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New Model for Discussing the Diffusion Phenomena Effect on a Thermoelastic Plate Associated with Three-phase Lag

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Abstract: Here, a new model was used to discuss the effect of a magnetic field on an isotropic, homogeneous, elastic material with generalized thermoelastic diffusion with two-temperature using a new technique. Most researchers in this domain discussed the behavior of the solution depending on two ways: the Laplace method and the normal mode method. Those two methods fail in explaining some of the physical meaning of the problems, especially the behavior of time. On the other hand, the separation of variables method solves the system of equations and gets the analytical solution directly. Copper material is used to discuss the results found in some detail. Comparisons are made in the presence and absence of a magnetic field.

Keywords: Thermoelastic diffusion, Three-phase-lag, Time function, Magnetic Field.

1 Introduction

The attention of most researchers has been drawn to studying the generalized thermo elasticity theories due to their relations with many practical applications. The researches on this topic are now obtainable and we can recall some recent interesting researches in [1-3].

Some problems of thermoelastic diffusion in solid materials are discussed in [4-7]. Problems with one relaxation time under the effect of diffusion were solved in [8-9]. Two- temperature theory was discussed in [10-12].

Magnetic field and initial stress under two-temperature discussed in [13]. A new mathematical model of equations was discussed in [14]. The effect of magnetic field and some fields investigated in [15-16]. Three Phase Lag theory and its stability were discussed in [17-18]. Two-dimensional problems are discussed under the theory of Three Phase Lag under some theories discussed in [19-20].

Most of the researches in this domain investigated the behavior of the physical quantities in two ways. The first way is using the Normal Mode method, which is based on the general form of the solution. The time was supposed to be imaginary, which does not give accurate physical meanings to the problems, see [21-22].

The second way is using Laplace Integral Method to separate the time and then discuss the behavior of the solution. This method has two defaults, one is it fails when the inverse of Laplace transform is difficult. The second fail is not obtaining directly, the function of time, see [23-24].

We adopt a new method in this study to investigate the influence of two-temperature and diffusion on a thermoelastic plate in two dimensions using the Three-Phase-Lag model in the presence and absence of a magnetic field. The general solutions of the physical quantities, under specific boundary conditions of the problem, were found in some detail.

2 Nomenclature

σ_{ij}	Stress tensor components
e_{ij}	Strain tensor components
$e = e_{kk}$	Dilatation cubic
δ_{ij}	Kronecker's delta
u, v	Vectors of displacement
T	Thermodynamic Temperature
T_o	Reference Temperature $\left|(T - T_o)/T_o\right| < 1$
φ	Conductive temperature
P	Chemical potential
C	Distribution of concentration
λ, μ	Lame's constants
ρ	Density

$\gamma=(3\lambda+2\mu)\alpha_t$, α_t – Linear thermal expansion coefficient

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$\beta_1 = (3\lambda + 2\mu)\alpha_c, \alpha_c$ –Diffusion thermal expansion coefficient

C_E Constant strain at Specific heat
K Thermal conductivity coefficient
K^* Material characteristic
τ_v Thermal displacement gradient
τ_q Phase lag of Heat flux
τ_T Phase lag of temperature gradient
a The measure of thermoelastic diffusion effects constant
b_1 The measure of diffusive effects constant
d Constant of thermoelastic diffusion
τ Relaxation time of diffusion
μ_o Magnetic permeability
ε_o Electric permeability
$\dot{u}$ Velocity of particle
$\mathbf{F}_i$ Lorentz force

$$\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}$$

3 Basic equations

Consider the case of a two-temperature isotropic, homogeneous thermoelastic half-space under the influence of diffusion and a magnetic field. As seen in Fig. 1, an initial constant magnetic field $\mathbf{H}=(0,0,H_o)$ causes induced magnetic $\mathbf{h}$ and electric E fields

