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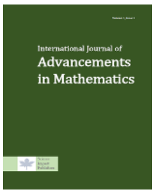

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NUMERICAL INVESTIGATION OF FLOW AND HEAT TRANSFER OVER A MOVING SURFACE WITH NON LINEAR VELOCITY AND VARIABLE THICKNESS IN A NANOFLUIDS IN THE PRESENCE OF BROWNIAN MOTION

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Abstract

The impacts of varying thickness, hydro magnetic flow, Brownian motion, and heat production on the heat transmission characteristics and mechanical qualities of a moving surface immersed in a cooling medium containing nanoparticles are investigated. The controlling boundary layer equations are converted to ordinary differential equations. For general circumstances, these equations are solved analytically with the shooting technique. The velocity, temperature, and concentration patterns within the boundary layer are displayed and described in depth for various values of the different parameters such as Brownian parameter, thermophoresis parameter, shape parameter, magnetic parameter, and heat source parameter. The impact of the cooling medium and flatness on the mechanical characteristics of the surface is examined.

Keywords: Nanofluid, MHD, Heat Generation, Radiations, Chemical reaction

INTRODUCTION

A boundary layer circulation is a mathematical simulation of action for heat treatment. Thermal treatment is numerically approximated by circulating a secondary current in the direction of the cooling medium over a moving surface. Heat-treated metal is used to modify or restore mechanical properties in domestic or industrial settings. We can improve the toughness, strength, and impact resilience of metal through thermotherapy. Furthermore, heat-treating metal can increase its ductility and flexibility. Flow in the reservoir M E. Ali and colleagues (1955). The researchers concentrated on the flow characteristics of a boundary layer on a movable surface placed in an ordinary fluid before adding nanofluid, a new fluid. Nanofluid is the term used to describe the mixture of potent 1-100 nanometer nanoparticles and a conventional heat transfer base fluid (Hamad, 2011, Oztop et al., (2008), Jacob et al., (2011), Prasad. 2010, etc.). (2012). Brownian behavior in nanofluids has been investigated by Rana, Alsaedi, Khan, and Anbuchezhian (2012). (2012). The impacts of thermal boundary layers and changing surface area with uniform thickness at various fluid speeds were the main topics of earlier research. Engineering areas are more prone than the horizontal line to experience thickness changes. Fang et al. (2012) used a stretching plate with a varying thickness to study blood flow in the border layer. Elbashbeshy et al. (2013) assessed blood flow and heat transmission in an area rotating in a nanofluid at a varying speed and various density. We looked into the properties of nanofluid heat transmission when subjected to nonlinear speeds and thermal radiation in a continuum. Three types of nanofluid have been studied: C_u, Ag and Al_2O_3Researchers created a set of nonlinear standard differential equations for general issues using the same transformation, which were then analytically solved. Numerical findings for surface friction, Nusselt number, and velocity temperature. Friction amount, surface area density parameter, velocity power index parameter, and radiation traits.

When the nanofluid is spread (shrinking) over a porous sheet with a range of thicknesses, the flow does not alter. For useful engineering systems, a sheet's capacity to resist heat transmission is crucial. Traditional issues with flow, heat, and mass transmission always disregard the profundity of the top. In order to better comprehend this phenomenon, our primary goal in this study is to concentrate on how wall thickness affects field variables and the transfer of heat and nanoparticles among solid surfaces and fluids. The concept of wall thickness change is thoroughly investigated by merging additional border inputs. Even better, the nanoparticles are equally distributed across the sheet's surface and the sheet is consistently heated. A specific boundary layer in the shape of PDEs controls the passage of nanoparticles and heat in fluids. To answer the boundary value PDE system, a collection of unknown changes must be created. These undimensioned factors allowed us to create a system of boundary value ODEs. (parameters). My argument is that, in terms of the governing factors, this issue clarifies and enhances all field quantities. The new data is presented in various diagrams and charts, followed by a comprehensive analysis and discussion. The density distribution of nanoparticles does, however, alter when there is a small variation in the thermophoresis force. In addition to analyzing wall thickness from two different angles and changing the temperature (concentration) profiles of the basic fluid by introducing nanoparticles, we also consider field factors. We discovered that using a uniformly heated sheet with a variable (uniform) thickness that expands and contracts at a variable (uniform) rate and injects and suctions at a variable (uniform) rate could handle mass and heat transmission issues in nanofluid. There are also two numerical answers to these problems. All answers in a table are examined to make sure they are all the same.

This debate is about heat transmission in nanofluids using flexion and extension (shrinking) and granular sheets of varying thickness. The new values are then applied to the partial differential equations that are being evaluated. The present examples will concentrate on traditional heat transfer models from rigid/porous and stretching/shrinking sheets, as well as Brownian motion. The boundary layer equation/boundary condition construction is used to create a system of linked and nonlinear ODEs. Nanofluids are essential in a number of fields, including the transit, pharmaceutical, and metallurgical businesses, as well as micro manufacturing. Additionally, the creation of complicated fluids, the refinement of petroleum oil from surfaces, and the manufacturing of nanostructured materials all depend on nanofluids.

Fluid sheet conductivity had a major effect on many engineering operations. Conjugate heat transmission is important in sweat cooling devices as well as heterogeneous chemical reaction mechanisms. The study, however, cannot be expanded at this moment without the details on interface temperature and concentrations." Their behavior is essentially significant because these two variables have distinct surfaces and ambient areas and thus diffuse, but they must be determined within the border layer using the correct set of governing equations.

