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MHD Hybrid Nano Liquid Permeable Stretching Sheet with Radiation Heat Transfer Enhancement Effect

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ABSTRACT

The current study describes a novel type of hybrid nanofluid that can improve heat transfer rate. The hybrid nanofluid has numerous uses in heat transmission, including medical, transportation, and manufacturing. This paper investigates the heat transmission and flow generated by an ever-increasing expanding nanoparticles hybrid sheet. Additionally considered are the effects of radiation and magnetohydrodynamics (MHD). The governing Equations are transformed using similarity transformations, and their numerical solutions are determined by employing the Keller Box Method, commonly known as the Implicit Finite Difference Scheme. With enhanced observations of nanoparticle volume fraction parameters velocity profiles decrease and temperature profile increases. A decrement in velocity profiles is noted for enhanced observations of Magnetic parameter. Numerical values of local parameters are computed and compared with existing literature and the results are found to be good and in agreement with previous literature.

Keywords: Stretching sheet, Hybrid nanofluid, MHD, Radiation, Keller Box Method.

1. Introduction

Hybrid nanofluids have been employed in various heat transfer recently submitted applications, including pipes with heat, the sun's energy, cooling and heating, exchanger of heat, ventilation, cooling system, a cooling agent in machining and production, spaceships, and so on. Hybrid nanofluid was created by suspending two distinct kinds of nanoparticles with diameters of 100 nm in common liquids like oils and water. One kind of hybrid nanofluid is fluid with improved thermal conductivity. A hybrid nanofluid is a novel type of heat transfer enhancement that has greater thermal conductivity and thermo-physical properties than a traditional fluid. Ubaidullah *et al.*[1] studied hybrid nanofluid flow with radiation influence using the bvp4c technique, increase in radiation parameter, and enhancement in velocity is observed. In this study, Sreedevi *et al.*[2] examined chemical reaction-slip effects and thermal radiation of an unsteady MHD over a stretching surface hybrid nano liquid flow using a finite element method solved numerically. Sidik *et al.*[3] discussed the uses of hybrid nanofluids in heat transmission. Sarkar *et al.*[4] studied about the benefits and drawbacks of hybrid nanofluids, as well as the ways to optimise the heat transfer conditions. SWCNTs and MWCNTs are two types of carbon nanotubes found in a conventional fluid such as water and the governing equations were solved numerically by M. Shanmugapriya *et al.*[5]. Sarada *et al.*[6] described the fluid movement behaviour of non-Newtonian fluid over a stretching sheet using R-K -Fehlberg along with the shooting method numerically and explained the nature of MHD and LTNE. The hybrid nano fluid flow of unsteady MHD over a stretching surface with chemical reaction is analysed and the numerical method is adopted here is the finite element method by Sreedevi *et al.*[7]. More researchers solved the MHD Heat transmission of a porous hybrid nanofluid with carbon nanotubes (CNTs) diminishing surface and joule heating numerically using MATLAB software using bvp4c tool[8-9] Nanometre-sized particles of colloidal suspensions base fluid were injected with nanoparticles by the researcher Choi[10] and these nanoparticles have many applications due to enhancement in heat transfer rate. L.T Fan, V. G Fox, and L E Erickson[11] discussed the mass and heat transport problem of injection/suction on a moving continuous flat plate was investigated. The thermal transport properties of all of these nanofluids were studied, and significant increase in thermal conductivity and viscosity were discovered by Huaqing Xie *et al.*[12] So many researchers investigated potential mechanisms to understand nanofluid thermal conductivity and explained most of the experimental data with nanosized powder suspensions enhancement of thermal transport

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properties in[13-14]. The transformation of similarity approach is employed in the transformation of hybrid nanofluid equations that govern. The transformed boundary value problem was investigated and addressed using the bvp4c technique by Umair Khan *et al.*[15]. Many research studied about hybrid nanofluid properties and enhancement of thermal exchange and enhancements in[16-19]. Ghosh, S. Mukhopadhyay S[20] studied the effects of silver (Ag) nanoparticles on an increasingly porous material nanofluid flow over a shrinking sheet in kerosene oil and water with two distinct base fluids, are examined and the transformed equations were solved numerically using the shooting method. Incompressible MHD viscous hydro-nano fluid flow over an upright plate was investigated numerically by Sridhar *et al.*[24]. Niihara[25] described the miniature composites that were improved using the mechanical and the thermal properties a previously unknown idea of significant design. Suresh *et al.*[26] investigated the production of a hybrid nanofluid. The generated nanocomposites comprised a novel nanostructure concept and significantly improved the mechanical and the thermal performance. Momin[27] investigated the experimental learning of a hybrid nanofluid in a tube that was inclined, laminar mixed convection flow. Suresh *et al.*[28] then investigated the effect of a hybrid (Al_2O_3 Cu+ water) exchange of heat by a nanofluid. Baghbanzadeh *et al.* & Umair Khan *et al.*[29-30] investigated the thermal conductivity of related nanofluids and the combination of multi and sphere-shaped silica divider carbon nanotube hybrid nanoparticles. Emam[31] studied the influence of radiation over a stretching horizontal cylinder and noted that increasing radiation parameter, heat flux will be reduced which causes rise in temperature distribution.