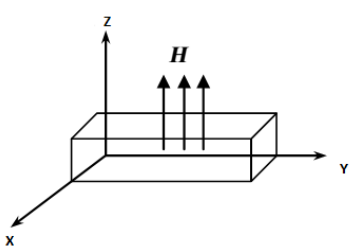

Fig.1 shows the perpendicular direction of magnetic field.
The linearized equations of slowly moving medium are

$$curl\,\mathbf{h} = \mathbf{J} + \varepsilon_o \dot{\mathbf{E}}, \quad (1)$$

$$curl\,\mathbf{E} = -\mu_o \dot{\mathbf{h}}, \quad (2)$$

$$div\,\mathbf{h} = 0, \quad (3)$$

$$\mathbf{E} = -\mu_o(\dot{\mathbf{u}} \times \mathbf{H}). \quad (4)$$

The equations of constitutive relations

$$\sigma_{ij} = 2\mu e_{ij} + \delta_{ij}[\lambda e - \gamma(T - T_o) - \beta_1 C], \quad (5)$$

$$P = -\beta_1 e + b_1 C - a(T - T_o), \quad (6)$$

$$e_{ij} = \frac{1}{2}(u_{i,j} + u_{j,i}). \quad (7)$$

In the absence of body force, the equation of motion is

$$\rho \ddot{u}_i = \sigma_{ij,j} + \mathbf{F}_i, \quad (8)$$

Where,

$$\mathbf{F_i} = \mu_o(\mathbf{J} \times \mathbf{H}). \quad (9)$$

Mass diffusion equation

$$d\beta_1 \nabla^2 e + da\nabla^2 T + \dot{C} + \tau \ddot{C} - db\nabla^2 C = 0. \quad (10)$$

The heat conduction equation

$$K^*\nabla^2\varphi + \tau_v^*\nabla^2\dot{\varphi} + K\tau_t\nabla^2\ddot{\varphi} = (1 + \tau_q\frac{\partial}{\partial t} + \frac{\tau_q^2}{2!}\frac{\partial^2}{\partial t^2})[\rho C_E \ddot{T} + \gamma T_o \ddot{e} + aT_o \ddot{C}], \quad (11)$$

Where,

$$\tau_v^* = (K + K^*\tau_v).$$

The two-temperature equation is as follows:

$$T = (1 - b\nabla^2)\varphi. \quad (12)$$

Notice that the symbols are defined in the nomenclature.

4 Formulation of the problem

In this paper, all quantities are functions of the coordinates x and y and the time variable t, such that

$$\vec{u} = (u, v, 0). \quad (13)$$

The stress functions take the forms

$$\sigma_{xx} = A\frac{\partial u}{\partial x} + \lambda\frac{\partial v}{\partial y} - \gamma T - \beta_1 C, \quad (14)$$

$$\sigma_{yy} = A\frac{\partial v}{\partial y} + \lambda\frac{\partial u}{\partial x} - \gamma T - \beta_1 C, \quad (15)$$

$$\sigma_{xy} = \mu(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}). \quad (16)$$

Then, Eq.(8) can be written as

$$\rho\ddot{u} = A\frac{\partial^2 u}{\partial x^2} + B\frac{\partial^2 v}{\partial x\partial y} + \mu\frac{\partial^2 u}{\partial y^2} - \gamma(1-b\nabla^2)\varphi_{,x}$$
$$-\beta_1 C_{,x} - \mu_o H_o\frac{\partial h}{\partial x} - \mu_o^2\varepsilon_o H_o^2\ddot{u}, \qquad (17)$$

$$\rho\ddot{v} = A\frac{\partial^2 v}{\partial y^2} + B\frac{\partial^2 u}{\partial x\partial y} + \mu\frac{\partial^2 v}{\partial x^2} - \gamma(1-b\nabla^2)\varphi_{,y}$$
$$-\beta_1 C_{,y} - \mu_o H_o\frac{\partial h}{\partial y} - \mu_o^2\varepsilon_o H_o^2\ddot{v}. \qquad (18)$$

