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Influence of Electromagnetic Generalized Thermoelasticity Interactions with Nonlocal Effects under Temperature-Dependent Properties in a Solid Cylinder

S. E. Khader [a*], A. A. Marrouf [a], M. Khedr [b]

[a] *Mathematical and Theoretical Physics Department, Egyptian Atomic Energy Authority, EGYPT*
[b] *Physics Department, Alexandria University Faculty of Science, EGYPT*

KEYWORDS

Electromagnetic theory;
Generalized thermoelasticity;
Nonlocal thermoelasticity;
Solid cylinder;
Temperature-dependent properties.

ABSTRACT

The temperature-dependent properties and the effect of non-local elasticity in the presence of a magnetic field have been studied in an infinitely long solid conductive circular cylinder. The issue arises in the setting of two relaxation times in extended magneto-thermoelasticity theory. In the presence of a uniform magnetic field in the direction of the axis, the lateral surface is traction-free and subjected to known temperatures. Techniques are employed to determine the answer in the Laplace transform domain. A numerical method based on Fourier series expansions is used to carry out the inversion operation. In addition, graphs depict comparisons to highlight the influence of various elements such as the difference in times and the effect of the non-local coefficient and Empirical material constant.

1. Introduction

The theory of thermoelasticity deals with the effect of thermal and mechanical disturbances on an elastic body. Earlier interest in it resulted in a large number of theoretical and experimental research works. Thermoelasticity is important because it has numerous applications in domains including aviation, nuclear reactors, modern propulsion system technology, plasma physics, and geophysics. Green and Lindsay [1] introduced the theory of generalized thermoelasticity, which is often referred to as the theory of generalized thermoelasticity with two relaxation times. The fundamental considerations of that theory have been the subject of numerous works. For example, Hany [2] has solved a model consisting of a half-space governed by thermoelastic equations with two relaxation times. The action at the ambient level is carried out by a combination of thermal and mechanical shocks that act for a limited time. Khader et al. [3] applied Green and Lindsay's theory to a model of transient heat response in infinitely long annular cylinder surfaces with an internal heat source. Surendra and Elsibai [4] applied the two different theories of generalized thermal elasticity to a spherical cavity, and their results were compared with the classical dynamic-coupled theory. The interaction of magnetic fields and pressure in a hot solid material is gaining popularity due to its numerous applications in geophysics, plasma physics, and other domains. Extremely high temperatures and temperature gradients, as well as magnetic fields occurring within nuclear reactors, have an impact on their design and operation in the nuclear field [5]. The heat equation under discussion is usually the uncoupled or coupled equation, not the generalized one, in these investigations. In some cases, where the answers determined using either of these equations deviate slightly quantitatively, this attitude is valid. When considering short-time impacts, however, the whole, generalized system of equations must be used; otherwise, a significant amount of accuracy would be lost. Among the authors who considered the generalized magneto-thermoelastic equations are Sherief [6-9]. Ezzat

* Corresponding author. Tel.: +2-01023804791
E-mail address: shabolaaaa@yahoo.com

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and others [10-14] have studied thermoelastic Bodies and viscoelastic materials with fractional. He [15] studied the generalized electromagnetic-thermoelastic problem for an infinitely long solid cylinder. Abd-Alla et al. [16] have discussed the Rayleigh surface wave propagation in an orthotropic rotating magneto-thermoelastic medium under the effect of gravity and initial stress. Othman and others [17-21] have presented many papers in which they studied Lord-Shulman theory, generalized thermoelasticity plane waves with two relaxation times, and temperature-dependent properties. Many authors contributed to this subject [22-37]. As is widely known, the physical properties of engineering materials vary significantly with temperature. Because the modulus of elasticity drops dramatically with temperature, the material's ability to elastically resist thermal loads declines. As a result, plastic deformation occurs at far lower thermal stresses than systems with constant physical properties imply. Araki [38] studied a thermal stress analysis of a thermos-viscoelastic hollow cylinder with temperature-dependent properties. Abbas [39] discussed the eigenvalue approach method in three-dimensional generalized thermoelastic with temperature-dependent material properties. Abouelregal [40] solved the boundary value problem of a one-dimensional semi-infinite piezoelectric medium. In several papers [41-56] the temperature-dependent properties of materials have been studied as the non-local theory of elasticity. In this work, the temperature-dependent properties and the effect of non-local elasticity in the presence of a magnetic field have been studied numerically in an infinitely long solid conductive circular cylinder.