In the present study, Al_2O_3-Cu/water hybrid nanofluid flow over a permeable stretching sheet with influence of MHD and thermal radiation effects are studied. The objectives of the present work are

1. To study a novel type of hybrid nanofluid that can improve heat transfer rate.

2. This paper investigates the heat transmission generated by hybrid nanofluid flow over permeable stretching sheet.

3. Al_2O_3-Cu/water hybrid nanofluid is considered with influence of Radiation and MHD.

4. Suitable similarity transformations are adopted to transform the governing PDE's to nonlinear ODE's and further it can be solved using an implicit finite difference scheme.

2. Mathematical Formulation

consider the Al_2O_3-Cu/water Hybrid Nanofluid flow via a stretched sheet with slip effects. Under the presumptions outlined above and with slip effects and thermal radiation presented by Asadi *et al.*[23] established the formulas that regulate the motion, the energy, and the concentration.Tiwari and Das[21] modeled the governing equations found in[21-22] using standard notation when boundary-layer approximations are used.

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

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + \vartheta\frac{\partial u}{\partial y} = -\frac{1}{\rho_f}\frac{\partial P}{\partial x} + v_{nf}\frac{\partial^2 u}{\partial y^2} - \frac{\sigma B^2(x)}{\rho_f}(u_e - u) \tag{2}$$

$$\frac{\partial T}{\partial t} + u\frac{\partial T}{\partial x} + \vartheta\frac{\partial T}{\partial y} = \frac{k}{\rho c_p}\frac{\partial^2 T}{\partial y^2} - \frac{1}{\rho c_p}\frac{\partial q_r}{\partial y} \tag{3}$$

$$\frac{\partial C}{\partial t} + u\frac{\partial C}{\partial x} + \vartheta\frac{\partial C}{\partial y} = D_B\frac{\partial^2 C}{\partial y^2} \tag{4}$$

$$u = U_w = u_0 + \alpha_0\frac{\partial u}{\partial y} \tag{5}$$

$$V = V_w(x) \tag{6}$$

$$T = T_w(x) + k_1\frac{\partial T}{\partial y} \tag{7}$$

$$C = C_w(x) + k_2\frac{\partial C}{\partial y} \tag{-}$$

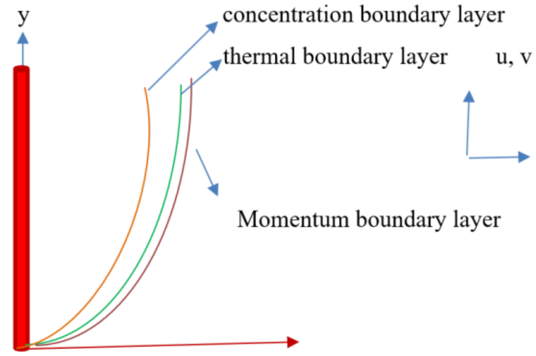

Figure 1: Flow model of the problem.

Boundary conditions are

$$u = U_w = u_0 + \alpha_0\frac{\partial u}{\partial y}, V = V_w(x), \quad T = T_w(x) + k_1\frac{\partial T}{\partial y}, \quad C = C_w(x) + k_2\frac{\partial C}{\partial y}, \text{ at } y = 0$$

$$u \to 0, T \to T_\infty(x), C \to C_\infty(x) \text{ as } y \to \infty \tag{8}$$

Using similarity transformation variables to the mathematical study of the problems as

$$\eta = y\sqrt{\frac{a}{\vartheta_f(1-ct)}},\ \psi = x\sqrt{\frac{a\vartheta_f}{(1-ct)}}f(\eta), \theta(\eta), \frac{T-T_\infty}{T_w-T_0}, \frac{C-C_\infty}{C_w-C_0} = \varphi(\eta) \tag{9}$$

