JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 2, 2022, p. 2589 - 2599
https://publishoa.com
ISSN: 1309-3452

Impact Of Variable Viscosity Mhd Convective Heat Transfer Of Ethylene Glycol-Cuo Nanofluid Past Stretching Surface

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ABSTRACT

We investigate the effects of variable viscosity and dissipation, diffusion of thermal, and hydromagnetic hall current of of glycol-based Cu nanofluids through a stretched surface in the existence of a heat generating/absorbing source, combined impact. The equations have been solved numerically. The flow characteristics have been analyzed for different parametric variations. It has been observed with increase in the viscosity parameter □ and C enhance in the boundary layer.

Keywords: Hall Effects, Variable Viscosity, Non-linear thermal radiation, Nanofluid, Stretching Surface, Partial Slip

1. INTRODUCTION

The continuous examination seeing as the time then, at that point, has reached out to usage of nano-fluids in micro-electronics, energy units, drug processes, crossover controlled & motors cool, means of transportations, warm administration, homegrown cooler, atomic reactor coolant, crushing, machining, space innovation, resistance and boats, and evaporator pipe gas temperature decrease [3]. Indisputably, the nanofluids are more stable and have acceptable viscosity and better wetting, spreading, and dispersion properties on a solid surface are analysed several authors [[4,7,8,12,13,23, 30,39], which is being used by also many current researchers ([14,15, 24,35,29]) have been reported to thermal and rheological properties.

For the combination of very low subatomic weight (hydrogen-helium) and medium subatomic weight (nitrogen-air) gases, the thermal effect of dispersion is considered to be so high that it cannot be excluded [16]. Alam et al[5] focused on the results of Dufour and Sourt on coherent convection and mass exchange flow in a nearly infinitely permeable vertical plane in a permeable medium. Many inventors (5, 6, 16, 19-21, 26, 32, 37, 41) consider the thickness and temperature of the fluid to accurately predict flow velocity and thermal motion.

It is important to note that the MHD has historically developed an interest in blocking or ignoring the limit position on a continuously moving disk with respect to the decoy field influenced by the Hall current. The MHD analysis with Hall Effect related have been thoroughly described to several researchers [1, 2, 10, 21, 26, 28, 30, 33, 34, 39, 40]. Mahanthesh *et al.* [18], Mustafa *et al.* [22], Anuradha et al [8], Sudhakara Reddy [38] debate a non linear stretching in the existence of Soret and Dufour effect with magnetite water and the pressure of non-linear thermal radiation on three dimensional steady flow of a nanofluid past.

At the present, the variable viscosity, Hall Effect, heat sources on non linear transmission heat transfer flow of Ethylene Glycol- Cuo nano fluid past stretching sheet effects. The resulting is numerically workout. The rate, temperature(θ), and concentration(C), Skin friction, Nusselt(Nu) and Sherwood(Sh) Numbers were showed in figures and table.

2. PROBLEM OF FORMULATION

We judge the consistent free- convective stream, mass&hotness replace of an concrete, gooey and electrifying be in control of liquid beyond an stretching-sheet extended with a speed relative to separation commencing a proper beginning O(Fig.1). A consistent solid attractive ground of solidarity B_0 is forced beside the ypivot.

Where is characterized as the Hall current boundary. An extremely fascinating reality, shock of Hall-current leads to power on z-heading

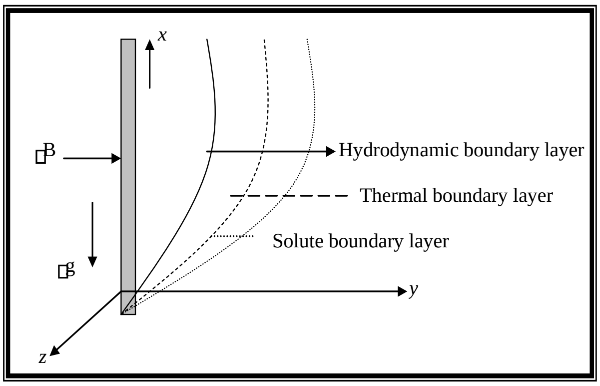

Fig. 1 : Physical System and Geometry of the Problem

whichever thusly creates a cross-stream speed toward already stated path & afterward, stream look right now three-layered. Temperature and species fixation sustain at surface approved consistent levels Tw, Cw and T□ and C□ are decent ratings left from the outside.