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Take into account the periodicity of a powerful, dense charge absorption by a nanofluid over the full region of motion within the range of longitudinal heat release Q(x) and magnetic field B.(x). The experts think that as a result, there is no spread of the generated pressure along the current and the small magnetic field produced by the passing of a conductive liquid. This indicates that the magnetic field has a low Reynolds number. Since there is no exterior electric field, the expense of a polarized electric field is also very low. Given their importance in industrial processes like papermaking, plastic extrusion, and cloth manufacturing, the liquid phase and nanoparticles are also anticipated to be thermally steady, with no slipping between them.

It is also thought to be possible to mathematically simulate the thermotherapeutic effects of metal surfaces exposed to varying rates of heating and cooling. Numerous studies have been conducted to examine the regularity of the boundary layer brought on by a shifting surface. These kinds of papers sparked researchers' interest in exploring the impact of different external pressures operating in the boundary layer, including electromagnetic pressure, radiation pressure, heat production pressure, suction-injection pressure, and transient motion. To chill the particles, Choi created a novel fluid. The findings of Choi's study led to the discovery of a novel liquid type that contained nanosized particles floating in a typical liquid like water, oil, or ethylene glycol.

These gauges have a wide range of applications, particularly in air cooling and heat treatment procedures, because of the enhanced thermal conductivity of the recirculation system. In their study (15), Rohini et al. looked into how a nanofluid's boundary layer behaved on a moving surface. He talked about how the decreasing plate's erratic operation effects the suction power's vision. Rana et., Al (16) The effect of nonlinear scale of the expanded plate was investigated in nanofluids. Aminreza et al. (17) investigated the effects of partial slide boundary conditions on the heat transmission and nanofluid flow through an exponentially extended plate with a uniform wall. Hamad (18) examined the movements of spontaneous convection of Nano fluids using electromagnetic fields and suggested an analytical approach. The discovery that a nanofluid moves along a sloped surface with an external shear current and a constrained convective surface area was made by Jacob et al. (19). Elbashbeshi et al. (2021) solved the issue of flow around a boundary layer of nanofluid on a moving surface in field and hydrostatic pressure for constant and unstable motion. Alsaedi et al. (22) examined the impact of heat release on the boundary layers of nanofluids. Magyari investigated the impact of radiant heat on the boundaries of different nanofluids. (23), Motsumi et al., (24), Khadi (25), Elbashbeshi and others. (26), Pantokratoras (27), MohyudDin et al., (28), Khan et al., (29) and Abdelwahed et al., In the previous work, a continuous flow of nanoparticles in the boundary layer was considered.

Anbuchezhyan et al. looked into how the dispersion of nanoparticles in the boundary layer was impacted by Brownian activity and heat movement. Changes in density are more probable in a design than on a planar surface, Kandasami et al. Fang and other experts have thoroughly examined the movement of copper oxide and titanium oxide nanofluids across a granular surface that is traveling vertically. A horizontal magnetic field exists parallel to the movement path. The words "heat radiation" and "heat dissipation" are used frequently in the energy equation. Separate differential equations with starting and boundary conditions are used to characterize this movement. He figured out the formulae describing the movement in two steps. The fundamental flow equations are transformed evenly into a range of suitable values to create partial differential equations. The Laplace transform technique is used to get precise answers to these dimensionless problems. The fluid accelerates as the Grashof number (Gr), porosity parameter (K), and heat sink (Q) numbers rise, while the Prandtl number (Pr) and graph results show comprehensive analysis of torque control and thermal profile with various associated parameters. the thermal slope being decreased. extensively utilized in commercial settings. The word "nanofluid," which describes a basic fluid containing nanoparticles, was first used by Choi (1). The thermal conductivity of the nanofluid is greater than that of common substances like water, mineral oil, and ethylene glycol. In their tests, Eastman et al. demonstrated that a nanofluid containing water nanoparticles and 5% by volume CuO can improve thermal conductivity by roughly 5%. There are single-phase and two-phase macroscopic models of nanofluid movement and heat transmission accessible. Single-phase methods handle nanoparticles and base fluid as a single relatively homogeneous fluid. In two-phase approaches, three distinct methodologies are used to calculate continuity, momentum, and energy equations for particles and the basic fluid. Despite the fact that two-phase models provide a greater grasp of both phases, single-phase models are simpler to compute but provide less detail about each step.

MATHEMATICAL MODEL

With the effects of a transverse magnetic field B(x), heat production Q(x), and chemical reaction, an incompressible viscous electrically conduction nano-fluid is moved in two dimensions laminarly over a moving surface. We believe that this is the case because the surface is completely level, there are no pressure gradients brought about by the flow of an electrically conducting solution, and the magnetic field produced by the fluid motion is minimal with a very low Reynolds number. Because there is no external electrical region, the electrical area caused by the polarization of costs is also minimal. The following are the governing equations:

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \tag{1}$$

$$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = \upsilon\frac{\partial^2 u}{\partial y^2} - \frac{\sigma\beta^2(x)}{\rho}u \tag{2}$$

$$u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} = \alpha\frac{\partial^2 T}{\partial y^2} + \tau\left[D_B\frac{\partial C}{\partial y}\frac{\partial T}{\partial y} + \frac{D_T}{D_8} + \left(\frac{\partial T}{\partial y}\right)^2\right] + \frac{Q(x)}{\rho Cp}(T - T_\infty) - \frac{1}{\left(\rho c_p\right)_f}\frac{\partial q_r}{\partial y} \tag{3}$$

$$u\frac{\partial C}{\partial x} + v\frac{\partial C}{\partial y} = D_B\frac{\partial^2 C}{\partial y^2} + \frac{D_T}{D_8}(\frac{\partial^2 T}{\partial y^2}) + k(C - C_\infty) \tag{4}$$

With boundary conditions

$$u = U_w,\ \ v = 0,\ \ T = T_{W,}\ \ \ C = C_{w,}\ \ \ \text{at}\ \ y = \delta(x+b)^{\frac{1-n}{2}} \tag{5}$$

$u=0$, $v=0$, , $T = T_{\infty,}$, $C = C_{\infty,}$ as $y \to \infty$.

