

RAYLEIGH WAVE PROPAGATION WITH THE EFFECT OF INITIAL STRESS, MAGNETIC FIELD AND TWO TEMPERATURE IN THE DUAL PHASE LAG THERMOELASTICITY

AASHISH KUMAR, SANGEETA¹, AND HEENA SHARMA

ABSTRACT. In the present study the governing equation of generalized thermoelasticity is formulated by considering Lord and Shulman theory under the influence of two temperature, initial stress, magnetic field and diffusion. The equations thus formed are considered for isotropic medium in xy-plane. Surface wave solution method is used to find the solution of these equations. The secular equation for Rayleigh wave thus obtained also satisfies radiation conditions. Effect of two-temperature, magnetic field, diffusion, initial stress, frequency has been shown graphically for a partical material.

1. INTRODUCTION

Rayleigh [1] discussed the first surface wave in elastic solid property in isotropic medium. Lord and Shulman[2] developed the gernralized dynamical theory of thermoelasticity with the help of heat transport equation which includes the time. Green and Lindsay [3] was obtained the theory of thermoelasticity under the action of two relaxation time. Nowaski [4] discussed the thermo diffusion with the help of differential equations. Chandrasekharaiah and Srikantaiah [5]

¹*corresponding author*

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discussed the temperature of Rayleigh wave propagation dependent on thermoelasticity in solid half-space. Tzou [6] discovered the dual phase lag thermoelastic model. Abd-Alla and Ahmed [7] developed the frequency equation of the thermoelastic orthotropic medium with gravity and initial stress. Abd-Alla et al. [8] studied the Rayleigh wave propagation under the impact of initial stress, magnetoelastic and gravity in half-space orthotropic medium. Sherief and Saleh [9] obtained the theory of generalized thermoelastic diffusion, which was allow the finite speed of thermal signal. Youssef [10] explained the new theory of generalized thermoelasticity considering thermodynamic and conductive temperature. Puri and Jordan [11] studied the effect of two temperature thermoelastic on plane harmonic wave. Ahmed [12] discussed the Rayleigh wave in a thermoelastic homogenous isotropic solid half space in the context of dual-phase-lag model and subjected to free stress, thermally insulated, boundary condition. Abd-Alla et al. [13] studied the effect of magneto-thermoelasticity, initial stress and gravity field on Rayleigh waves propagation. Singh et al. [14] studied the Rayleigh wave propagation in isotropic medium with initial stress and generalized magneto-thermoelastic. Mohmound [15] discussed the effect of diffusion on generalized magneto-thermoelastic of infinite rotating nonhomogeneous medium. Marin et al. [16] used thermoelasticity in the form of heat conduction that was depend on two temperature. Ghatuary and Chakraborty [17] used the Green-Lindsay theory for seen the effect of thermomagnetic on Rayleigh waves with initial stress in Isotropic medium. The field equation considering two-temperature thermoelasticity with diffusion was discussed by Kumari and Singh [18]. Singh et al. [19] discussed the dispersive equation of Rayleigh wave propagation with two-temperature dual phase lag model. Kaur and Iata [20] studied the Rayleigh wave propagation in transversely isotropic magneto-thermoelastic homogenous medium in the presence of diffusion and three phase-lag heat transfer.

2. BASIC EQUATIONS

Following Sherief et al (2004), the governing equations for a linear, isotropic and homogeneous elastic solid with generalized thermodiffusion at constant temperature T in the absence of body force are:

(i) The displacement-strain relation

$$e_{ij} = \frac{1}{2}(u_{i,j} + u_{j,i}).$$

(ii) The energy equation

$$-q_{i,i} = \rho T_0 \dot{S}.$$

(iii) The modified Fourier's law

$$-K_{ij}\Phi_{,j} = q_i + \tau_0 \dot{q}_i.$$

(iv) The equation of motion

$$(2.1) \quad \mu u_{i,jj} + (\lambda + \mu)u_{j,ij} - \beta_1 \Theta_{,i} - \beta_2 C_{,i} = \rho \ddot{u}_i.$$

(v) The equation of heat conduction:

$$(2.2) \quad \rho c_E (\dot{\Theta} + \tau_0 \ddot{\Theta}) + \beta_1 T_0 (\dot{e} + \tau_0 \ddot{e}) + a T_0 (\dot{C} + \tau_0 \ddot{C}) = K \Phi_{,ii}.$$