2. Governing Equations and Mathematical Model

Let (r, φ, z) be cylindrical polar coordinates with the z-axis coinciding with the axis of a solid; infinitely long, elastic circular cylinder of a homogenous, isotropic material of radius r, $0 \le r \le a$, $-\infty \le z \le \infty$. The cylinder is placed in a magnetic field, as shown in Figure 1. Due to Maxwell's equations, electrodynamics equations are linearly simplified for a perfectly homogeneous, conducting elastic solid

$$\text{curl}\,\mathbf{h} = \mathbf{J} + \varepsilon_0 \frac{\partial \mathbf{E}}{\partial t}, \text{curl}\,\mathbf{E} = -\mu_0 \frac{\partial \mathbf{h}}{\partial t},$$
$$\text{div}\,\mathbf{B} = 0,\ \text{div}\,\mathbf{D} = 0, \tag{1}$$
$$\mathbf{B} = \mu_0\left(\mathbf{H}_0 + \mathbf{h}\right), \mathbf{D} = \varepsilon_0\,\mathbf{E}$$

Ohm's law for moving media

$$\mathbf{J} = \sigma_0\left(\mathbf{E} + \mu_0 \frac{\partial \mathbf{u}}{\partial t} \times \mathbf{H}_0\right) \tag{2}$$

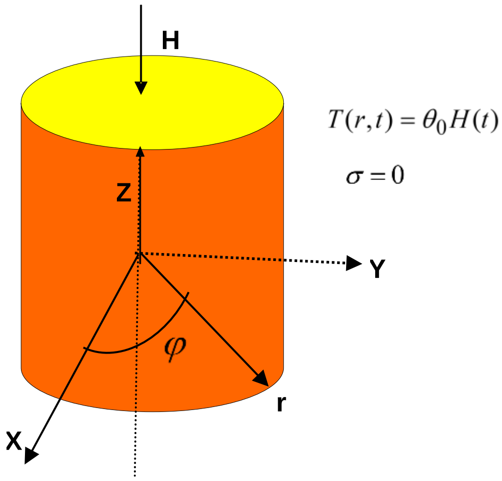

Fig. 1. An infinitely long solid cylinder

From (1) and (2), we obtain:

$$\frac{\partial h}{\partial r} = -\left[J + \varepsilon_0 \frac{\partial E}{\partial t}\right] \tag{3}$$

$$\frac{1}{r}\frac{\partial}{\partial r}(rE) = -\mu_0 \frac{\partial h}{\partial t} \tag{4}$$

$$J = \sigma_o\left(E - \mu_0 H_0 \frac{\partial u}{\partial t}\right) \tag{5}$$

from equations (3) and (5), we get

$$\frac{\partial h}{\partial r} = \sigma_0 \mu_0 H_0 \frac{\partial u}{\partial t} - \left(\sigma_0 E + \varepsilon_0 \frac{\partial E}{\partial t}\right) \tag{6}$$

from equations (4) and (6), we obtain

$$\left[\nabla^2 - \sigma_0\mu_0 \frac{\partial}{\partial t} - \mu_0\varepsilon_0 \frac{\partial^2}{\partial t^2}\right] h = \sigma_0\mu_0 H_0 \frac{\partial e}{\partial t} \tag{7}$$

The strain components

$$e_{rr} = \frac{\partial u}{\partial r},\ e_{\phi\phi} = \frac{u}{r},\ e_{zz} = e_{rz} = e_{z\phi} = e_{r\phi} = 0 \tag{8}$$

The cubic dilatation e is given by

$$e = \frac{\partial u}{\partial r} + \frac{u}{r} = \frac{1}{r}\frac{\partial (ru)}{\partial r} \tag{9}$$

The stress tensor σij's are given by

$$\sigma_{rr} = 2\mu \frac{\partial u}{\partial r} + \lambda e - \gamma\left(T - T_0 + \tau_1 \frac{\partial T}{\partial t}\right) \tag{10}$$

$$\sigma_{\phi\phi} = 2\mu \frac{u}{r} + \lambda e - \gamma\left(T - T_0 + \tau_1 \frac{\partial T}{\partial t}\right) \tag{11}$$

$$\sigma_{zz} = \lambda e - \gamma\left(T - T_0 + \tau_1 \frac{\partial T}{\partial t}\right) \tag{12}$$

$$\sigma_{r\phi} = \sigma_{rz} = \sigma_{\phi z} = 0 \tag{13}$$

The equations of motion and equation of heat conduction [53]

$$\sigma_{ij} + F_i = \rho\left(1 - \varepsilon^2 \nabla^2\right) \frac{\partial^2 u_i}{\partial t^2} \tag{14}$$

$$\mathbf{F} = \mathbf{J} \times \mathbf{B} \tag{15}$$

$$k \nabla^2 T = \rho c_E \left(\frac{\partial}{\partial t} + \tau_2 \frac{\partial^2}{\partial t^2}\right) T + \gamma T_0 \frac{\partial e}{\partial t} \tag{16}$$

$$\nabla^2 = \frac{1}{r}\frac{\partial}{\partial r}\left[r \frac{\partial}{\partial r}\right]$$