(6)

The speed components in directions of (x,y), while (t,q) is viscosity of the bottom liquid, (r), (electronic conductivity), (a), (b) and (db) are Brownian diffusion coefficients. As an example, D_T stands for thermophoretic Diffusion Coefficient, s stands for the proportion of the nanoparticle's heat cap potential to the liquid's heat functionality, and B(x) is a measure of the electromagnetic subject's power. The type of magnetic material. In order to find a similarity solution, the warmth era $B(x) = B_0(x+b)^{n-1/2}$ and $Q(x) = Q_0(x+b)^{n-1}$ are selected. Prasad has also considered this form of B(x).

They are supposed to be expressed in terms of: velocity, temperature, nanoparticle concentration.

$$U_w(x)\ (x) = a(x+b)^n,\ \ \theta(\eta) = \frac{T\ \ - T_\infty}{T_W - T_\infty}\ ,\ \ \ \varphi(\eta) = \frac{C - C_\infty}{C_W - C_\infty}\ . \tag{7}$$

The two constants in the equation. n is the parameter for the shape. Consider n > 1 in this work where we validate the functions and their similarities.

Transformation of Similarities

A similarity option of Eqs. (1-4) is sought under boundary conditions of equation (5) of the following type.

$$\eta = y\sqrt{(\frac{n+1}{2})(\frac{a(x+b)^{n-1}}{\nu})}\ ,\qquad \psi = \sqrt{(\frac{2}{n+1})((x+b)^{n+1}a\nu}\ F(\eta) \tag{8}$$

because of the stream function which has been defined as follows: G = similarity variable, w ψ = stream function.

Putting the values in equators.

$$F''' + FF' - \left(\frac{2}{n+1}\right)F'^2 - \left(\frac{2}{n+1}\right)MF' = 0 \tag{9}$$

$$\frac{1}{pr}\theta'' + F\theta' + \left(\frac{2}{n+1}\right)\lambda\theta + Nb\theta'\emptyset' + Nt\theta'^2 + (1+Rd)\theta'' = 0 \tag{10}$$

$$\varphi''' + \frac{1}{2}Lef\varphi' + \left(\frac{Nt}{Nb}\right)\vartheta'' - p\gamma Le\gamma_1\emptyset = 0 \tag{11}$$

With boundary condition

$$\mathrm{F}(0)=\alpha\left(\frac{1-n}{1+n}\right), \quad F'(0) = 1, \quad \theta(0) = 1 \ and \ F'(\infty) = 0, \quad \theta(\infty) = 0, \ \varphi(\infty) = 0$$

Differentiation is indicated by priming in this context, here is the symbol (ζ), where

$$\mathrm{Pr}=\frac{\nu}{\alpha}, \qquad Le = \frac{\nu}{D_B}, \quad M = \frac{\beta_o^2\sigma}{a\rho}, \ \lambda = \frac{Q_0}{a\rho Cp}, Nb = \frac{\tau D_B}{\nu}(C_W - C_\infty), \tag{12}$$

$$Nt = \frac{\tau D_t}{\nu T_\infty}(T_W - T_\infty) \ and \qquad \tau = (\rho CP)_p/(\rho CP)_f \tag{13}$$

These numbers are referred to as the Prandtl (Pr), Lewis (Le), magnetic discipline (M), warm-supply (W) and thermophoresis (Nt) parameters.

OUTCOMES

The skin friction coefficient, Nusselt number, and Sherwood number are three of the most important fluxes that tangibly indicate surface share stress and anxiety, mass transfer rate, and price of warm transfers. These properties have an immediate effect on the quantity of temperature rise, which indicates that higher temperatures result in improved product quality. Heat transfer from a surface can be enhanced by raising the rate of heat transfer, which increases the hardness, rigidity, and strength of the character while decreasing surface elasticity. Surface shear stress

$$\tau_w = \mu\left(\frac{\partial u}{\partial y}\right)_{y=\delta(x+b)^{1-\frac{n}{2}}} = \mu U_w\sqrt{\frac{a}{\upsilon}\left(n+\frac{1}{2}\right)(x+b)^{n-1}F''(0)} \tag{14}$$

Since the friction coefficient given by

$$C_f = \frac{2\tau_w}{\rho U_w^2} \quad i.e \ 2\sqrt{\left(\frac{n+1}{2}\right)F''(0) = \sqrt{R_e C_{f_x}}} \tag{15}$$

Surface heat flux

$$q_w = -k\left(\frac{\partial t}{\partial y}\right)_{y=\delta(x+b)^{\frac{1-n}{2}}} = -k(T_w - T_\infty)\sqrt{\left(\frac{n+1}{2}\right)\frac{a}{\nu}}(x+b)^{\frac{n-1}{2}}\vartheta'(0) \tag{16}$$

Since the Nusselt number given by

$$Nu = \frac{(x+b)q_w}{k(T_w - T_\infty)} \text{ i.e. } \frac{Nu}{\sqrt{R_e}} = -\sqrt{\frac{n+1}{2}}\,\theta'(0) \tag{17}$$