The governing equations (2-4) are transformed to (10-12) by using similarity transformations mentioned in (9)

$$f''' + \frac{A_2}{A_1}ff'' - \frac{A_2}{A_1}f'^2 - \frac{A_2}{A_1}\left(f' + \frac{\eta}{2}f''\right) - A_1M(1-f') = 0 \tag{10}$$

$$(1+A_4R)\theta'' - Pr\frac{A_3}{A_4}\frac{\gamma}{2}(\eta\theta' + 2\theta) = 0 \tag{11}$$

$$\varphi'' + Sc\frac{\gamma}{2}(\varphi' + 2\varphi) = 0 \tag{12}$$

boundary conditions are:

$$f(0) = V_0, f'(0) = 1 + \lambda f'', \theta(0) = 1 + \xi\theta', \varphi = 1 + \beta\varphi' \text{ at } \eta = 0$$

$$f' \to 1, \theta \to 0, \varphi \to 0 \text{ at } \eta \to \infty \tag{13}$$

Where M= $\frac{\sigma {B_0}^2}{\rho a}$, $\lambda = L\left(\frac{a}{2V}\right), \gamma = \frac{c}{a}, \xi = k_1\left(\frac{a}{2V}\right), \beta = k_2\left(\frac{a}{2V}\right)$, Sc= $\frac{V}{D_B}$, Pr = $\frac{Vf}{\alpha f}$, $R = \frac{16\sigma^* T_\infty^3}{3k*kf}$

are the patient parameters.

$$A_1 = \frac{1}{(1-\phi_1)^{2.5}\,(1-\phi_2)^{\,2.5\prime}}$$

$$A_2 = (1-\phi_2)\,[(1-\phi_1) + \phi_1(\frac{\rho_{s1}}{\rho_f}) + \phi_2\,(\frac{\rho_{s2}}{\rho_f})]$$

$$A_{3=}(1-\phi_2)\,[(1-\phi_1) + \phi_1(\frac{(\rho c_p)_{s1}}{(\rho c_p)_f}) + \phi_2\,(\frac{(\rho c_p)_{s2}}{(\rho c_p)_f})]$$

$$A_4 = \frac{k_{hnf}}{k_f} \tag{14}$$

Introducing $f' = p, p' = q, g = \theta, g' = t, s = \phi, s' = n$

The non-linear ODE's are reduced to linear form. Further by introducing finite differences concept and using Newton's method the ODE's are reduced to system of linear equations. These equations are solved by using LU decomposition method.

The hybrid nanofluid's density, thermal conductivity, dynamic viscosity, and heat capacity are listed as follows

Properties	**Hybrid Nanofluid**
Density	$\rho_{hnf} = (1-\phi_2)\,[(1-\phi_1)\rho_f + \phi_1\rho_{s1} + \phi_2\rho_{s2}$
Heat capacity	$(\rho c_p)_{hnf}$=$(1-\phi_2)\,[(1-\phi_1)\left(\rho c_p\right)_f + \phi_1\left(\rho c_p\right)_{s1} + \phi_2\,(\rho c_p)_{s2\prime}]$
Dynamic viscosity	$\mu_{hnf} = \frac{\mu_f}{(1-\phi_1)^{2.5}\,(1-\phi_2)^{\,2.5\prime}}$
Thermal conductivity	k_{hnf}=$k_f * (\frac{k_{s1}+2k_f-2\phi_1(k_f-k_{s1})}{k_{s1}+2k_f+2\phi_1(k_f-k_{s1})} * (\frac{k_{s2}+2k_{nf}-2\phi_2(k_{nf}-k_{s2})}{k_{s2}+2k_{nf}+2\phi_2(k_{nf}-k_{s2})}),$

The Skin-friction coefficient $C_{fx} = \frac{\tau_w}{\rho {U_w}^2}$,

The Nusselt number $Nu_x = \frac{xq_w}{k_f(T_w - T_\infty)}$,

The Sherwood number $Sh_x = \frac{xq_m}{D_B(C_w - C_\infty)}$ (15)

Where $\tau_w = \mu_{hnf}\,(\frac{\partial u}{\partial y})\ at\ y = 0,\quad q_w = -k_{hnf}\,(\frac{\partial T}{\partial y})\ at\ y = 0,$
$q_m = -D_B\,(\frac{\partial C}{\partial y})\ at\ y = 0$

Parameters skin friction coefficient, Nusselt number, and Sherwood numbers are transformed to

$\sqrt{Re}\,C_{fx} = \frac{f''(0)}{(1-\phi_1)^{2.5}(1-\phi_2)^{2.5}}, \frac{Nu_x}{\sqrt{Re}} = -(`1+R)A_4\theta'(0),$

$\sqrt{Re}\,Sh_x = -\varphi'(0)$

Where, $Re = \frac{xU_w}{V_f}$.

Table 1: Thermo physical properties of fluid and nanoparticles.