By applying the initial and boundary conditions, we can solve the problem.

$$u(r,t) = \frac{\partial u(r,t)}{\partial t} = \frac{\partial^2 u(r,t)}{\partial t^2} = E(r,0) = \frac{\partial E(r,t)}{\partial t} = h(r,0) = \frac{\partial h(r,t)}{\partial t} = T(r,t) = \frac{\partial T(r,0)}{\partial t} = \frac{\partial^2 T(r,0)}{\partial t^2} = 0 \ at \ t = 0 \tag{17}$$

The induced magnetic and electric fields are continues.

$$h(r,t) = h^0(r,t), \quad E(r,t) = E^0(r,t), \ \text{at } r = a \ , t > 0 \tag{18}$$

Traction-free and thermal shock,

$$\sigma_{rr}(r,t) = 0 \ , \quad T(r,t) = \theta_0 H(t) \ , \quad \text{at } r = a \tag{19}$$

from equations (4) and (18), substituting Fr into equation (14), we get

$$(\lambda + 2\mu)\nabla^2 e + \left[\mu_0^2 \varepsilon_0 H_0 \frac{\partial^2}{\partial t^2} - \mu_0 H_0 \nabla^2\right] h - \gamma\nabla^2\left(1 + \tau_1 \frac{\partial}{\partial t}\right) T = \rho\left(1 - \varepsilon^2 \nabla^2\right)\frac{\partial^2 e}{\partial t^2} \tag{20}$$

to discuss the effect of the temperature-dependent material on the considered physical fields of the problem, following [39], we assume that

$$(\lambda, \mu, k) = \left(\lambda^*, \mu^*, k^*\right) f(T_0)$$

$$f(T_0) = 1 - \alpha^* T_0$$

temperature-independent properties, when we are put $f(T_0) = 1$

3. Solution of the Problem

Let us introduce the non-dimension variables [20]

$$\left(r^*, u^*\right) = c_0 \eta \ (r, u) \ , \left(t^*, \tau_i^*\right) = c_0^2 \eta \ \ (t, \tau_i) \ ,$$

$$\mathrm{E}^* = \frac{\eta}{\sigma_0 {\mu_0}^2 H_0 c_0} E, \ \ \mathrm{h}^* = \frac{\eta}{\sigma_0 \mu_0 H_0} h, \ \ {\sigma^*}_{\mathrm{ij}} = \frac{\sigma_{ij}}{\mu},$$

$$\theta = \frac{\gamma(\mathrm{T} - \mathrm{T}_0)}{(\lambda + 2\mu)}, \quad \eta = \frac{\rho c_E}{k} \quad , \quad c_0^2 = \frac{\lambda + 2\mu}{\rho}$$

The equations (4), (7), (10), (16), and (20), can be written in the non-dimensional form,

$$\frac{1}{r}\frac{\partial}{\partial r}(rE) = -\frac{\partial h}{\partial t} \tag{21}$$

$$\left[\nabla^2 - \upsilon \frac{\partial}{\partial t} - V^2 \frac{\partial^2}{\partial t^2}\right] h = \frac{\partial e}{\partial t} \tag{22}$$

$$\sigma_{rr} = \alpha_0 \left[2 \frac{\partial u}{\partial r} + (\beta^2 - 2) e - \beta^2 \theta\right] \tag{23}$$

$$\nabla^2 \theta = \alpha_0 \left(1 + \tau_2 \frac{\partial}{\partial t}\right) \frac{\partial \theta}{\partial t} + \varepsilon_1 \frac{\partial e}{\partial t} \tag{24}$$

$$\nabla^2 e - \varepsilon_2 \upsilon \left[\nabla^2 - V^2 \frac{\partial^2}{\partial t^2}\right] h - \left(1 + \tau_1 \frac{\partial}{\partial t}\right) \nabla^2 \theta = \alpha_0 \left(1 - \varepsilon^2 \nabla^2\right) \frac{\partial^2 e}{\partial t^2} \tag{25}$$

where

$$\upsilon = \frac{\sigma_0 \mu_0}{\eta}, \varepsilon_1 = \frac{T_0 \gamma^2}{c_E \rho^2 c_0^2}, \varepsilon_2 = \frac{\alpha_0 \mu_0 H_0^2}{\lambda + 2\mu}, V = \frac{c_0}{c},$$

$$c^2 = \frac{1}{\varepsilon_0 \mu_0}, \beta^2 = \frac{\lambda + 2\mu}{\mu}, \alpha_0 = \frac{1}{1 - \alpha^* T_0}$$

