20} = \frac{d_4 d_7}{d_9} \), \( d_{21} = \frac{d_4 d_7}{d_9} \), \( d_{22} = \frac{d_4 d_7}{d_9} \), \( d_{23} = \frac{d_4 d_7}{d_9} \), \( d_{24} = \frac{d_4 d_7}{d_9} \), \( d_{25} = \frac{d_4 d_7}{d_9} \), \( d_{26} = \frac{d_4 d_7}{d_9} \), \( d_{27} = \frac{d_4 d_7}{d_9} \), \( d_{28} = \frac{d_4 d_7}{d_9} \), \( d_{29} = \frac{d_4 d_7}{d_9} \), \( d_{30} = \frac{d_4 d_7}{d_9} \), \( d_{31} = \frac{d_4 d_7}{d_9} \), \( d_{32} = \frac{d_4 d_7}{d_9} \), \( d_{33} = \frac{d_4 d_7}{d_9} \).
\[ H_{3m} = \frac{[d_{13} H_{2m}]}{\left[d_{29} - d_{11} r_m^2\right]}, \quad H_{4m} = [d_{32} + r_m d_{20} H_{1m} - d_{21} H_{2m} - d_{22} H_{3m}], \]

\[ H_{5m} = [d_{33} + r_m d_{19} H_{1m} - d_{21} H_{2m} - d_{22} H_{3m}], \quad H_{6m} = [r_m d_{23} + d_{34} H_{1m}], \]

\[ d_{35} = d_6 d_e (d_{30} - d_e) + d_{15} (d_6 d_{24} + d_{25} d_{27}), \]

\[ d_{36} = (d_{30} - d_e) (d_6 d_{24} + d_{25} d_{27}) + (d_{25} - d_{31}) (d_6 d_{27} - d_6 d_{26}), \]

\[ d_{37} = d_{27} d_{28} (d_{30} - d_e) + d_{28} (d_6 d_{27} - d_6 d_{26}), \]

\[ d_{38} = d_{27} d_{26} (d_{30} - d_e) (d_{25} d_6 - d_5 d_{27}) + (d_5 - d_{17}) (d_6 d_{27} - d_6 d_{26}), \]

\[ d_{39} = (d_5 d_6 - d_5 d_{27}) (d_{15}). \]

3. Boundary conditions

To determine the parameters \( L_1, L_2, L_3, L_4 \) and \( M_1, M_2, M_3, M_4 \), the boundary conditions at the interface \( z = 0 \) have been taken as,

\[ \sigma_{zz}^I - \sigma_{zz}^{II} = \rho I e^{i \omega t}, \quad \sigma_{zr}^I = \sigma_{zr}^{II}, \quad u_1^I = u_1^{II}, \quad u_3^I = u_3^{II}, \quad T_1 = T_2; \]

\[ \frac{\partial N}{\partial z} = \frac{s}{D_e} N. \] (53)

where \( \rho I \) is the magnitude of the mechanical force.

Using the expressions for \( \sigma_{rr}^I, \sigma_{rz}^I, \sigma_{zz}^I, \sigma_{zz}^{II}, u_1^I, u_1^{II}, u_3^I, u_3^{II}, T_1, T_2 \), and \( N \) from (32), (39–44), and (45–51) into above boundary conditions (53), we obtain the following non-homogenous linear equations as,

\[ \sum_{n=1}^{4} |R_{n1} L_n| - \sum_{m=1}^{4} |H_{5m} M_m| = -\rho_1 \sum_{n=1}^{4} |R_{n1} L_n| - \sum_{m=1}^{4} |H_{5m} M_m| = 0, \]

\[ \sum_{n=1}^{4} |R_{n1} L_n| - \sum_{m=1}^{4} |H_{1m} M_m| = 0, \]

\[ \sum_{n=1}^{4} |R_{n1} L_n| - \sum_{m=1}^{4} |H_{2m} M_m| = 0, \]

\[ \sum_{n=1}^{4} |R_{n1} L_n| - \sum_{m=1}^{4} |H_{3m} M_m| = 0. \]

After solving the above system of non-homogeneous equations, we get the values of constants \( L_1, L_2, L_3, L_4, M_1, M_2, M_3, M_4 \), and \( M_1 \) hence obtain the components of normal displacement, temperature distribution, normal force stress, and tangential couple stress for a thermoelastic micropolar solid with cubic symmetry at the interface of the semi-infinite semiconducting medium.