Physical properties	**Fluid (Water)**	**Cu**	**Al_2O_3**
Density(ρ)	997.1	8933	3970
Specific heat(C_p)	4179	385	765
Thermal conductivity(k)	0.613	400	40

Table 2: Comparison of $-\theta'(0)$ values for $\phi_1 = \phi_2 = 0$

Pr	**Waini *et al.*[31]**	**Sreedevi *et al.*[7]**	**Present results**
6.13	1.759682	1.759676	1.795791
7.0	1.895400	1.895397	1.899018
20.0	3.353902	3.353915	3.355597

Table 3: Comparison of -θ'(0) values for ϕ_1=ϕ_2=0

ϕ_1	ϕ_2	**M**	**Pr**	**R**	$f''(0)$	$-\theta'(0)$	$-\phi'(0)$
0.01	0.01	0.1	6.2	0.1	-1.292188	1.194424	-0.392645
0.05	0.01	0.1	6.2	0.1	-1.247801	0.846969	-0.395998
0.01	0.01	0.1	6.2	0.1	-1.292188	1.194424	-0.392645
0.01	0.05	0.1	6.2	0.1	-1.417818	1.162789	-0.393549
0.01	0.01	0.1	6.2	0.1	-1.292188	1.194424	-0.392645
0.01	0.01	0.2	6.2	0.1	-1.428469	1.494002	-0.395338
0.01	0.01	0.1	6.2	0.1	-1.292188	1.194424	-0.392645
0.01	0.01	0.1	7	0.1	-1.428469	1.439649	-0.395338
0.01	0.01	0.1	6.2	0.1	-1.292188	1.194424	-0.392645
0.01	0.01	0.1	6.2	0.5	-1.428469	1.986530	-0.395338

Table 1 denotes the thermo physical properties of the base fluid and nanomaterials used. **Table 2** denotes a comparative study of the Nusselt number for increasing observations of the Prandtl number. As the Nusselt number is a function of the Prandtl number so Nusselt number increases proportionately with enhanced values of the Prandtl number. Results are fairly in agreement with existing Literature. **Table 3** denotes Local parameter observations for distinct observations of Magnetic parameter, Prandtl number, Radiation constraint and volume fraction of nanoparticles. It is observed that for increasing

observations of the Magnetic parameter, Prandtl number, and Radiation parameter, Skin friction and Sherwood number decreases and the Nusselt number increases. Also, for enhanced observations of nanoparticle volume fraction parameter observations increment in skin friction and decrement in Nusselt number and Sherwood numbers are noted. To validate the numerical method a comparative study of calculating -$\theta'(0)$ for various values of Prandtl number, a good correlation is observed between existing values and present results. Also, skin friction, Nusselt number, and Sherwood numbers are calculated for various parameters. For increasing values of Magnetic parameter skin friction, Sherwood numbers decrease and Nusselt number increases. Also, for higher values of Prandtl number, radiation parameter skin friction and Nusselt number decreases and Sherwood number increases.

3. Results and Discussion

The influence of various parameters is analysed by constructing profiles of velocity, thermal and concentration using MATLAB.

Figure [2,3] represents velocity profiles of volume fraction of alumina and copper it is observed that for enhanced values of volume fraction parameter velocity decreases, because for rising standards of nanoparticle volume fraction parameter thickness of the momentum boundary layer decreases

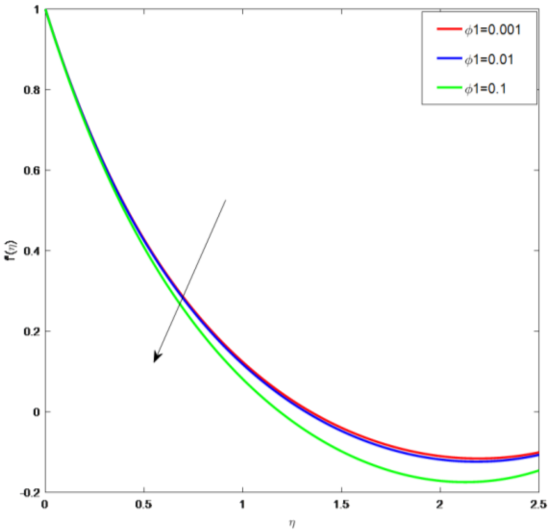

Figure 2: Velocity profiles of ϕ_1.