Applying the Laplace transform with parameter s to both sides of equations (21)-(25), we obtain

$$\frac{1}{r}\frac{\partial}{\partial r}(r\bar{E}) = -s\bar{h} \tag{26}$$

$$\left[\nabla^2 - \upsilon s - V^2 s^2\right] \bar{h} = s\bar{e} \tag{27}$$

$$\bar{\sigma}_{rr} = \alpha_0 \left[2 \frac{\partial \bar{u}}{\partial r} + (\beta^2 - 2)\bar{e} - \beta^2 \bar{\theta}\right] \tag{28}$$

$$\nabla^2 \bar{e} - \varepsilon_2 \upsilon \left[\nabla^2 - V^2 s^2\right] \bar{h} - (1 + \tau_1 s) \nabla^2 \bar{\theta} = \alpha_0 \left(1 - \varepsilon \nabla^2\right) s^2 \bar{e} \tag{29}$$

$$\nabla^2 \bar{\theta} = \alpha_0 \left(s + \tau_0 s^2\right) \bar{\theta} + \varepsilon_1 s \bar{e} \tag{30}$$

Eliminating $\bar{\theta}, \bar{\mathrm{h}}$ from equations (27), (29), and (30), we get

$$(\nabla^6 - m_1 \nabla^4 + m_2 \nabla^2 - m_3)\bar{e} = 0 \tag{31}$$

where

$$m_1 = \frac{s\left[\left(\alpha_0 s+\upsilon\varepsilon_2\right)+\left(1+\varepsilon\alpha_0 s^2\right)\left(\upsilon+sV^2\right)+\alpha_0\left(1+\tau_2 s\right)\left(1+\varepsilon\alpha_0 s^2\right)+\varepsilon_1\left(1+\tau_1 s\right)\right]}{\left(1+\varepsilon\alpha_0 s^2\right)}$$

$$m_2 = \frac{s^2}{\left(1+\varepsilon\alpha_0 s^2\right)}\Big\{\left(\upsilon+V^2 s\right)\left[\alpha_0 s+\alpha_0\left(1+\tau_2 s\right)\left(1+\varepsilon\alpha_0 s^2\right)+\varepsilon_1\left(1+\tau_1 s\right)\right] + s\alpha_0\left(1+\tau_2 s\right)+\upsilon\varepsilon_2\left[sV^2+\alpha_0\left(1+\tau_2 s\right)\right]\Big\}$$

$\bar{h}$ and $\bar{\theta}$ satisfy the equations,

$$(\nabla^6 - m_1\nabla^4 + m_2\nabla^2 - m_3)\bar{h} = 0 \tag{32}$$

$$(\nabla^6 - m_1\nabla^4 + m_2\nabla^2 - m_3)\bar{\theta} = 0 \tag{33}$$

The solutions of equations (31)-(33), have the forms

$$\bar{e} = \sum_{i=1}^{3} A_i I_0(k_i r) \tag{34}$$

$$\bar{\theta} = \sum_{i=1}^{3} \frac{\varepsilon_1 s}{k_i^2 - \alpha_0(s+\tau_2 s^2)} A_i I_0(k_i r) \tag{35}$$

$$\bar{h} = \sum_{i=1}^{3} \frac{s}{k_i^2 - s\left(\upsilon + sV^2\right)} A_i I_0(k_i r) \tag{36}$$

where, I_0 is the modified Bessel function of the first kind of order zero, and k_1^2, k_2^2 *and* k_3^2 are the roots of the characteristic equation:

$$k^6 - m_1 k^4 + m_2 k^2 - m_3 = 0 \tag{37}$$

from equations (26) and (36), we obtain

$$\bar{E} = \sum_{i=1}^{3} \frac{-s^2}{k_i\left[k_i^2 - s\left(\upsilon + sV^2\right)\right]} A_i I_1(k_i r) \tag{38}$$