(vi) The equation of mass diffusion:

$$(2.3) \quad D^* \beta_2 e_{,ii} + D^* a \Theta_{,ii} + \dot{C} + \tau \ddot{C} - D^* b C_{,ii} = 0.$$

(vii) Maxwell stresses

$$\bar{\sigma}_{ij} \mu_e [H_i h_j + H_j h_i - (H \cdot h) \delta_{ij}].$$

(viii) The constitutive equations

$$\begin{aligned} \sigma_{ij} &= 2\mu e_{ij} + \delta_{ij}(\lambda e_{kk} - \beta_1 \Theta - \beta_2 C), \\ \rho T_0 S &= \rho c_E \Theta + \beta_1 T_0 e_{kk} + a T_0 C, \\ P &= -\beta_2 e_{kk} + b C - a \Theta, \end{aligned}$$

where ρ is the density, λ, μ are constant of Lamé, σ_{ij} is the stress tensor, e_{ij} is the strain tensor, u_i is the displacement vector, w_{ij} is the rotation tensor, S is the entropy per unit mass, C is the mass-concentration, c_E is the specific-heat at constant strain, K is the thermal-conductivity, D^* is the thermal diffusion, τ_0 is thermal relaxation, τ is diffusion relaxation time, $a^* > 0$ is the two-temperature parameter, a, b are the thermal diffusion effects and diffusive effects, p_0 is the initial stress parameter, h is the perturbed magnetic field over, j is the electric current density, μ_e is the magnetic permeability, $h = \nabla \times (\mu \times H_0)$ and $H = H_0 + h$, $\beta_1 = (3\lambda + 2\mu)\alpha_t$ and $\beta_2 = (3\lambda + 2\mu)\alpha_c$, α_t is the Linear thermal-expansion, α_c is the diffusion expansion.

The temperature relation:

$$(2.4) \quad \Phi - \Theta = a^* \Phi_{(ii)},$$

and $\Theta = T - T_0$ is the small temperature increment, T is the absolute temperature, T_0 is the reference uniform temperature such that $\frac{\Theta}{T_0} \ll 1$ Φ is the conductive temperature and a^* is the parameter of two temperature.

3. FORMULATION OF PROBLEM AND SOLUTION

We consider a isotropic and homogenous medium of Rayleigh wave with initial stress, diffusion and magneto-thermo-elastic half-space of an infinite extent with Cartesian coordinate (x, y, z) which is at uniform temperature previously. The origin is being taken on plane surface and consider $(z > 0)$ normal into the medium. We consider the plane stress parallel to the x - z plane in the present study and the displacement vector is $(u_1, 0, u_3)$

$$(3.1) \quad u_1 = \frac{\partial \phi}{\partial x} - \frac{\partial \psi}{\partial z}, u_3 = \frac{\partial \phi}{\partial z} + \frac{\partial \psi}{\partial x},$$

By using of equation (2.4) and (3.1), after solving the equations from (2.1)-(2.3) then we have

$$(3.2) \quad \left(\mu - \frac{p_0}{2}\right)(\psi_{,11} + \psi_{,33}) = \rho \ddot{\psi},$$

$$(3.3) \quad (\lambda + 2\mu + \mu_e H_0^2)(\phi_{,11} + \phi_{,33}) - \beta_1 \Theta - \beta_2 C = \rho \ddot{\phi},$$

$$(3.4) \quad K(\Phi_{,11} + \Phi_{,33}) = \rho c_E \tau_m \dot{\Theta} + \beta_1 T_0 \tau_m \frac{\partial}{\partial t} \nabla^2 \phi + a T_0 \tau_m \dot{C},$$

$$(3.5) \quad D^* \beta_2 \nabla^2 (\phi_{,11} + \phi_{,33}) + D^* a (\Theta_{,11} + \Theta_{,33}) - D^* b (C_{,11} + C_{,33}) + \tau_n \dot{C} = 0,$$

where $\tau_m = 1 + \tau_n \frac{\partial}{\partial t}$ and $\tau_n = 1 + \tau \frac{\partial}{\partial t}$. Surface waves moves along the x -axis in magneto-thermo-elastic with isotropic medium, so potential functions ψ, ϕ, Φ, C are considered in the form of which are given as:

$$(3.6) \quad [\psi, \phi, \Phi, C] = [\hat{\psi}(z), \hat{\phi}(z), \hat{\Phi}(z), \hat{C}(z)] e^{t(\eta x - \chi t)}.$$