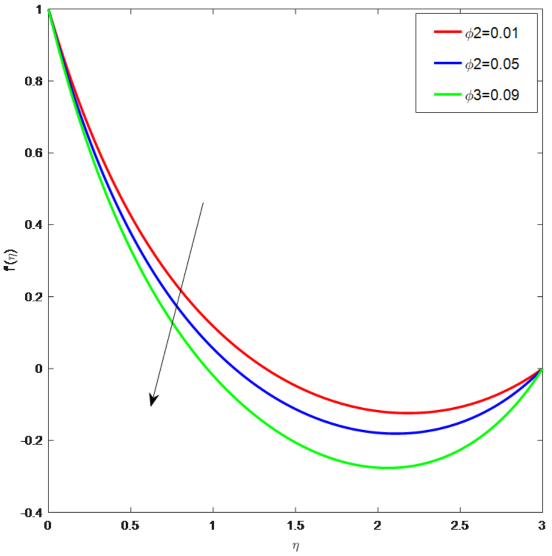

Figure 3: Velocity profiles of ϕ_2

Figure [4] depicts velocity profiles of the Magnetic parameter M, for stronger values of M, an opposing force known as the Lorentz force is produced by the magnetic field. The resulting velocity of the fluid reduces.

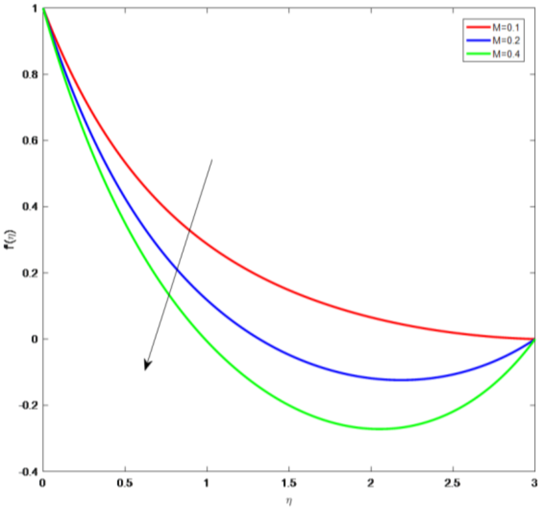

Figure 4: Velocity profiles of M

Figure [5] portrays velocity profiles of the suction parameter. For progressive standards of suction parameter, it causes a reduction in boundary layer thickness so the velocity of the fluid decreases.

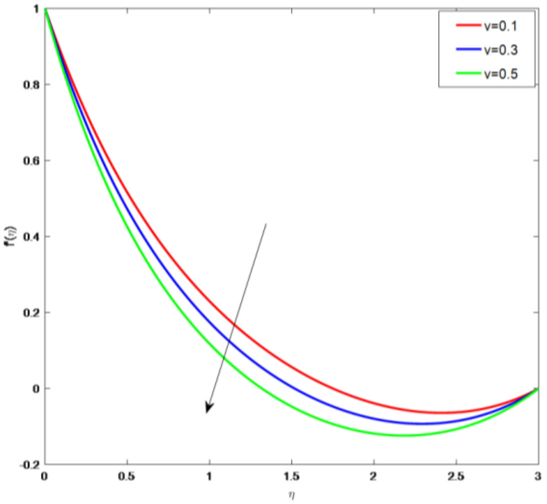

Figure 5: Velocity profiles of V.

Figure [6] represents velocity profiles of the velocity slip parameter. It is noted that for increasing standards of velocity slip parameter, slip velocity increases so the velocity of fluid rises.

Figure [7,8] shows temperature profiles of volume fraction of alumina and copper, it is well-known that temperature increases due to higher values of nano particle volume fraction parameter values strengthen the thickness of the thermal boundary layer.

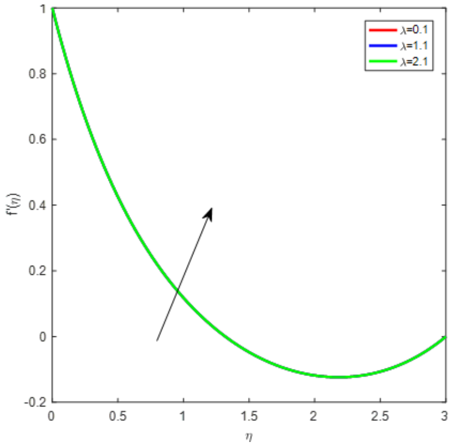

Figure 6: Velocity profiles of λ.

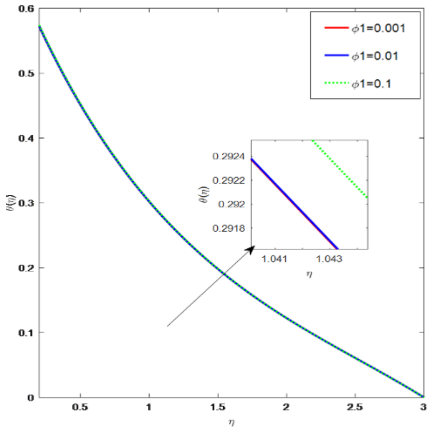

Figure 7: Temperature profiles of ϕ_1.