The displacement, $\bar{u}$, can be found in equations (9) and (34)

$$\bar{u} = \sum_{i=1}^{3} \frac{A_i}{k_i} I_1(k_i r) \tag{39}$$

from equations (34), (35), (39), and 28), we obtain

$$\bar{\sigma}_{rr} = \alpha_0 \sum_{i=1}^{3} A_i \left\{\beta^2\left(1 - \frac{\varepsilon_1 s(1+\tau_1 s)}{k_i^2 - \alpha_0 s(1+\tau_2 s)}\right) I_0(k_i r) - \frac{2}{k_i r} I_1(k_i r)\right\} \tag{40}$$

in the free space, around the cylinder, the induced fields E0 and h0 satisfy the following equations,

$$s\bar{h}^0 = -\frac{1}{r}\frac{\partial}{\partial r}(r\bar{E}^0) \tag{41}$$

$$V^2 s\bar{E}^0 = -\frac{\partial \bar{h}^0}{\partial r} \tag{42}$$

From equations (41) and (42) by eliminating $\bar{E}^0$, we get

$$\left(\nabla^2 - V^2 s\right)^2 \bar{h}^0 = 0 \tag{43}$$

The solution of equation (43) is given by

$$\bar{h}^0 = A_4(s) K_0(sVr) \tag{44}$$

where K_0 is a modified Bessel function of the second kind of order zero, and $A_4(s)$ is some parameter depending on s only.
from equation (44) and equation (42), we obtain

$$\bar{E}^0 = \frac{A_4(s)}{V} k_1(sVr) \tag{45}$$

The boundary conditions after taking the Laplace transform of both sides, we obtain

$$\bar{h} = \bar{h}^0,\ \bar{E} = \bar{E}^0,\ \bar{\sigma}_{rr}(a,s) = 0, \quad \bar{\theta}(a,s) = \frac{\theta_0}{s}, \quad \text{at } r = a \tag{46}$$

by using equations (46), we can obtain the systems of linear equations for the unknown parameters A_1, A_2, A_3 and A_4

$$\sum_{i=1}^{3} \frac{\varepsilon_1 s}{k_i^2 - \alpha_0 s(1+\tau_2 s)} A_i I_0(k_i a) = \frac{\theta_0}{s} \tag{47}$$

$$\sum_{i=1}^{3} A_i \left\{\beta^2\left(1 - \frac{\varepsilon_1 s(1+\tau_1 s)}{k_i^2 - \alpha_0 s(1+\tau_2 s)}\right) I_0(k_i a) - \frac{2}{k_i a} I_1(k_i a)\right\} = 0 \tag{48}$$

$$\sum_{i=1}^{3} \frac{s}{k_i^2 - s\left(\upsilon + sV^2\right)} A_i I_0(k_i a) = A_4 k_0(sVa) \tag{49}$$

$$\sum_{i=1}^{3} \frac{-s^2}{k_i\left[k_i^2 - s\left(\upsilon + sV^2\right)\right]} A_i I_1(k_i a) = \frac{A_4}{V} k_1(sVa) \tag{50}$$

4. Numerical results

To get the inverse of Laplace transforms, we use the method proposed in [57]. A numerical analysis is performed to study the effects of nonlocal and temperature-dependent properties. For the purpose of illustration, the material properties are listed as [6], [39].

$$\lambda^* = 7.76(10)^{10}, \mu^* = 3.8(10)^{10}, \rho = 8954, T_0 = 293, k^* = 386,$$
$$\alpha_t = 1.78\times10^{-5}, C_E = 381, C_E = 381, \varepsilon_1 = 0.0168, \eta = 8886.73,$$
$$V = 1.39\times10^{-5}, \upsilon = 0.008, \varepsilon_0 = 10^{-9}/36\pi, \sigma_0 = 5.7\times10^{7},$$
$$\mu_0 = 4\pi\times10^{-7}, \tau_1 = 0.01, \tau_2 = 0.02$$