Now put the value of ψ in equation (3.2) from equation (3.6), we have

$$\frac{r_4^2}{\eta^2} = 1 - \frac{\rho c^2}{\mu - p_2/2}.$$

Again, after put the value of ϕ, Φ, C in equations (3.3)-(3.5) from (3.6), then we get the following non trivial solution

$$D^6 - LD^4 + MD^2 - N = 0,$$

$$\begin{aligned} \text{where } L &= 3\eta^2 - [(\bar{K} - a^*)(\chi^2\tau_n^* \frac{\lambda+2\mu+\mu_e H_0^2}{\rho} - D^*a\chi^2 - \bar{\beta}_2 D^*\beta_2) \\ &- D^*a(\frac{\lambda+2\mu+\mu_e H_0^2}{\rho} + \bar{\beta}_1\epsilon_1) + D^*b(\chi^2\epsilon_2 a^* - \epsilon_2 \frac{\lambda+2\mu+\mu_e H_0^2}{\rho}) \\ &+ \bar{\beta}_2 D^*\beta_2 a^*] / [D^*a(a^*\epsilon_1 \bar{\beta}_1 - \frac{\lambda+2\mu+\mu_e H_0^2}{\rho}(\bar{K} - a^*)) \\ &+ a^* D^*b(\frac{\lambda+2\mu+\mu_e H_0^2}{\rho}\epsilon_2 + \bar{\beta}_2\epsilon_1)], \\ M &= 3\eta^4 - 2\eta^2[(\bar{K} - a^*)(\chi^2\tau_n^* \frac{\lambda+2\mu+\mu_e H_0^2}{\rho} - D^*a\chi^2 - \bar{\beta}_2 D^*\beta_2) \\ &- D^*a(\frac{\lambda+2\mu+\mu_e H_0^2}{\rho} + \bar{\beta}_1\epsilon_1) + D^*b(\chi^2\epsilon_2 a^* - \epsilon_2 \frac{\lambda+2\mu+\mu_e H_0^2}{\rho}) \\ &+ \bar{\beta}_2 D^*\beta_2 a^* + \tau_n^*((\bar{K} - a^*)\chi^4 + \beta_1\epsilon_1 + \frac{\lambda+2\mu+\mu_e H_0^2}{\rho}) \\ &- \chi^2(D^*a + \epsilon_2 D^*b) - D^*\beta_2(\bar{\beta}_2 + \bar{\beta}_1\epsilon_2)] / [D^*a(a^*\epsilon_1 \bar{\beta}_1 \\ &- \frac{\lambda+2\mu+\mu_e H_0^2}{\rho}(\bar{K} - a^*)) + a^* D^*b(\frac{\lambda+2\mu+\mu_e H_0^2}{\rho}\epsilon_2 + \bar{\beta}_2\epsilon_1)], \\ N &= \eta^6 - 2\eta^4[(\bar{K} - a^*)(\chi^2\tau_n^* \frac{\lambda+2\mu+\mu_e H_0^2}{\rho} - D^*a\chi^2 - \bar{\beta}_2 D^*\beta_2) \\ &- D^*a(\frac{\lambda+2\mu+\mu_e H_0^2}{\rho} + \bar{\beta}_1\epsilon_1) + D^*b(\chi^2\epsilon_2 a^* - \epsilon_2 \frac{\lambda+2\mu+\mu_e H_0^2}{\rho}) + \bar{\beta}_2 D^*\beta_2 a^* \\ &+ \tau_n^*((\bar{K} - a^*)\chi^4 + \beta_1\epsilon_1 + \frac{\lambda+2\mu+\mu_e H_0^2}{\rho}) - \chi^2(D^*a + \epsilon_2 D^*b) \\ &- D^*\beta_2(\bar{\beta}_2 + \bar{\beta}_1\epsilon_2) - \chi^4\tau_n^* - \eta^2[\tau_n^*((\bar{K} - a^*)\chi^4 + \beta_1\epsilon_1 + \frac{\lambda+2\mu+\mu_e H_0^2}{\rho}) \\ &- \chi^2(D^*a + \epsilon_2 D^*b) - D^*\beta_2(\bar{\beta}_2 + \bar{\beta}_1\epsilon_2)] / [D^*a(a^*\epsilon_1 \bar{\beta}_1 \\ &- \frac{\lambda+2\mu+\mu_e H_0^2}{\rho}(\bar{K} - a^*)) + a^* D^*b(\frac{\lambda+2\mu+\mu_e H_0^2}{\rho}\epsilon_2 + \bar{\beta}_2\epsilon_1)], \\ \epsilon_1 &= \frac{\beta_1 T_0}{\rho c_E}, \epsilon_2 = \frac{T_0}{\rho c_E}, \bar{K} = \frac{K}{\chi^2 \rho c_E \tau^*}, \tau_m^* = \frac{i\tau_m}{\chi}, \tau_n^* = \frac{i\tau_n}{\chi} \end{aligned}$$