Surface Mass flux

$$q_m = -D_B\left(\frac{\partial C}{\partial Y}\right)_{y=\delta(x+b)^\wedge({}^{1-n}/2)} = -D_B(C_w - C_\infty)\sqrt{\frac{n+1}{2}\frac{a}{\upsilon}(x + b^{\frac{n-1}{2}})\Phi'(0)} \tag{18}$$

Since the Sherwood number given by

$$\text{Sh} = \frac{(x+b)q_m}{D_B(C_w - C_\infty)} \text{ i. e } \qquad \frac{Sh}{\sqrt{R_e}} = -\sqrt{(\frac{n+1}{2})\varphi'(0)}$$

$$q_m = -D_B\left(\frac{\partial E}{\partial Y}\right)_{y=\delta(x+b)^\wedge({}^{1-n}/2)} \tag{19}$$

RESULTS AND DISCUSSION

Shape and motion parameters (n) are of significant interest to us due to their role in influencing the type of motion and boundary layer behavior. Our primary goal is to investigate the controlling aspects in the behavior of these parameters and quantities.

As the surface shape changes so with the variability of the value of n, we can judge the shape of the outer surface. The outer surface of n=1 would be flat and of the specified thickness. When n1 is used, the thickness of the surface increases and the outer shape becomes convex; when n>1, the surface thickness decreases, and the outer body becomes concave.

It is also possible to adjust the type of motion with this parameter as well. As soon as n=0, a straight line is created, with n = 1 indicates deceleration, while n > 1 indicates acceleration.

A non-permeable surface is indicated by the boundary condition F(0) =0 when n=1. This parameter can also affect the behavior of the normal boundary layer. The boundary condition F(0)=0 for n=1 causes the suction process. F(0) =0 is the boundary condition for n=1, which indicates the injection process. Figures 2-4 show how this parameter affects temperature velocity and nanoparticle concentration. However, raising the value of nanoparticle concentration has the reverse effect of increasing the temperature and boundary layer velocity. This is due to the fact that the concentration of nanoparticles near the surface is reduced. It has an effect on velocity gradient, temperature gradient, concentration gradient, and frictional forces, as well as Nusselt and Sherwood numbers. It is shown in Tables 2 and 3 as well.

There is a process of reversal between the values of the velocity, temperature, and concentration gradient slopes and the value of the form parameter n. The Nusslet number, Sherwood number, rate of heat transfer, and mass transfer are all decreased as n rises as a result of rising surface friction. The friction will greatly rise as n is increased in a similar manner.

Figures 7 and 8 show the thickness parameter's effects on speed, temperature, and particulate content. Speed and temperature drop as the value rises, while the concentration of nanoparticles at the surface grows as the value rises and diminishes as the value falls.

Tables 2 and 3, for example, show how skin friction and the Nusslet number influence the velocity gradient, temperature gradient, and concentration gradient, as well as the skin friction numbers in Table 2. Our results indicate that as the thickness parameter increases in temperature, all of the previously stated physical characteristics increase. Copper water nanofluids move heat to the plate more quickly. Cu-water nanofluid has reduced shear tension at the plate when compared to conventional nanofluid.