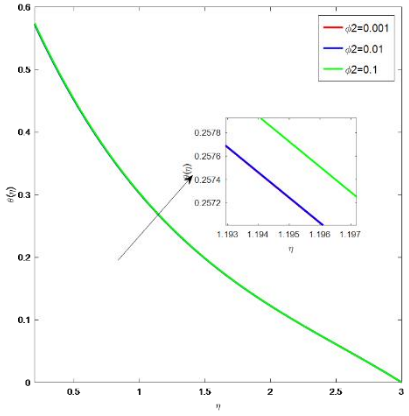

Figure 8: Temperature profiles of ϕ_2

Figure [9] depicts temperature profiles of Prandtl number, for higher values of Prandtl number thermal conductivity of fluid reduces, so temperature shows decreasing tendency.

Figure [10] represents temperature profiles of radiation. For higher values of radiation, more heat will be generated with this effect temperature of the fluid increases.

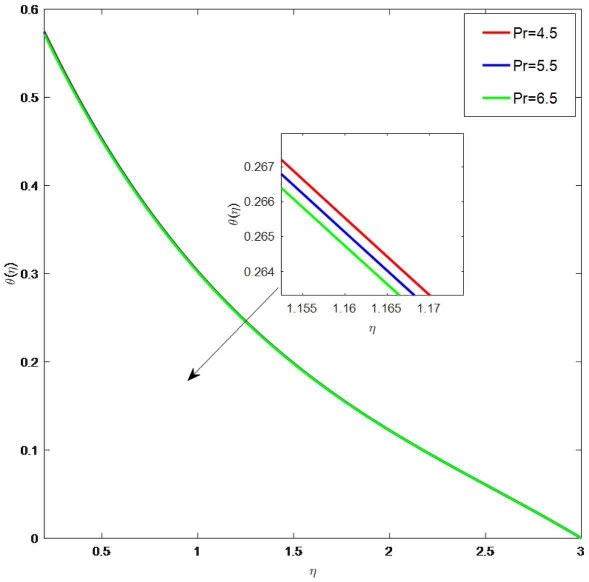

Figure 9: Temperature profiles of Pr.

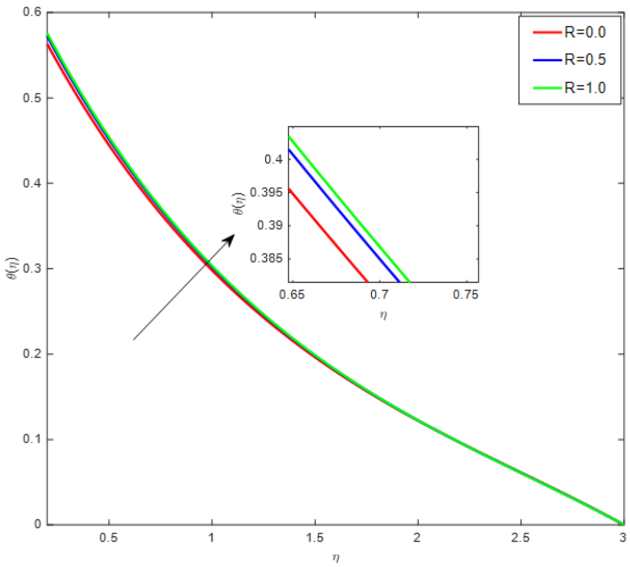

Figure 10: Temperature profiles of R.

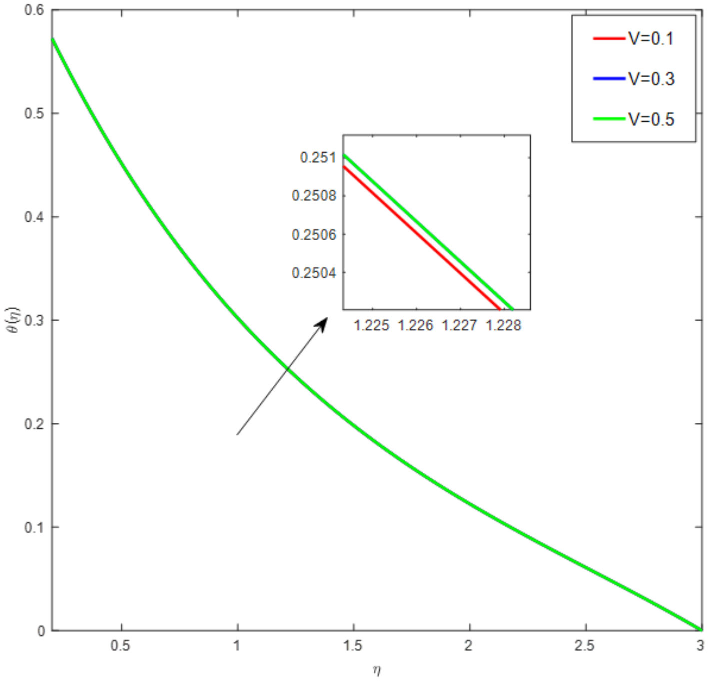

Figure 11: Temperature profiles of v.