Some general solutions of equations (3.2) to (3.5) are given as

$$(3.7) \quad \psi(z) = [E \exp(-r_4 z) + E' \exp(r_4 z)] e^{\iota(\eta x - \chi t)},$$

$$(3.8) \quad \phi(z) = \sum_{i=1}^3 [F_i \exp(-r_i z) + F_i' \exp(r_i z)] e^{\iota(\eta x - \chi t)},$$

$$(3.9) \quad \Phi(z) = \sum_{i=1}^3 [G_i \exp(-r_i z) + G_i' \exp(r_i z)] e^{\iota(\eta x - \chi t)},$$

$$(3.10) \quad C(z) = \sum_{i=1}^3 [H_i \exp(-r_i z) + H_i' \exp(r_i z)] e^{\iota(\eta x - \chi t)},$$

where $E, F_i, G_i, H_i, E', F_i', G_i', H_i'$ are the arbitrary constants, In general the roots are complex, therefore W.L.O.G we assume $\text{Real}(r_1) > 0$. With the help

of the $\psi(z), \phi(z), \Phi(z), C(z) \rightarrow 0$ as $z \rightarrow \infty$ as .Then the solution (3.7)-(3.10) reduces to the particular solution in the half space if $z > 0$

$$(3.11) \quad \psi(z) = E \exp(-r_4 z) e^{\iota(\eta x - \chi t)},$$

$$(3.12) \quad \phi(z) = \sum_{i=1}^3 F_i \exp(-r_i z) e^{\iota(\eta x - \chi t)},$$

$$(3.13) \quad \Phi(z) = \sum_{i=1}^3 P_i F_i \exp(-r_i z) e^{\iota(\eta x - \chi t)},$$

$$(3.14) \quad C(z) = \sum_{i=1}^3 P_i^* F_i \exp(-r_i z) e^{\iota(\eta x - \chi t)},$$

here $G_i = P_i F_i$ and $H_i = P_i^* F_i$ and

$$P_i = \eta^2 \frac{\epsilon_2 [\frac{\mu - p_0}{\rho} (-1 + \frac{r_i^2}{\eta^2}) + \frac{\chi^2}{\eta^2}] + \beta_2 \epsilon_1 (-1 + \frac{r_i^2}{\eta^2})}{\epsilon_2 \bar{\beta}_1 [1 - a^* \eta^2 (-1 + \frac{r_i^2}{\eta^2})] - \bar{\beta}_1 [\bar{K} \eta^2 (-1 + \frac{r_i^2}{\eta^2}) + 1 - a^* \eta^2 (-1 + \frac{r_i^2}{\eta^2})]}$$

$$P_i^* = \eta^2 \frac{\bar{\beta}_1 D^* \beta_2 (-1 + \frac{r_i^2}{\eta^2})^2 + D^* a [\frac{\mu - p_0}{\rho} (-1 + \frac{r_i^2}{\eta^2}) + \frac{\chi^2}{\eta^2}]}{\bar{\beta}_2 [D^* b (-1 + \frac{r_i^2}{\eta^2}) + \frac{\chi^2}{\eta^2}] + \bar{\beta}_2 D^* a (-1 + \frac{r_i^2}{\eta^2})} \quad (i = 1, 2, 3).$$