3.1. Particular cases

(i) Letting \( \delta, D_e, \kappa, E, d_e \to 0 \) in medium II, we obtain the corresponding expressions for components of normal displacement, temperature distribution, normal force stress, and tangential couple stress for a thermoelastic micropolar medium with cubic symmetry with an overlying thermoelastic half space.

(ii) Neglecting medium II, i.e. the free surface of thermoelastic micropolar medium with cubic symmetry. The corresponding expressions for components of normal displacement, temperature distribution, normal force stress, and tangential couple stress are obtained in the medium when a mechanical force is acting along the free surface of micropolar thermoelastic cubic crystal half space (Kumar & Ailawalia, 2005).
3.2. Special cases

(1) Substituting $A_1 = (\lambda_1 + 2\mu_1 + k), A_2 = \lambda_1, A_3 = (\mu_1 + k), A_4 = \mu_1, B_3 = \gamma$, in the above section, we obtain the expression for micropolar thermoelastic solid (MTS).

(2) Neglecting micropolarity effect i.e. $B_3 = j = 0$ and, in the above section, the corresponding expressions are obtained in a thermoelastic solid with cubic symmetry (TSCS).

(3) Taking, $A_1 = (\lambda_1 + 2\mu_1), A_2 = \lambda_1, A_3 = \mu_1, A_4 = \mu_1, B_3 = 0$ in expression obtained in previous steps, the expression for normal displacement, temperature distribution and normal force stress is obtained for thermoelastic solid (TS).

(4) Neglecting thermal effect i.e. $K^*_1 = c^*_1 = \nu_1 = 0$, in the step (2) the corresponding expressions are obtain in a thermoelastic solid with cubic symmetry without thermal effect (ESCS).

(5) Taking, $K^*_1 = c^*_1 = \nu_1 = 0$ in the step (3) the corresponding expressions are obtain in a thermoelastic solid without thermal effect (ES).

4. Numerical results, discussions, and conclusions
For numerical computations, we consider the values of physical constants as,

(1) For micropolar solid with cubic symmetry as (Kumar & Partap, 2010):

$A_1 = 19.6 \times 10^{10} \text{ N/m}^2$, $A_2 = 11.7 \times 10^{10} \text{ N/m}^2$, $A_3 = 5.6 \times 10^{10} \text{ N/m}^2$, $A_4 = 4.3 \times 10^{10} \text{ N/m}^2$, $B_3 = 0.98 \times 10^{-9} \text{ N}$.

(2) For micropolar thermoelastic solid, we take the following values of relevant parameters in case of Magnesium crystal-like material as (Kumar & Partap, 2010):

$\lambda_2 = 9.4 \times 10^{10} \text{ N/m}^2$, $\mu_2 = 4.0 \times 10^{10} \text{ N/m}^2$, $\rho_1 = 1.74 \times 10^3 \text{ kg/m}^3$, $k = 10^{10} \text{ Nm}^{-2}$, $\gamma = 0.779 \times 10^{-9} \text{ N}$, $j = 0.0000002 \times 10^{-14} \text{ m}^2$, $c^*_1 = 0.104 \times 10^{4} \text{ Nm/kg/K}$, $T_0 = 298 \text{ K}$, $K^*_1 = 1.7 \times 10^{4} \text{ Ns}^{-1} \text{ K}^{-1}$, $\nu_1 = 0.0268 \times 10^{8} \text{ N/m}^2 \text{ K}$, $\tau_0 = 6.131 \times 10^{-13} \text{ kg/m}^3$.

(3) For semi-infinite semiconducting medium, we take the following values of relevant parameters in case of Silicon as (Song et al., 2012):

$\lambda_2 = 3.64 \times 10^{10} \text{ N/m}^2$, $\mu_2 = 5.46 \times 10^{10} \text{ N/m}^2$, $\rho_2 = 2.33 \times 10^3 \text{ kg/m}^3$, $K^*_2 = 150 \text{ W/(mk)}$, $c^*_2 = 695 \text{ J/(kgK)}$, $r = 5 \times 10^{-3} \text{ s}$, $s = 2 \text{ m/s}$, $d_n = -9 \times 10^{-31} \text{ m}^3$, $a_s = 4.14 \times 10^{-6} \text{ K}^{-1}$, $D_e = 2.5 \times 10^{-3} \text{ m}^2 \text{s}^{-1}$, $E_g = 1.11 \text{ eV}$.