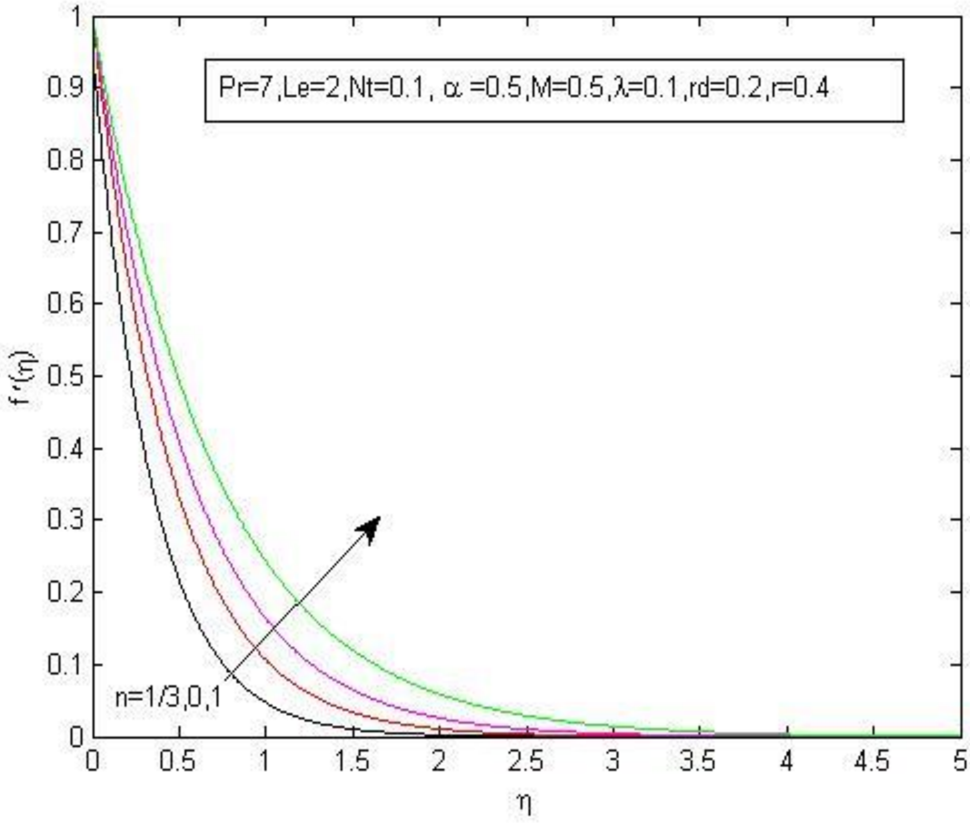

Figure 2 **The temperature distribution with increasing of shape parameter(n)**

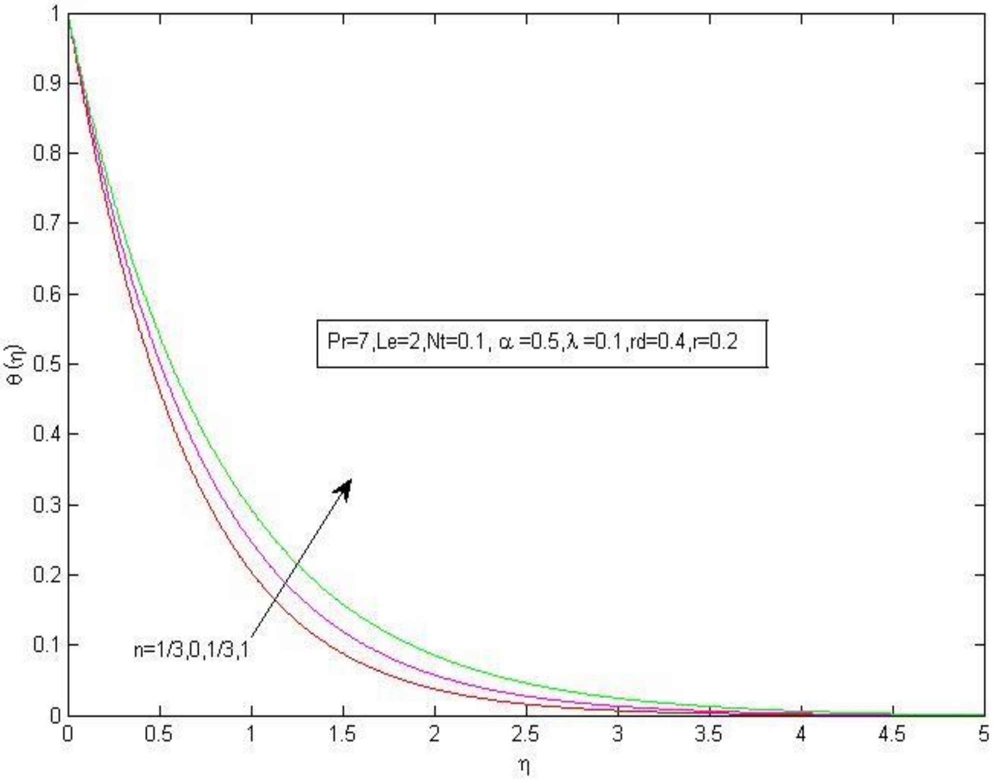

Figure 3 The acceleration figure with increasing of body framework(n

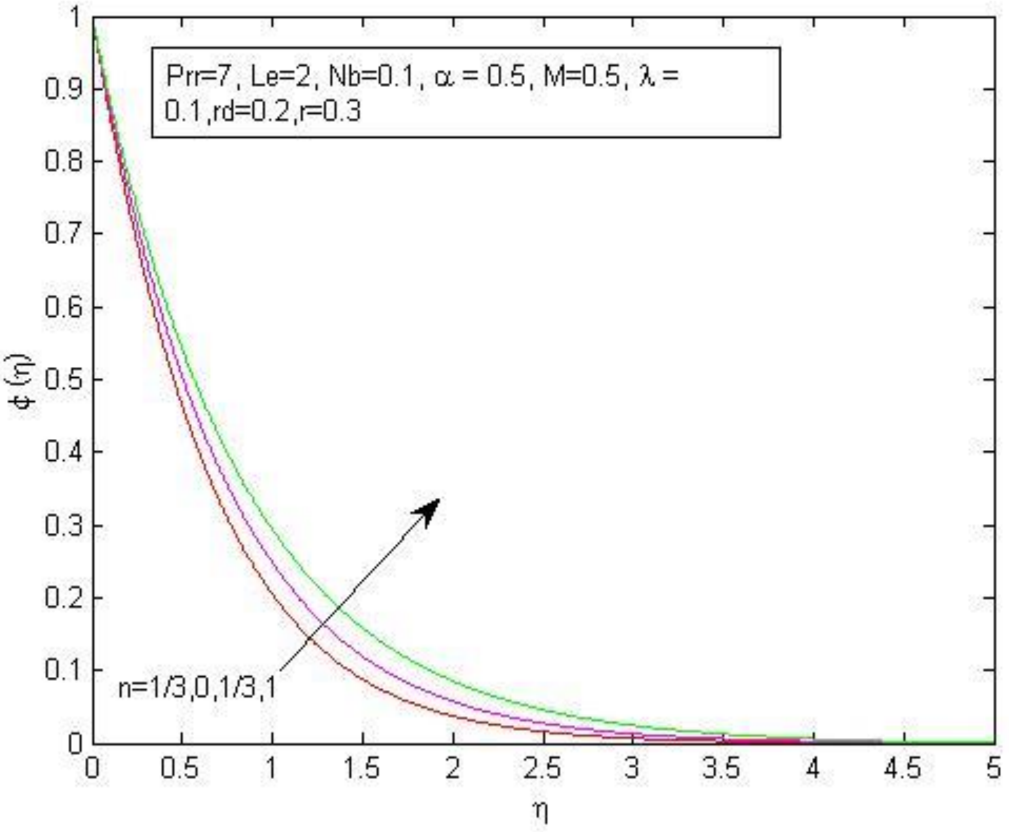

Figure 4 The temperature figure with increasing of body framework(n)