4. BOUNDARY CONDITION

The appropriate boundary conditions at stress free surface $z = 0$ are

$$(4.1) \quad \sigma_{zz} + \bar{\sigma}_{zz} = 0, \quad \sigma_{zx} + \bar{\sigma}_{zx} = 0, \quad \frac{\partial P}{\partial z} = 0, \quad \frac{\partial \Theta}{\partial z} + h\Theta = 0.$$

Thus, applying the boundary condition (4.1) in equation equations (3.11) to (3.14) then find the homogeneous system of equation E, F_1, F_2 and F_3

$$(4.2) \quad 4\mu^2 \frac{r_4 - h}{\eta} [\frac{r_1}{\eta} S_2 \frac{r_3}{\eta} Z_3 - S_3 \frac{r_2}{\eta} Z_2 - \frac{r_2}{\eta} S_1 \frac{r_3}{\eta} Z_3 - S_3 \frac{r_1}{\eta} Z_1 + \frac{r_3}{\eta} S_1 \frac{r_2}{\eta} Z_1 - S_2 \frac{r_1}{\eta} Z_2]$$

$$- [(\mu + \frac{p_0}{2}) + \frac{r_4^2}{\eta} (\mu - \frac{p_0}{2}) - \frac{h}{\eta}] [R_1 S_2 \frac{r_3}{\eta} Z_3 - S_3 \frac{r_2}{\eta} Z_2 - R_2 S_1 \frac{r_3}{\eta} Z_3 - S_3 \frac{r_1}{\eta} Z_1$$

$$+ R_3 S_1 \frac{r_2}{\eta} Z_1 - S_2 \frac{r_1}{\eta} Z_2]$$

where

$$\begin{aligned}
 R_i &= -(\lambda + \mu_e H_0^2) + (\lambda + 2\mu_e H_0^2) \frac{r_i^2}{\eta^2} - \beta_1 \left[1 - a^* \left(-1 + \frac{r_i^2}{\eta} \right) \right] \frac{P_i^2}{\eta^2} - \beta_2 \frac{P_i^*}{\eta^2}, \\
 (i &= 1, 2, 3) \\
 S_i &= \beta_2 \left(-1 + \frac{r_i^2}{\eta^2} \right) + b \frac{P_i^*}{\eta^2} - a \left[1 - a^* \left(-1 + \frac{r_i^2}{\eta} \right) \right] \frac{P_i}{\eta^2}. \\
 Z_i &= 1 - a^* \left(-1 + \frac{r_i^2}{\eta^2} \right).
 \end{aligned}$$

Then the expression (4.2) is known as frequency or dispersive equation of propagating Rayleigh-Surface waves with magnetic, diffusion and initial stress in two-temperature-thermo-elastic medium along with dual-phase lag.

5. SPECIAL CASE

For thermally insulated case ($h \rightarrow 0$) and in the absence of initial stress, magnetic field, two temperature, Diffusion, the frequency equation (4.2) reduces to

$$(5.1) \quad \left(2 - \frac{c^2}{c_2^2} \right)^2 = \sqrt{4 \left(1 - \frac{c^2}{c_1^2} \right) \left(1 - \frac{c^2}{c_2^2} \right)},$$

where $X_i, Y_i, P_i, P_i^*, R_i, S_i, Z_i$ calculated accordingly. Expression (5.1) is the Rayleigh wave speed equation for elastic medium.

6. NUMERICAL RESULTS AND DISCUSSION

For the calculation of propagation of non dimensional speed of Rayleigh-waves, following Kumari and Singh (2016) the constant are taken for two-temperature thermo-elasticity solid half-space with diffusion, such as

$$\begin{aligned}
 T_0 &= 300 \text{ KC}, K = 0.494 \times 10^2 \text{ W.m}^{-1}.\text{s}^{-1}.\text{deg}^{-1}, \lambda = 5.775 \times 10^{10} \text{ N.m}^2, \\
 c_E &= 2.361 \times 10^2 \text{ J.Kg}^{-1}.\text{deg}^{-1}, \tau_0 = 0.05 \text{ s}, a = 0.005, b = 0.05, \rho = 2.7 \times 10^3 \text{ Kg.m}^{-3}.
 \end{aligned}$$

We obtain the dimensionless wave speed of Propagation of Rayleigh wave from equation (4.2) for different range of diffusion relaxation time (τ), thermos-diffusion (D^*), two-temperature a^* , frequency (χ), which is solved by the method of Fortran iteration method, using with the above value of physical different parameter.