Where

$$A = \lambda + 2\mu, and\, B = \lambda + \mu.$$

For aim of numerical evaluation, we introduced some dimensionless quantities

$$(x', y', u', v') = c_1\eta(x, y, u, v),$$
$$\left(t', \tau', \tau_T', \tau_q', \tau_v'\right) = c_1^2\eta\left(t, \tau, \tau_T, \tau_q, \tau_v\right), P' = \frac{P}{\beta_1}$$
$$C' = \frac{\beta_1}{A}C, \sigma_{ij}' = \frac{\sigma_{ij}}{A}, (T', \varphi') = \frac{\gamma}{A}(T, \varphi),$$
$$b' = c_1^2\eta^2 b, h' = \frac{h}{H_o}, \eta = \rho C_E / K \text{ and}$$
$$c_1^2 = A/\rho. \qquad (19)$$

Defining the displacement components in terms of potential functions $q(x, y, t)$ and $\psi(x, y, t)$ are

$$u = q_{,x} - \psi_{,y}, v = q_{,y} + \psi_{,x}. \qquad (20)$$

Eqs. (10), (11), (17), and (18) can be written as using Eqs. (19) and (20). (after suppressing the primes)

$$\nabla^4 q + a_1(1-b\nabla^2)\nabla^2\varphi + a_2\dot{C} + \tau a_2\ddot{C} - a_3\nabla^2 C = 0, \qquad (21)$$

$$a_4\nabla^2\varphi + (1 + a_4\tau_\upsilon)\nabla^2\dot{\varphi} + \tau_T\nabla^2\ddot{\varphi} =$$
$$(1 + \tau_q\frac{\partial}{\partial t} + \frac{1}{2}\tau_q^2\frac{\partial^2}{\partial t^2})\left[(1-b\nabla^2)\ddot{\varphi} + a_5\nabla^2\ddot{q} + a_6\ddot{C}\right], \qquad (22)$$

$$a_7\ddot{q} = a_{12}\nabla^2 q - (1-b\nabla^2)\varphi - C, \qquad (23)$$

$$a_7\ddot{\psi} = a_{10}\nabla^2\psi, \qquad (24)$$

In the same way, we can get the stress functions in the dimensional form

$$\sigma_{xx} = \frac{\lambda}{A}\frac{\partial u}{\partial x} + \lambda\frac{\partial v}{\partial y} - \varphi - C, \qquad (25)$$

$$\sigma_{yy} = \frac{\partial v}{\partial y} + \frac{\lambda}{A}\frac{\partial u}{\partial x} - \varphi - C, \qquad (26)$$

$$\sigma_{xy} = \frac{\mu}{A}(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}). \qquad (27)$$

Finally, the potential function is

$$P = -\nabla^2 q + a_{13}C - a_{14}T. \qquad (28)$$

Where

$$a_1 = \frac{aA}{\beta_1\gamma}, a_2 = \frac{A}{d\beta_1^2\eta}, a_3 = \frac{b_1 A}{\beta_1^2}, a_4 = \frac{K^*}{\rho C_E c_1^2},$$
$$a_5 = \frac{\gamma^2 T_o}{\eta AK}, a_6 = \frac{a\gamma T_o}{\eta\beta_1 K}, a_7 = 1 + \frac{\mu_o^2\varepsilon_o H_o^2}{\rho}, a_8 = \frac{1}{\eta c_1},$$
$$a_9 = \frac{B}{\rho c_1^3\eta}, a_{10} = \frac{\mu}{\rho c_1^3\eta}, a_{11} = \frac{\mu_o H_o^3}{\rho c_1^2}, a_{12} = a_8 + a_{11},$$
$$a_{13} = \frac{b_1 A}{\beta_1^2}, and\, a_{14} = \frac{aA}{\gamma\beta_1}. \qquad (29)$$