The calculations have been carried out for non-dimensional time $t = 0.2$ in the range $0 \leq x \leq 10.0$ and on the surface $z = 1.0$. The variations of numerical values for normal displacement, temperature distribution, normal force stress, and tangential couple stress are shown in Figures (2)–(5) for G-L theory by taking $n_0 = 0$, the mechanical force with magnitude, $P_1 = 1.0$, $\omega = \omega_0 + i\xi$, $\omega_0 = -0.3$, $\xi = 0.1$, and $a = 0.9$ for,
Figure 3. Variation of normal force stress with horizontal distance.

(a) Micropolar thermoelastic solid with cubic symmetry (MTSCS) by a solid line with the centered symbol ♦.
(b) Micropolar thermoelastic solid (MTS) by a dotted line with the centered symbol ■.
(c) Thermoelastic solid with cubic symmetry (TSCS) by dashed line with the centered symbol ▲.
(d) Thermoelastic solid (TS) by dashed line with centered symbol ×.
(e) Elastic solid with cubic symmetry (ESCS) by a solid line with the centered symbol •.
(f) Elastic solid (ES) by dashed and dotted line with centered symbol *.

Figure 4. Variation of temperature distribution with horizontal distance.

Figure 5. Variation of tangential couple stress with horizontal distance.
5. Discussions
The variations of normal displacement for TSCS and ES are similar in nature and are more oscillatory as compared to the variations in another medium. Also, the values of normal displacement for ESCS, MTSCS, and TS lie in a short range. Near the point of application of source, the value of normal displacement is least for MTS and maximum for ES. It is also observed that the values of normal displacement for MTSCS, ESCS, and TS lie in a short range and these values are almost identical at \( x = 9.0 \). The variations of normal displacement are more oscillatory in nature for TSCS and ES i.e. in the absence of microrotation. The variation of normal displacement is shown as in Figure 2.

Contrary to the values obtained for normal displacement, the values of normal force stress near the point of application of source are minimum in case of ES and maximum for MTS. It is also seen that the variations are similar in nature for MTS and TSCS. The variations of normal force stress are highly oscillatory in nature for TSCS, MTS, and ES as compared to the variations in another medium. Also, these highly oscillatory behavior is opposite in nature for TSCS and ES. These values of normal displacement lie in a short range for MTSCS and ESCS. These variations of normal force stress are shown in Figure 3.

It is observed from Figure 4 that the variations of temperature distribution are almost identical for MTS and TS. Also, these variations are similar in nature for MTSCS and TSCS. These variations show the appreciable effect of anisotropy and microrotation in the medium.

The effect of anisotropy is also evident from the variations of tangential couple stress shown in Figure 5. The variations of tangential couple stress for both MTSCS and MTS may seem to be similar in nature but differ significantly in magnitude.

6. Conclusion
(1) The values of normal displacement are least for micropolar thermoelastic medium and maximum for an elastic medium, near the point of application of mechanical force. But these values are of opposite nature for normal force stress in case of both the mediums.
(2) The values of normal displacement and normal force stress for micropolar thermoelastic cubic crystal and elastic cubic crystal lie in a short range.
(3) The values of temperature distribution are identical in nature for an isotropic medium i.e. micropolar thermoelastic medium and thermoelastic medium which shows the least effect of microrotation on temperature distribution.
(4) A significant effect of anisotropy is witnessed in the variation of tangential couple stress.
(5) Anisotropic, microrotation, and thermal effect are observed on all the quantities as illustrated in graphical results.

Nomenclature

**Medium-I**

\[ A_1, A_2, A_3, A_4, B_3 \]  
material constants  
\[ \sigma_{ij} \]  
stress tensor  
\[ m_{yz} \]  
tangential couple stress  
\[ \bar{u}^i \]  
displacement vector  
\[ \rho_1 \]  
density  
\[ j \]  
microinertia  
\[ K_1^* \]  
the coefficient of thermal conductivity  
\[ \lambda_1, \mu_1 \]  
Lame’s constants  
\[ C_1 \]  
specific heat at constant strain
\[ \nu_1, \quad T_1, \quad \tau_0, \tau_1, \quad \alpha_{t_1}, \quad \nu_1 = (A_1 + 2A_2)\alpha_{t_1} \]

**Medium-II**

\[ \lambda_2, \mu_2, \quad \sigma_{ij}, \quad N, \quad \mathbf{u}^l, \quad \rho_2, \quad \delta_n, \quad \kappa, \quad D_e, \quad E_g, \quad \tau, \quad C_J^{*}, \quad K^{*}_t, \quad \alpha_{t_2}, \quad \gamma_{t_2} = (3\lambda_2 + 2\mu_2)\alpha_{t_2} \]

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