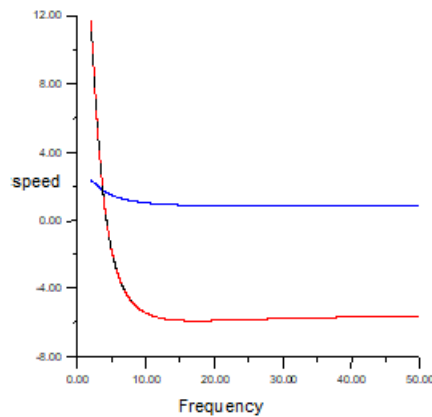


FIGURE 1. speed plot against frequency

Figure 1 shows that the speed is plotted against frequency for the different values of the $H_0 = -10, 0, 10$. It shows that for the value of magnetic field -10, 10 speed sharply decreases and then remain constant for the increase of the frequency. For the magnetic field 0 the value slowly decreases and then remains constant for the increase of the frequency.

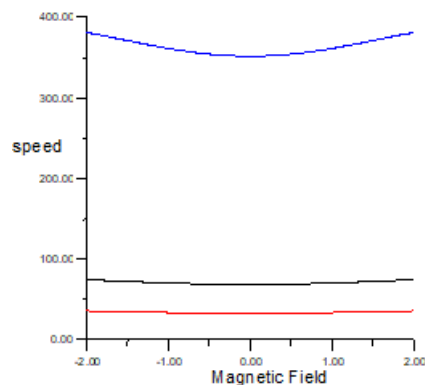


FIGURE 2. Speed plotted against Magnetic Field

Figure 2 Shows that the speed plotted against the Magnetic field for the different values of the two temperature parameter $a^* = 0.1, 0.5, 0.9$. It shows that the speed remains constant for the values of two temperature parameter 0.1 and 0.5. For the value of two temp. parameter 0.9 it slowly decrease and then slowly increase with increase of the Magnetic field.

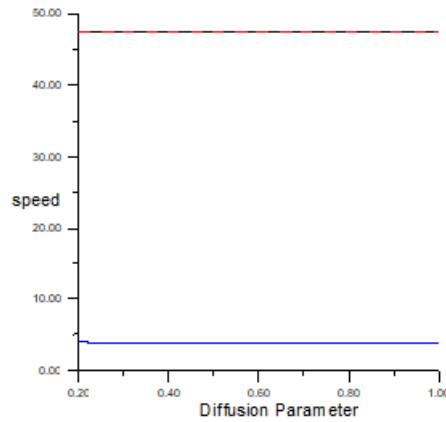


FIGURE 3. Speed Plotted against Diffusion

Figure 3 Shows that the speed is plotted against the Diffusion parameter for the different values of the magnetic field . Speed remains constant for all the values of magnetic field against the diffusion parameter. It shows the comparison for the different values of magnetic field parameter $(-10, 0, 10)$.

7. CONCLUSION

The general surface wave solutions of the governing equations of isotropic initial stress, magnetic field, two-temperature and diffusion thermo-elasticity are obtained. With the help of suitable radiation conditions, the general solutions are reduced to particular solutions in the half-space. The particular solutions satisfy the required boundary conditions at stress free thermally insulated or isothermal surface and we obtain the frequency equation of Rayleigh wave. Some particular cases of the frequency equation are derived. In absence of initial stress, Magnetic field, diffusion and two temperature parameters, the frequency equation reduces to the classical isotropic elastic case. The frequency equation is approximated for numerical purpose and then solved numerically for a particular model of the material. The non-dimensional speed of propagation is plotted against the frequency, Initial stress, Magnetic field, two-temperature and diffusion parameters. The numerical results describe the effects of frequency, initial stress, magnetic field, two-temperature and diffusion on the non-dimensional speed of propagation.