5 A New model of solution

Here, the solution of the problem is representing as the sum of two functions, the first in position and the second in time. Then, the physical variables are defined as (20)

$$q(x, y, t) = q_1(x, y) + f(t),$$
$$\varphi(x, y, t) = \varphi_1(x, y) + f(t),$$
$$\psi(x, y, t) = \psi_1(x, y) + f(t), \qquad (30)$$
$$C(x, y, t) = C_1(x, y) + f(t),$$
$$; t \in [0, T], T < 1.$$

Where, the amplitudes of the functions q, φ, ψ, C are $q_1, \varphi_1, \psi_1, C_1$, respectively, and $f(t)$ is function in time that satisfies the following conditions

$$f(0) = T_o, \quad f(\infty) = 0. \qquad (31)$$

Using Eq.(30) on Eqs. (21) - (24) become respectively

$$\nabla^4 q_1 + a_1(1-b\nabla^2)\nabla^2\varphi_1 - a_3\nabla^2 C_1 + a_2(\dot{f} + \tau\ddot{f}) = 0, \qquad (32)$$

$$a_4\nabla^2\varphi_1 = (1 + \tau_q\frac{\partial}{\partial t} + \frac{1}{2}\tau_q^2\frac{\partial^2}{\partial t^2})(\ddot{f} + a_6\ddot{f}), \qquad (33)$$

$$a_7\ddot{f} = a_{12}\nabla^2 q_1 - \varphi_1 + b\nabla^2\varphi_1 - C_1 - 2f, \qquad (34)$$

$$a_7\ddot{f}=a_{10}\nabla^2\psi_1. \tag{35}$$

6 A suitable time function

In this section, we are discussing the different forms of time functions, and then choosing a suitable function that satisfies the conditions.

The first formula of time can be obtained from (32), and under condition (31), we have

$$f=T_o e^{\frac{t}{\tau}}. \tag{36}$$

This formula fails at $t\to\infty$, where it gives $f(\infty)=\infty$

II - The second formula of time is obtaining from (33), under (31),

$$f(t)=T_O e^{\frac{-t}{\tau_q}}\cos(\frac{t}{\tau_q}). \tag{37}$$

III- The third formula, after using (34) and (31) takes the form

$$f(t)=T_o\cos(\sqrt{\frac{2}{a_7}}t) \tag{38}$$

This function is finite as $t\to\infty$.
IV- The fourth formula, from (35) and (31) is

$$f=T_o, \tag{39}$$

This formula gives constant values of heat function $f(t)$ for all times.
From Eqs. (36-39), we will consider the second formula of time , as it is general form of the other forms.
Here, the general form of time function depends on the value of the primary temperature and the type of constants of the properties of the material. For this purpose, we choose the cooper material for numerical computations.
Now, we are seeking to get the solution of the coordinate functions.

7 The functions of position

After finding analytically the time function, we are going to discuss the functions of position.
From Eqs. (32)- (35), we get the following

$$\nabla^4 q_1-a_3\nabla^2 C_1=0, \tag{40}$$

$$\nabla^2\varphi_1=0, \tag{41}$$

$$a_{12}\nabla^2 q_1-\varphi_1-C_1=0, \tag{42}$$

$$\nabla^2\psi_1=0. \tag{43}$$

Taking in mind that all functions are considered equal zero at $(x,y)=(0,0)$, and

$$\frac{\partial\varphi^*}{\partial y}=0,\sigma^*{}_{xx}=f_1,\ \frac{\partial C^*}{\partial y}=f_2,\ \sigma^*{}_{xy}=0 \tag{44}$$
$$at\ (x,y)=(0,0),\varphi^*=0\quad at\ (x,y)=(0,L).$$

Where $f_1, and\ f_2$ is a function in y.
Using the basic information of partial differential equation of separating the variables, we have the following results.
The temperature function is

$$\varphi(x,y;t)=\sum_{n=0}^{\infty}B_n\sin(s_n y)e^{-s_n x}+T_o e^{\frac{-t}{\tau_q}}\cos(\frac{t}{\tau_q}). \tag{45}$$