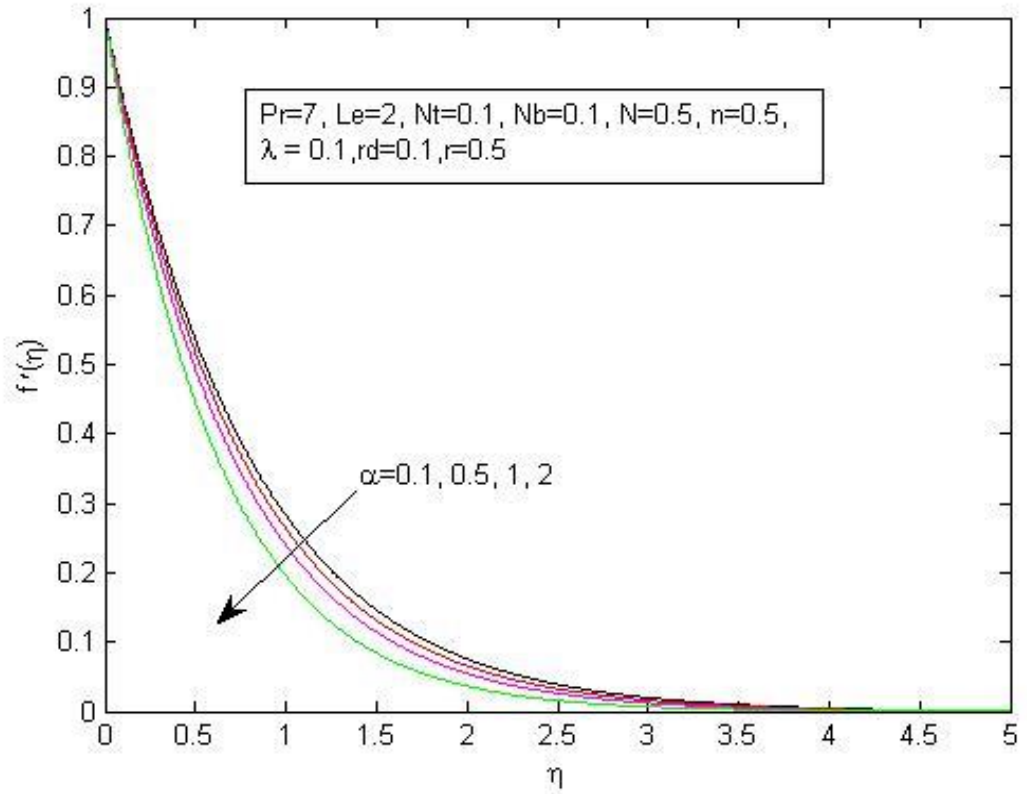

Figure 5 The concentration figure with increasing of body framework(n)

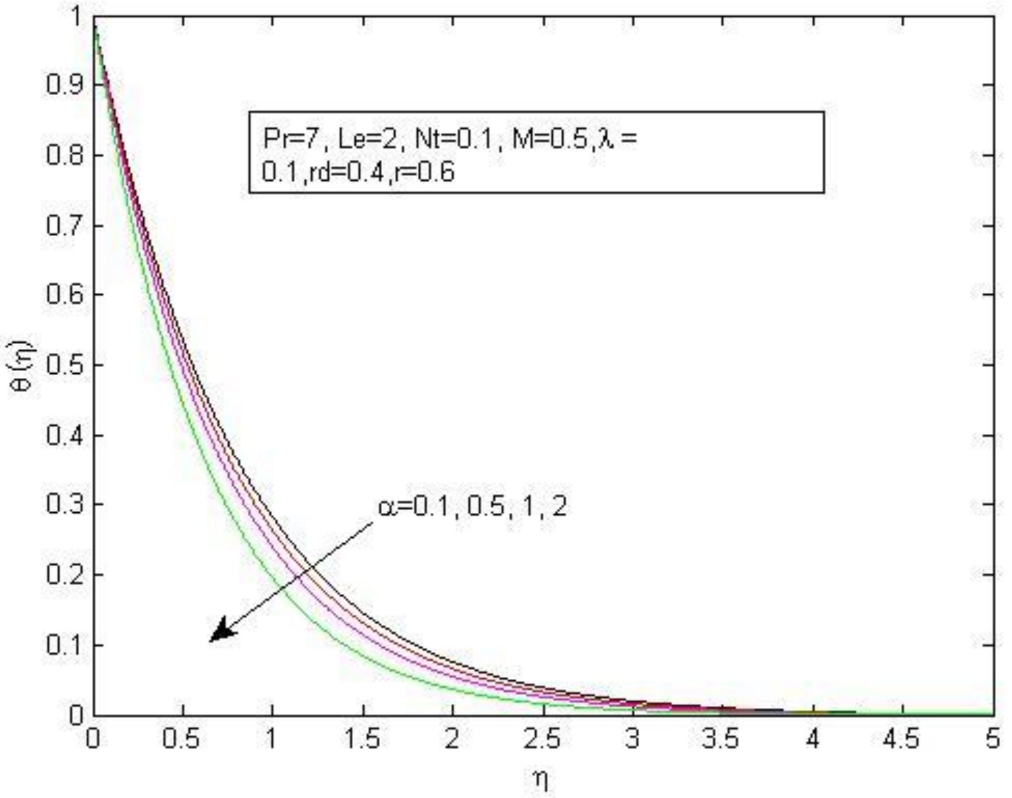

Figure 6 The acceleration figure with increasing of body thickness framework(n)