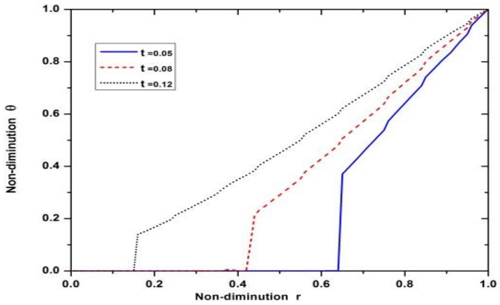

Fig. 2. Temperature distribution

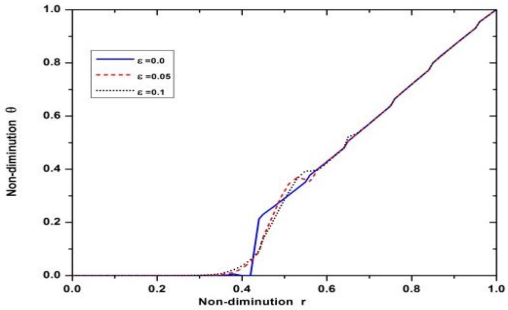

Fig. 7. Temperature distribution

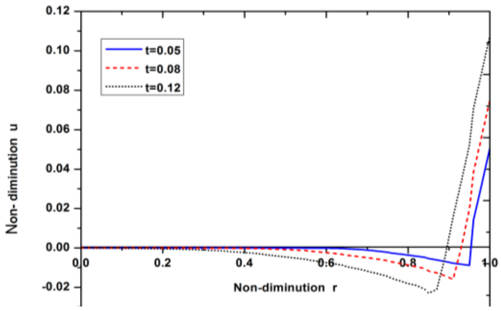

Fig. 3. Displacement distribution

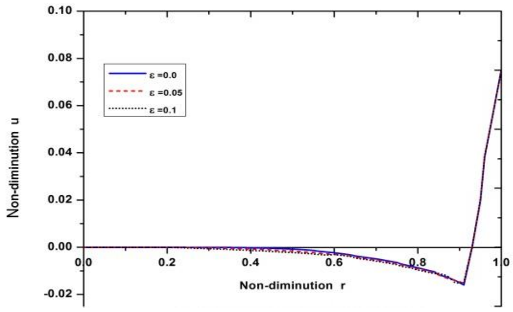

Fig. 8. Displacement distribution

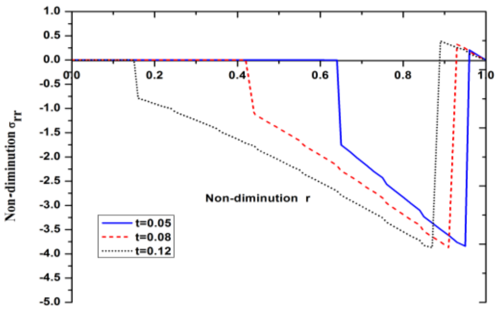

Fig. 4. Radial stress distribution

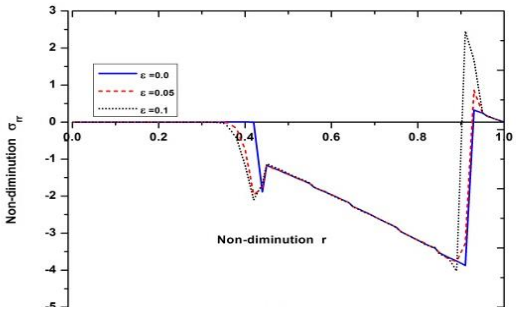

Fig. 9. Radial stress distribution

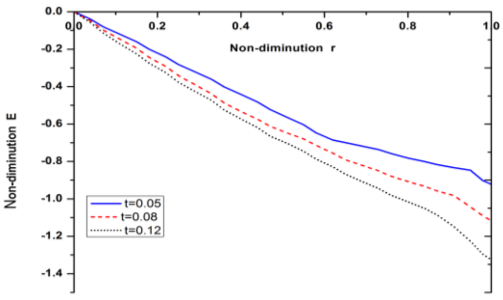

Fig. 5. Electric field distribution

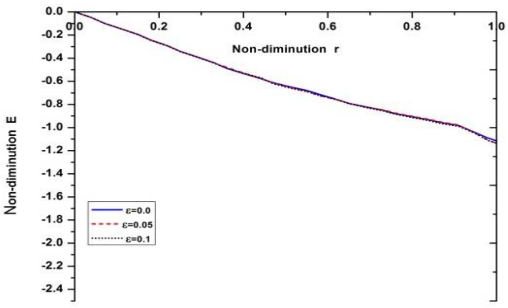

Fig. 10. Electric field distribution

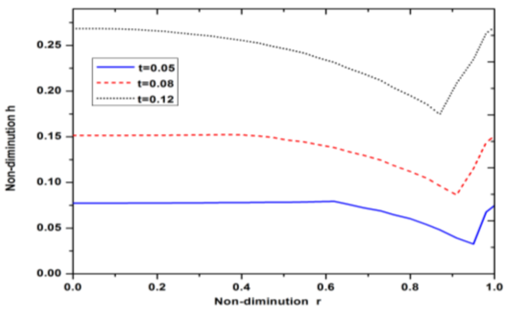

Fig. 6. Induced magnetic field distribution

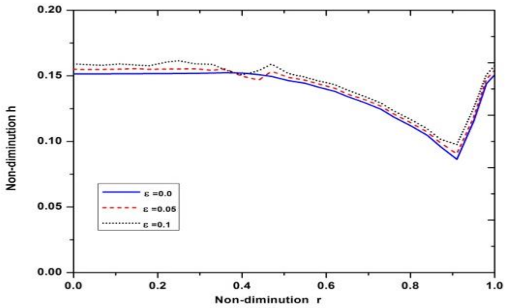

Fig. 11. Induced magnetic field distribution

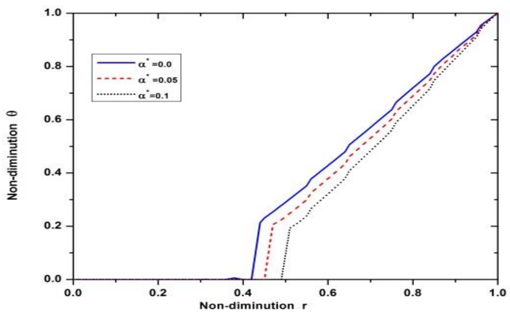

Fig. 12. Temperature distribution

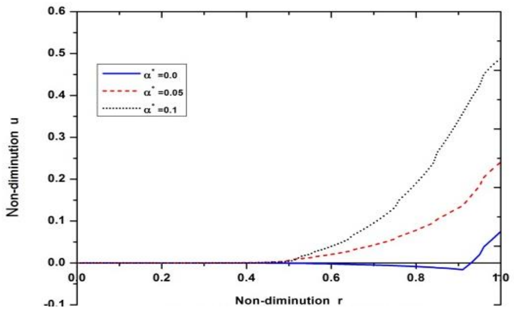

Fig. 13. Displacement distribution

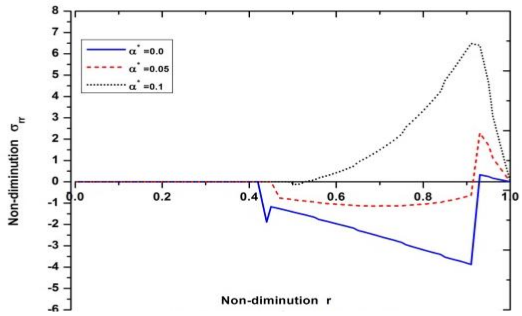

Fig. 14. Radial stress distribution

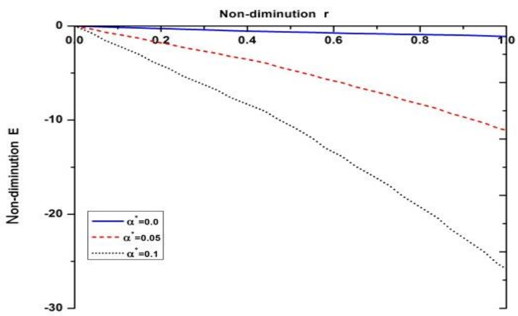

Fig. 15. Electric field distribution

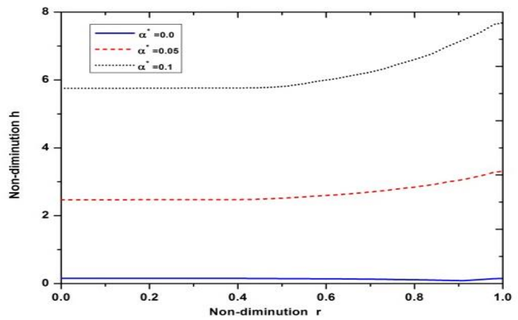

Fig. 16. Induced magnetic field distribution

Figures (2-6) represent the graphs for the induced electric and magnetic field, stress, displacement, and temperature, in the case of absent nonlocal ($\varepsilon = 0$) and temperature-independent properties ($f(T_0) = 1$). We can solve the problem by using three values of times, namely for $t = 0.05$, $t = 0.08$, and $t = 0.12$. Solid lines represent the case when t = 0.12, Dotted lines represent the solution for t = 0.05, and dashed lines represent the solution for t = 0.08. We first evaluate the derivation in the last section and the numerical inverse of the Laplace transform algorithm. The temperature on the cylinder surface is constant at 1. From all the graphs, it is easy to see that all functions satisfy the boundary conditions. We observe that the value of the temperature increases when the value of time increases. The position of the maximum points of stress and displacement-induced electric and magnetic fields with respect to radius increases when the time increases. The finite speed of wave propagation is seen in all graphs, which is the major distinguishing feature of the expanded theory with two relaxation times. That is, unlike in the coupled theory, the effects of thermal shock on the boundary do not immediately fill the entire body of the cylinder.