And, the displacement functions are

$$u(x,y;t)=\sum_{n=0}^{\infty}[(\frac{B_n+F_n}{2a_{12}}y-D_n s_n)\cos(s_n y)-s_n I_n\sin(s_n y)]e^{-s_n x}$$
$$+T_O e^{\frac{-t}{\tau_q}}\cos(\frac{t}{\tau_q}), \tag{46}$$

And,

$$v(x,y;t)=\sum_{n=0}^{\infty}\begin{matrix}[(\frac{B_n+F_n}{2a_{12}}y-D_n s_n)\sin(s_n y)\\ +(I_n s_n-\frac{B_n+F_n}{2s_n a_{12}})\cos(s_n y)]e^{-s_n x}\end{matrix}$$
$$+T_o e^{\frac{-t}{\tau_q}}\cos(\frac{t}{\tau_q}). \tag{47}$$

After using the famous relations between the displacement functions and the stress components, one can obtain

$$\sigma_{xx}(x,y;t)=\sum_{n=0}^{\infty}\{(\frac{2s_n{}^2 I_n\mu}{A_\mu}+\frac{(B+F)\lambda}{a_{12}A_\mu}-B_n-F_n)(1-a_2+a_1)\sin(s_n y)$$
$$-\frac{2\mu}{A_\mu}[s_n y(\frac{B_n+F_n}{2a_{12}})-D_n s_n{}^2]\cos(s_n y)\}e^{-s_n x} \tag{48}$$
$$+T_o e^{\frac{-t}{\tau_q}}\cos(\frac{t}{\tau_q}),$$

$$\sigma_{yy}(x,y;t)=\sum_{n=0}^{\infty}\{(\frac{-2\mu s_n{}^2 I_n}{A_\mu}+\frac{B+F}{a_{12}}-B_n-F_n)\sin(s_n y)$$
$$-\frac{2\mu s}{A_\mu}[(\frac{B_n+F_n}{2a_{12}})y-D_n s_n]\cos(s_n y)\}e^{-s_n x}+T_o e^{\frac{-t}{\tau_q}}\cos(\frac{t}{\tau_q}),$$

(49)

And,

$$\sigma_{xy}(x,y;t)=\sum_{n=0}^{\infty}\frac{\mu}{A_\mu}[(\frac{B_n+F_n}{a_{12}}-2s_n{}^2I_n)\cos(s_n y)$$

$$-s_n(\frac{B_n+F_n}{a_{12}}y-2Ds)\sin(s_n y)]e^{-s_n x}+T_o e^{\frac{-t}{\tau_q}}\cos(\frac{t}{\tau_q}).$$

(50)

Finally, the potential function is

$$P(x,y;t)=\sum_{n=1}^{\infty}[a_{13}F_n-a_{14}B_n-\frac{B_n+F_n}{a_{12}}]\sin(s_n y)]e^{-s_n x}$$

$$+T_o e^{\frac{-t}{\tau_q}}\cos(\frac{t}{\tau_q}). \quad (51)$$

Where

$$s_n=\frac{n\pi}{L},\; D_n=\frac{f_1 A_\mu}{2\mu s_n^2}, B_n=\frac{f_3}{s_n},\; F_n=\frac{f_2}{s_n},$$

$$I_n=\frac{B_n+F_n}{2s_n{}^2a_{12}}, n=0,1,2,3,\dots .$$

8 Special case

If we consider $C=a=b_1=\beta_1=0$, we have the case of absence of diffusion, which means neglecting the effect of diffusion.