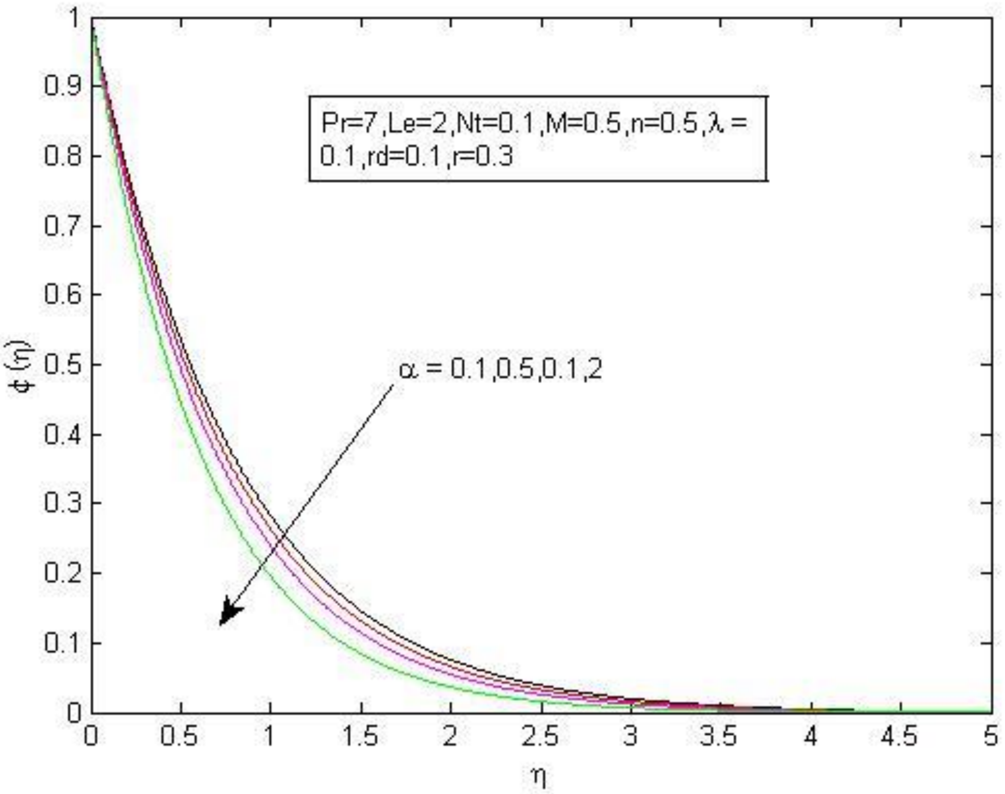

Figure 7 The temperature figure with increasing of body thickness framework

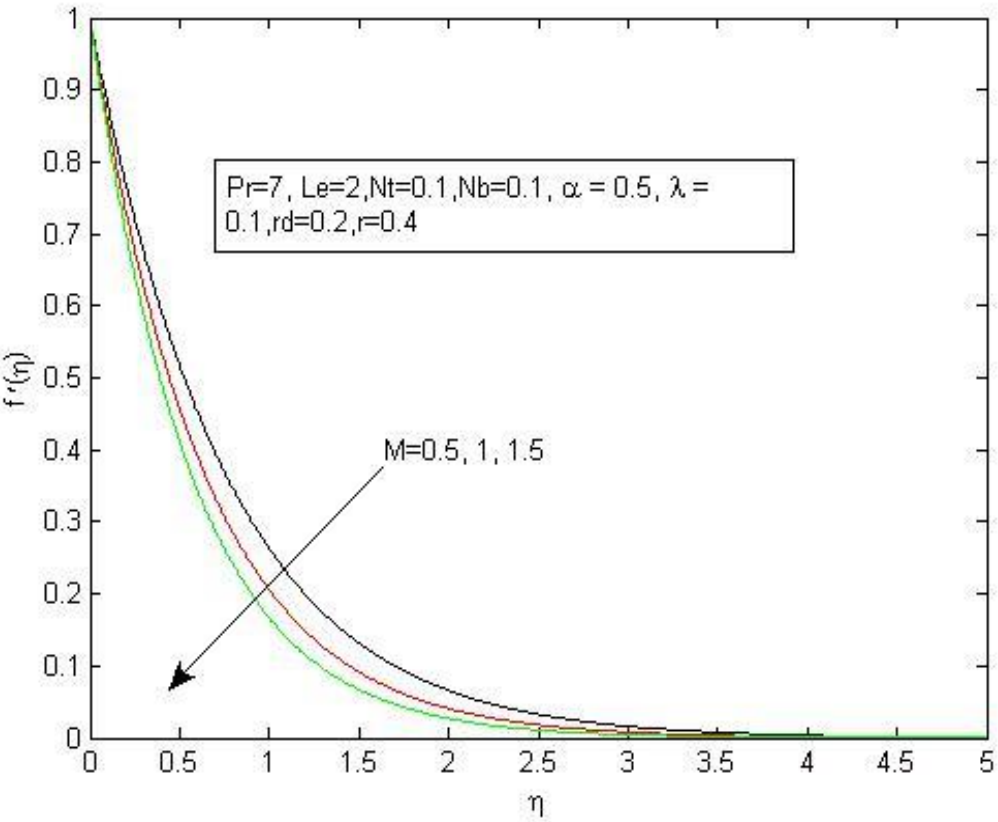

Figure 8 The concentration figure with increasing of body thickness framework

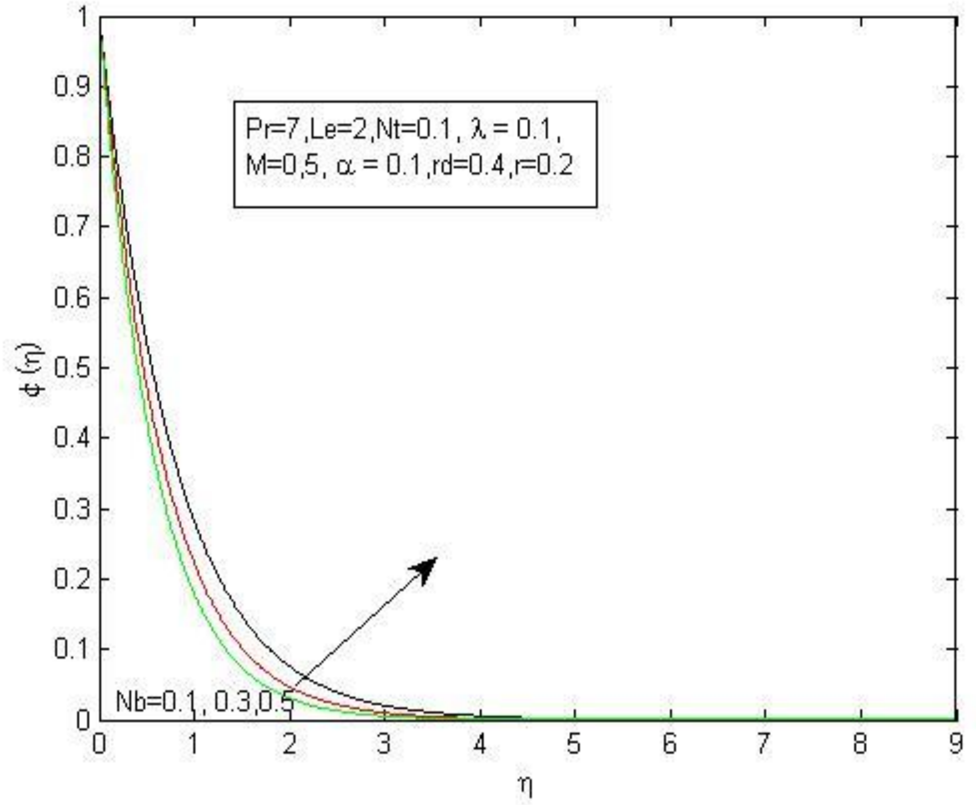

Figure 9 The acceleration figure with increasing of magnetic framework(n)

Table 1

N	M	λ	Pr	Rd	Nb	Nt	Le	r1	A
-1/3	-1.7643	1.7754	1.7861	2.1744	1534.74	2.5465	4.7654	3.7547	4.8566
0	- 1.16659	8.186514	6.241713	-0.00165	3247.92	- 2360.33	5.3456	3.5467	5.5648
	-1.02325	7.996330	1.157908	-0.00251	1220.29	-686.672	3.3456	4.5675	6.5367
	-1.00100	- 1.56034	1.479281	-0.00283	925.990	- 349.900	2.3456	5.5478	4.4356
1/3	-2.83433	-17.3577	13.1235865	-0.04011	6595.18	-5335.27	1.3545	6.5384	5.4537
1	-1.14874	-2.49558	2.888074	-0.00243	16123.93	-1145,20	5.3568	8.5478	6.5436
	-1.00001	-7.30130	0.569266	-0.00283	9784990	-336.890	7.5679	3.4647	3.5643

CONCLUDING REMARKS

The heat treatment procedure of a moving continuous surface with varying thickness using nanofluid as a cooling medium is mathematically simulated in the current research. Figures 2 to 9 illustrate how all incorporated factors affect the outer layer's motion, temperature, and nanoparticle content. The water used as the basic fluid has a steady Prandlt number of 7. Consequences of mass transition and chemical reaction are also considered. We used a capturing method to fix the paired common differential equations device. In addition, the previously released work is evaluated. The top three findings are outlined as follows: Charge account presentations diminishing sample and the reverse behavior is evident in the thermal boundary layer when the magnetic field intensity is increased. Increase within the Deborah range causes the lower in charge effect to occur, and the temperature degree curve exhibits the reverse behavior. With an increase in warmness extended leisure time, temperature account drops. Lowering sample for the attention profile is displayed by the Schmidt range and chemical reaction parameter. The goal of this study is to obtain accurate solutions for the nanofluid's unstable herbal convection limitation layer slide next to a moving infinite vertical plate while enduring a transverse regular magnetic field. The radiative warm temperature flow inside the energy equation is explained using the Roseland estimate. The Laplace rewrite technique was used to help obtain the equations for the rate and temperature degree in closed form. Graphical representations of the effects of the relevant factors on the charge and extra temperature degree profiles are given. The effects of the exact same standards on shear pressure and tension, as well as the charge of the heat switch on the plate, are also thoroughly discussed. The most important concluding remarks are as follows: An increase in the radiation component causes a decrease in the fluid charge as well as the temperature degree within the restriction layer region. Increased Grashof range and duration cause a rise in fluid charge and temperature. Cu water Nano fluid has a higher charge of the thermal sensor on the plate. The shear strain on the plate for the Cu water Nano fluid is decreased.

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