REFERENCES

- [1] L. RAYLEIGH: *Waves propagated along the plane surface of an elastic solid*, Proc. Land. Math. Soc., **17** (1885), 4–11.
- [2] W. H. LORD, Y. SHULMAN: *On a generalized dynamical theory of thermoelasticity*, J. Mech. Phys. Solid, **15** (1967), 299 – 309.
- [3] A. E. GREEN, K. A. LINDSAY : *Thermoelasticity*, J. Elast., **2** (1972), 1 – 7.
- [4] W. NOWASKI: *Problem of thermoelastic diffusion in solid 1,2*, Bull. Acad. Pol. Sci. Ser. Tech., **22** (1974), 129 – 135.
- [5] D. S. CHANDARSEKHARAIHAH, K. R. SRIKANTAIHAH: *Problem of thermoelastic diffusion in solid*, Grelands and Beitrage zur Geophysik, **93** (1984), 133 – 141.
- [6] D. Y. TZOU: *Unified approach for heat conduction from macro to micro-scales*, ASME J. Heat Transfer, **117** (1995), 8 – 16.
- [7] A. M. ABD-ALLA, S. M. AHMED: *Rayleigh wave in an orthotropic thermoelastic medium under gravity and initial stress*, E. M. Planets, **75** (1997), 185 – 197.
- [8] A. M. ABD-ALLA, H. A. H. HAMMAD, S. M. ABO-DAHAB: *Rayleigh waves in a magnetoelastic half-space of orthotropic material under influence of initial stress and gravity field*, App. Math. Comp., **154** (2004), 583 – 597.
- [9] H. SHERIEF, H. A. SALEH: *On the theory of generalized thermoelastic diffusion*, I. J. Eng. Sci., **42** (2004), 591 – 608.
- [10] H. M. YOUSSEF: *On theory of two-temperature generalized thermoelasticity*, IMA J. App. Math., **71** (2006), 383 – 390.
- [11] P. PURI, P. M. JORDAN: *On the propagation of harmonic plane under the two-temperature theory*, I. J. Eng. Sci., **44** (2006), 1113 – 1126.
- [12] E. A. AHMED: *On Rayleigh wave propagation in thermoelastic solid half space using dual-phase-lag model*, I. J. E. Sci., **49** (2011), 781 – 791.
- [13] A. M. ABD-ALLA, S. M. ABO-DAHAB, H. A. H. HAMMAD: *Propagation of Rayleigh waves propagation in generalized magneto-thermoelasticity orthotropic material under initial stress and gravity field*, Appl. Math. Modeling, **35** (2011), 2981 – 3000.
- [14] B. SINGH, S. KUMARI, J. SINGH : *On Rayleigh wave in generalized magneto-thermoelastic media with hydrostatic initial stress*, Bull. Po. Ac. Sci. Tech. Sci., **60** (2012), 349 – 352.
- [15] S. R. MAHMOUD: *An analytical solution for effect of magnetic field and initial stress on an infinite generalized thermoelastic rotating non-homogenous diffusion medium*, Abs. Appl. Analysis, 2013.
- [16] M. MARIN , R. P. AGARWAL, S. R. MAHMOUD: *Modeling a Microstretch Thermoelastic Body with two temperatures*, Abs. App. Analysis, **2013** (2013), 7 pages.
- [17] R. GHATUARY, N. CHAKRABORTY: *Thermomagnetic effect on the Propagation of Rayleigh waves in an isotropic homogeneous elastic half-space under initial stress*, Cogent Eng., **2** (2015), 7 pages.
- [18] S. KUMARI, B. SINGH: *On Propagation of Rayleigh surface wave in two-temperature thermoelastic solid half space with diffusion*, J. Adv. App. Math., **1** (2016), 195 – 202.

- [19] S. KUMARI, B. SINGH, J. SINGH: *Propagation of Rayleigh wave in two-temperature dual phase lag thermoelasticity*, Mech. and Mech. Eng., **21** (2017), 105 – 116.
- [20] I. KAUR, P. LATA : *On Rayleigh wave propagation intranseversely isotropic magneto-thermoelastic medium with three phase-lag heat transfer and diffusion*, I. J. Mech. Material Eng., **1** (2019), 1 – 11.

DEPARTMENT OF MATHEMATICS
UNIVERSITY OF CHANDIGARH
GHARUAN, PUNJAB, INDIA
Email address: uis.18msm1002@gmail.com

DEPARTMENT OF MATHEMATICS
UNIVERSITY OF CHANDIGARH
GHARUAN, PUNJAB, INDIA
Email address: Sangwan.sangeeta@gmail.com

DEPARTMENT OF MATHEMATICS
UNIVERSITY OF CHANDIGARH
GHARUAN, PUNJAB, INDIA
Email address: heena.phdmaths@gmail.com