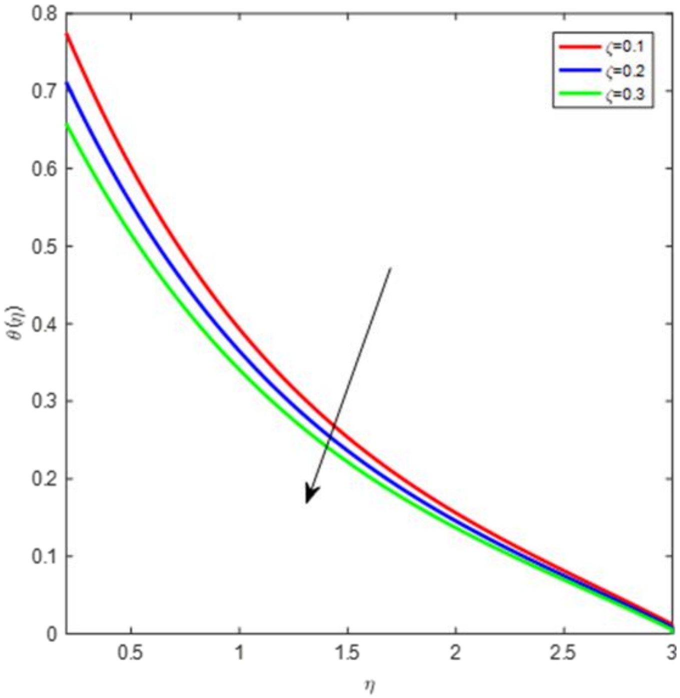

Figure 12: Temperature Profiles of ζ.

Figure [11] displays temperature profiles of suction parameter increasing suction parameter temperature of fluid increases. Figure [12] represents temperature profiles of the thermal slip parameter. It is noted that for higher values of thermal slip parameter temperature was found to be decreasing. For higher values of the thermal slip parameter resisting force near the stretching surface reduces so the temperature of the fluid reduces.

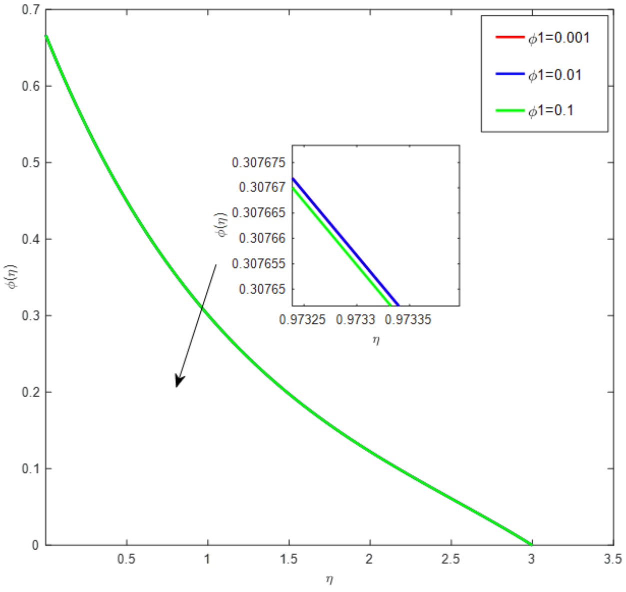

Figure 13: concentration profile for ϕ_1.

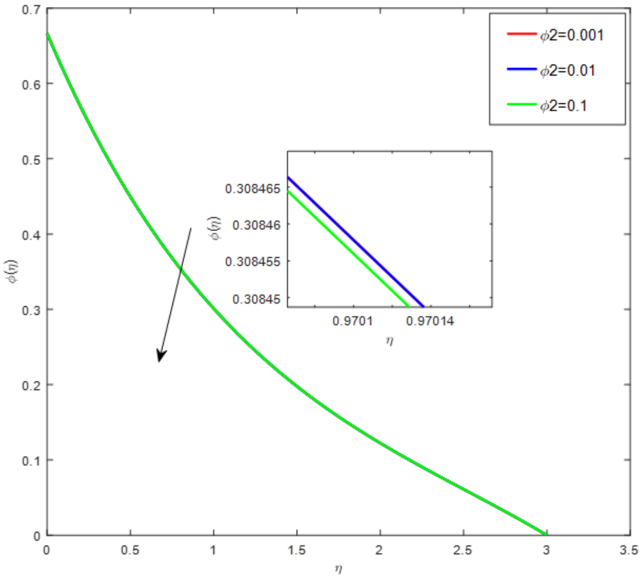

Figure 14: Concentration profiles of ϕ_2.