Then, the temperature function is

$$\varphi(x,y;t)=\sum_{n=0}^{\infty}B_{1n}\sin(h_n y)e^{-h_n x}+T_o e^{\frac{-t}{\tau_q}}\cos(\frac{t}{\tau_q}). \quad (52)$$

The displacement functions are

$$u(x,y;t)=\sum_{n=0}^{\infty}[(\frac{yB_{1n}}{2a_{12}}-D_{1n}h_n)\cos(h_n y)-h_n I_{1n}\sin(h_n y)]e^{-h_n x}$$

$$+T_o e^{\frac{-t}{\tau_q}}\cos(\frac{t}{\tau_q}), \quad (53)$$

And,

$$v(x,y;t)=\sum_{n=0}^{\infty}\begin{matrix}[(\frac{yB_{1n}}{2a_{12}}-D_{1n}h_n)\sin(h_n y)\\ +(I_{1n}h_n-\frac{B_{1n}}{2h_n a_{12}})\cos(h_n y)]e^{-h_n x}\end{matrix}$$

$$+T_o e^{\frac{-t}{\tau_q}}\cos(\frac{t}{\tau_q}).$$

(54)

The stress functions are

$$\sigma_{xx}(x,y;t)=\sum_{n=0}^{\infty}[2\mu D_{1n}h_n{}^2-\frac{\mu y B_{1n}h_n}{2a_{12}A_\mu}]\cos(h_n y)$$

$$+[\frac{2\mu h_n{}^2 I_{1n}}{A_\mu}+\frac{B_{1n}\lambda}{a_{12}A_\mu}-B_{1n}]\sin(h_n y)]e^{-h_n x}+T_o e^{\frac{-t}{\tau_q}}\cos(\frac{t}{\tau_q}), \quad (55)$$

$$\sigma_{yy}(x,y;t)=\sum_{n=0}^{\infty}\{\frac{2\mu h_n}{A_\mu}[\frac{yB_{1n}}{2a_{12}}-D_{1n}h_n]\cos(h_n y)$$

$$+[\frac{B_{1n}}{a_{12}}-\frac{2\mu h_n{}^2 I_{1n}}{A_\mu}-B_{1n}]\sin(h_n y)\}e^{-h_n x}+T_o e^{\frac{-t}{\tau_q}}\cos(\frac{t}{\tau_q}), \quad (56)$$

And,

$$\sigma_{xy}(x,y;t)=\sum_{n=0}^{\infty}\{\frac{2\mu}{A_\mu}[(\frac{B_{1n}}{2a_{12}}-I_{1n}h_n{}^2)\cos(h_n y)$$

$$-h(\frac{yB_{1n}}{2a_{12}}+h_n D_{1n})\sin(h_n y)]\}e^{-h_n x}+T_o e^{\frac{-t}{\tau_q}}\cos(\frac{t}{\tau_q}). \quad (57)$$

Where,

$$h_n=\frac{n\pi}{L}, B_{1n}=\frac{f_3}{h_n}, D_{1n}=\frac{f_1}{2\mu h_n^2}, I_{1n}=\frac{B_{1n}}{2h_n{}^2a_{12}}, n=0,1,2,\dots$$

9 Numerical results

To explain the problem graphically, we will use copper material as an example for the thermoelastic material, which have the following values of physical constants.

$T_o=293\,K,\,,\lambda=7.76\times10^{10}\,kg/(m.s^2)$
$,\alpha_t=1.78\times10^{-5}\,K^{-1}, C_E=383.1\,J/(kg.K)$
$,\mu=3.86\times10^{10}\,kg/(m.s^2), \rho=8954\,kg/m^3$
$,\alpha_c=1.98\times10^{-4}\,m^3/kg, K=300\,W$
$,a=1.2\times10^4\,m^2/(s^2.K)\,, y=0.6, \tau=0.01,$
$,b_1=0.9\times10^6\,m^5/(kg.s^2),\; d=0.85\times10^{-8}\,(kg.s)/m^3$
$K^*=2.97\times10^{13}, f_1=0.1, f_2=0.2, f_3=0.5,\; \tau_q=0.08,$
$\varepsilon_0=36\Pi\times10^{-9}, H_o=1000, \mu_o=4\Pi\times10^{-7}.$

The numerical calculations were used to show the behavior of u, σ_{xx}, σ_{xy}, φ, and C on the vertical axis with x at $y=0.5$, in presence and absence of magnetic field.