Figures 7-11 represent nonlocal and temperature-independent properties ($f(T_0) = 1$). The problem was solved for t = 0.08 and three values of nonlocal parameter, namely for $\varepsilon = 0$, $\varepsilon = 0.05$, and $\varepsilon = 0.1$ dotted lines represent the solution for $\varepsilon = 0.1$, the dashed lines represent the solution for $\varepsilon = 0.05$, and solid lines represent the case when $\varepsilon = 0$.

It clearly shows the effect of the nonlocal parameter on the temperature and stress (Figures 7 and 9). In figure 7, when ε = 0 (absent of nonlocal), the impacts of the thermal shock arrive at namely r = 0.4, but in present nonlocal the impacts of the thermal shock arrive namely r = 0.35. In figure 9, the effect of nonlocal is appearing at the point of discontinuity. The effect of the nonlocal parameter is very small in the displacement, induced electric and magnetic fields, figures (8, 10, and 11).

Figures 12-16, represent the case of absent nonlocal and temperature-dependent properties. The problem was solved for t = 0.08 and three values of Empirical material constant namely for $\alpha^* = 0$, $\alpha^* = 0.05$, and $\alpha^* = 0.1$. Dotted lines represent the solution for $\alpha^* = 0.1$, the dashed lines represent the solution for $\alpha^* = 0.05$, and solid lines represent the case when $\alpha^* = 0$. In Figure (12), we note that by increasing the

Empirical material constant α*, the speed of heat wave propagation decreases; this is due to the change in the physical properties of matter. At $\alpha^* = 0$ the impacts of the thermal shock have arrived at namely r = 0.44, at $\alpha^* = 0.05$ the impacts of the thermal shock, have arrived at namely r = 0.47, at $\alpha^* = 0.1$ the impacts of the thermal shock, have arrived at namely r = 0.51. In all the figures (12-16), it should be noted that there is a significant difference in the values of the considered function. This may be due to the fact that the temperature in thermoelasticity is an infinitesimal deviation from the reference temperature. Thus, the dependence of the modulus of elasticity on reference temperature has a significant effect on the thermal and mechanical interactions. And we show that by increasing the Empirical material constant α*, increases the values of the functions, which indicates that the physical reasons for elastic behavior can be quite different for different materials. In metals, lattice changes size and shape when forces are applied (energy is added to the system). This is evident from the figures (13-14).

5. Conclusions

In this work, the temperature-dependent properties and the effect of non-local elasticity in the presence of a magnetic field have been studied numerically in an infinitely long solid conductive circular cylinder. We can draw the following conclusions in light of the above analysis: The physical quantities satisfy the boundary conditions, the finite speed of wave propagation is apparent, and all the results are in concurrence with the generalized theory of thermoelasticity. The studied physical quantities are affected by the presence of a non-local parameter, as they are strongly affected by some physical quantities such as temperature and stress, and have a negligible effect on some physical quantities such as displacement, and electric and magnetic fields. The dependence of the modulus of elasticity on the reference temperature has a significant effect on thermal and mechanical interactions. This is very clear from the graphs. The magnitude of all studied physical quantities increased in the presence of temperature-dependent properties. This study is useful for these problems. The study mentioned above is important in the study of structural components and mechanical elements such as pressure vessels and pipes in nuclear reactors, chemical plants, and high-speed aircraft. It is subject to thermal loads due to high temperature, high-temperatures gradients, and periodic temperature changes.

Nomenclature

J	electric current density
ε_0	electric permeabilities
μ_0	magnetic permeabilities
D	electric induction vectors
σ_0	electric conductivity
u	displacement vector
λ, μ	Lamé's modulii
γ	material constant
T	absolute temperature
ρ	density
θ_0	constant
H_0	magnetic field
∇^2	Laplace's operator
α_t	coefficient of linear thermal expansion
T_0	reference temperature
k	thermal conductivity
c_E	specific heat at constant strain
τ_1, τ_2	the relaxation time
H(t)	Heaviside unit step function
E_0	Induced electric fields in the free space
h_0	Induced magnetic fields in the free space
F	Lorentz force
λ^*, μ^*, k^*	Constants
α^*	Empirical material constant
B	magnetic induction vectors
ε	nonlocal parameter

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Conflicts of Interest

The author declares that there is no conflict of interest regarding the publication of this manuscript. In addition, the authors have entirely observed the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy.

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