Concentration profiles of the volume fraction of alumina and copper are mentioned in Figure [13,14]. For higher values of volume fraction of alumina concentration decrement in width of concentration boundary layer hence the concentration of fluid decreases.

Figure [15] explains about concentration profiles of Schmidt number. Escalating values of the Schmidt number lead to an increase in viscosity so the concentration of fluid decreases. Figure [16] portrays concentration profiles of the velocity slip parameter. For intensifying values of the velocity slip parameter.

Figure [17] represents the concentration profiles of the suction parameter. For higher values of suction, thickness of the concentration boundary layer deteriorates, hence concentration of fluid decreases.

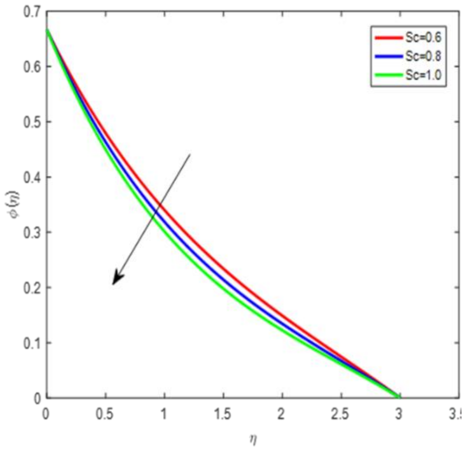

Figure 15: Concentration profiles of Sc.

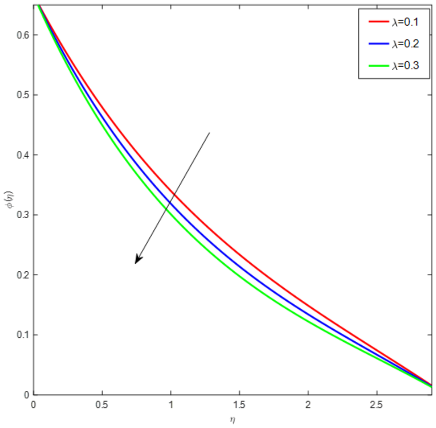

Figure 16: Concentration profiles of λ.

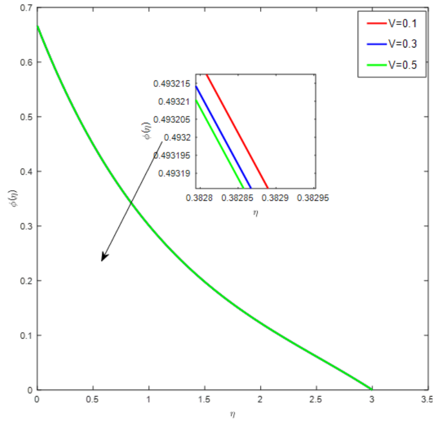

Figure 17: Concentration profiles of V.

Conclusion

In the present study and hybrid nanofluids flow unevenly in a two-dimensional barrier layer across a permeable stretching sheet. With radiation effect by considering Al2O3-Cu/water hybrid nanofluid flow along with slip effects is considered. The effects of various parameters are studied by constructing velocity, temperature and concentration profiles using MATLAB. The following conclusions are drawn.

- A decreasing tendency is noted in velocity profiles of nanoparticle volume fraction parameters of alumina and copper, Magnetic parameter, and suction parameter, and the reverse trend is noted in the case of the velocity slip parameter.
- Enhancement in temperature profiles is noted for nanoparticle volume fraction parameter, radiation parameter, velocity slip parameter and decrement trend is noted in Prandtl number, thermal slip parameter
- Decrement in concentration profile is noted in the case of nanoparticle volume fraction parameters of alumina and copper, Schmidt number, and velocity slip parameter.

NOMENCLATURE

u, ϑ	Velocity components in x, y directions
υ_{nf}	Kinematic viscosity of nanofluid
σ	Electrical conductivity
$B(x)$	Magnetic field strength
ρ_f	Density of fluid
U_w	Stretching sheet velocity
V_w	mass flux velocity
T_w	Temperature of the stretching sheet
k	Thermal conductivity
c_p	Specific heat
q_r	Radiative heat flux
D_B	Brownian diffusion parameter
ϕ_1, ϕ_2	Volume fraction parameters of nano particles
M	Magnetic parameter
V	Suction parameter
λ	Velocity slip parameter
Pr	Prandtl number
R	Radiation parameter
ζ	Thermal slip parameter
β	Concentration slip parameter
Sc	Schmidt number
γ	stretching constant

Conflict of interests

No.

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