Fig. 1 depicts the distribution of displacement components u against x in the presence and absence of a magnetic field. The displacement function has a greater value in the presence of a magnetic field than in the absence of one. The two curves begin with negative values and gradually climb until they attain stability. The stress distribution function σ_{xx} against x in the presence of a magnetic field is depicted in Fig. 2. The two curves begin with a positive value and gradually decrease until they reach a point of stability at zero. The fluctuation of the stress function σ_{xy} against x in the presence and absence of a magnetic field is depicted in Fig. 3. The two curves begin with a negative value and gradually increase until they attain stability. The distribution of the temperature function φ and the concentration function C in presence and absence of magnetic field are shown in Figs. 4 and 5. In the two figures, the two cases are implacable on their others. The curves start from positive value decreasing till reaching zero. Fig. 6 shows the distribution of the potential function P against x. The curves start from negative value and then began to increase until they decay to zero.

10 Conclusion and Discussion

From previous work, we can deduce the following

1. Isotropic, homogenous, thermoelastic body discussed under the effect of diffusion, magnetic field and two- temperature.
2. Separation of variables is used to get the physical quantities.
3. The displacement was separated from the time, to explain the physical meanings of the problem.
4. Cooper is used to get the numerical values of the quantities we get.
5. The behavior of temperature function were discussed at certain values using programming.
6. The behavior of temperature and diffusion weren't affected by the influence of magnetic field.
7. The physical quantities tends to infinity when the $H_o > 10^3$, which means that it vanish.
8. Results discussed numerically and graphically using Matlab program in presence and absence of magnetic field.

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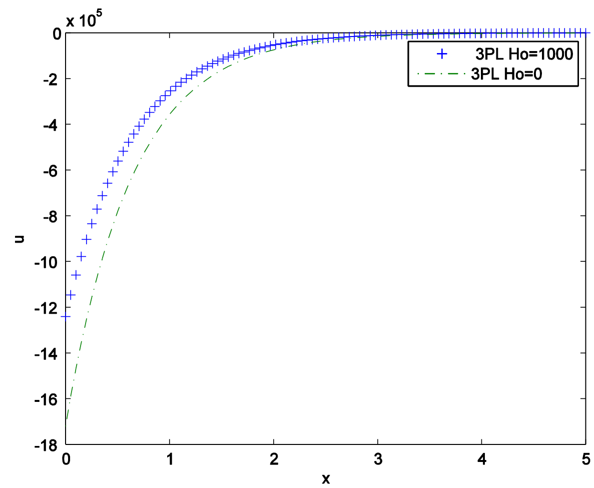

Fig. 1 The displacement distribution u in presence and absence of magnetic field.

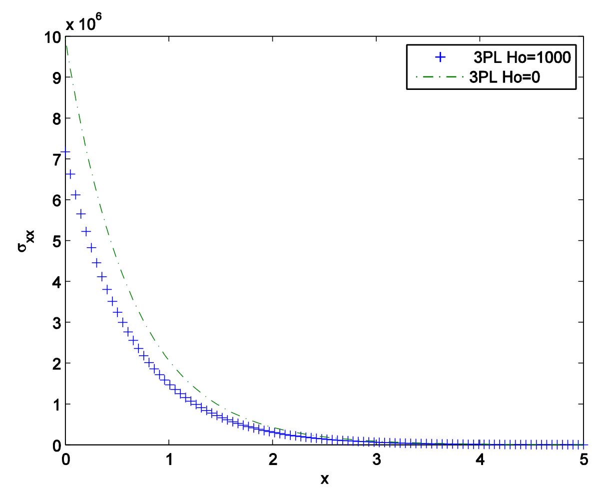

Fig. 2 The stress distribution σ_{xx} in presence and absence of magnetic field.

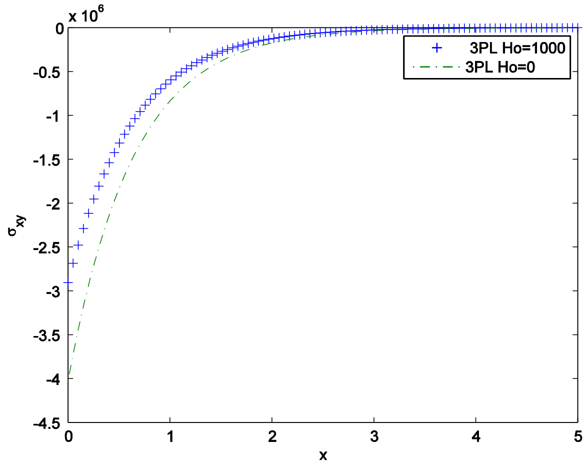

Fig. 3 The stress distribution σ_{xy} in presence and absence of magnetic field.

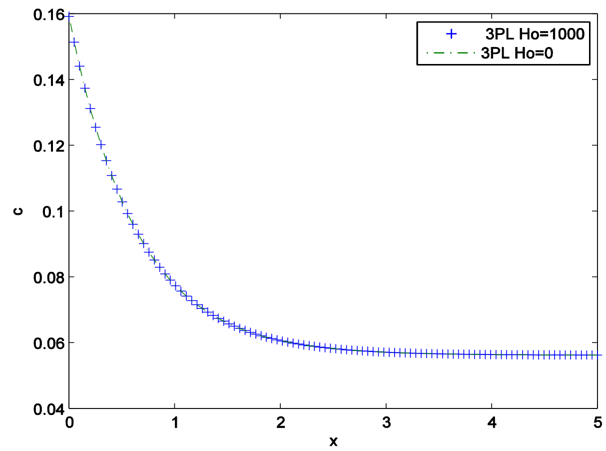

Fig. 5 The concentration distribution C in presence and absence of magnetic field.

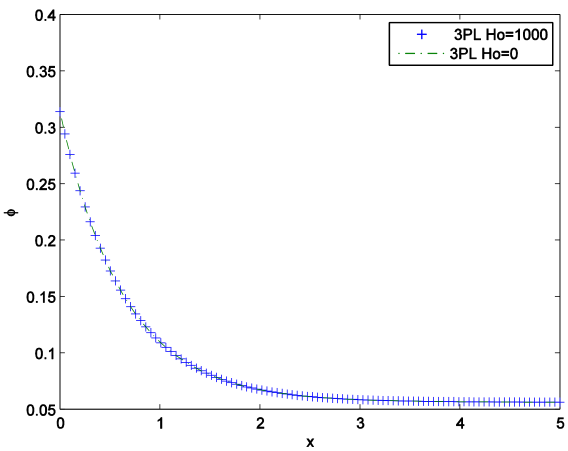

Fig. 4 The temperature distribution φ in presence and absence of magnetic field.

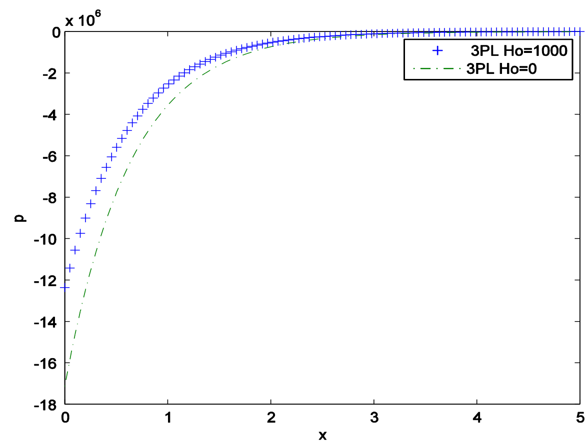

Fig. 6 The potential distribution P in presence and absence of magnetic field.