Assuming the flowing thickness □ varies as the inverse of a linear role of warmth, as shown below

$$\frac{1}{\mu}=\frac{1}{\mu_\infty}[1+\gamma_0(T-T_\infty)]$$

$$\frac{1}{\mu_\infty}=a(T-T_\infty) \qquad (1)$$

$$a=\frac{\gamma_0}{\mu_\infty} \text{ and } T_r=T_\infty-\frac{1}{\gamma_0} \qquad (2)$$

Because of the above presumptions, the limit layer free convective stream with mass vehicle and the summed up Ohm's law and Rossland guess administering conditions with Hall current impact are

□u □v
—— □ —— □0 (3)
□x □y

□nf □□□u□□ux □v□□uy□□□□□nf —— } □□y2u2 □(□□)nf g T T□ □ □□ (4)

□nf B02
□1 —— □m2 (u mw□)

□nf □□□u□□wx □v□□wy□□□□□nf □□y2u2 □□1□nf mB022 (mu w□) (5)

p nf —— —— nf —— 2 H □ nf —— □y

(□C) (u□T □v□T) □k □T 2 □Q (T□T) □□ (u 2 □w2) □□(qr) □ 0 (6)
□x □y □y

$$u\frac{\partial C}{\partial x}+v\frac{\partial C}{\partial y}=D_m\frac{\partial^2 C}{\partial y^2}-k_0\left(C-C_\infty\right)+\frac{D_mK_T}{T_m}\frac{\partial^2 T}{\partial y^2} \qquad (7)$$

somewhere (u, v, w) exist rate mechanism (x, y, z) length. Dm, K_T, C_s, Q_1', C_p, T_m are solution diffusivity, thermal diffusion ratio, concentration susceptibility, specific heat at constant pressure, coefficient of radiation absorption and mean fluid temperature respectively.

The relevant conditions are

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$$u=bx+A'_{11}\frac{\partial u}{\partial y},\ v=w=0,\ T=T_w,\ C=C_w \quad \text{at } y=0 \qquad (8)$$

$$u\to 0,\ w\to 0,\ T\to T_\infty,\ C\to C_\infty \quad \text{at} \quad y\to\infty \qquad (9)$$

According to reference Mustafa[22] Nanofluids were clear followed to below properties:

$$\left.\begin{array}{l} \mu_{nf}=\mu_f/(1-\phi)^{2.5} \qquad \alpha_{nf}=\dfrac{k_{nf}}{(\rho C_p)_{nf}} \qquad \rho_{nf}=(1-\phi)\rho_f+\phi\rho_s \\ (\rho C_p)_{nf}=(1-\phi)(\rho C_P)_f+\phi(\rho C_P)_s \qquad (\rho\beta)_{nf}=(1-\phi)(\rho\beta)_f+\phi(\rho\beta)_s \\ k_{nf}=\dfrac{k_f(k_s+2k_f-2\phi(k_f-k_s)}{(k_s+2k_f+2\phi(k_f-k_s)} \end{array}\right\} \qquad (10)$$

The nanofluid of the thermophysical spectacles were given in Table 1.

Physical Properties	**Fluid phase (Ethylene Glycol)**	**CuO (Copper))**	**Al2O3 (Alumina)**	**T_iO_2 (Titanium dioxide)**
Cp(j/kg K)	2415	385	765	686.2
ρ(kg m^3)	1110	8933	3970	4250
k(W/m K)	0.26	401	40.00	8.95
βx10^{-5} 1/k)	57.00	1.67	0.630	0.85
σx10^7	1.07	5.96	1.0x10^3	0.85x10^3

The non-dimensional temperature $\theta(\eta)=\dfrac{T-T_\infty}{T_w-T_\infty}$ can be simplified as

$$T=T_\infty(1+(\theta_w-1)\theta) \qquad (11)$$

where $\theta=\dfrac{T_w}{T_\infty}$ is the temperature parameter (12)

Under the dimensionless variable

$$u=bxf'(\eta);v=-\sqrt{bv}f(\eta);w=bxg(\eta);$$
$$\eta=\sqrt{\frac{b}{v}}y;\theta(\eta)=\frac{T-T_\infty}{T_w-T_\infty};\phi=\frac{C-C_\infty}{C_w-C_\infty} \qquad (13)$$

the Eqs. (4)-(7) shrink to

$$\left(\frac{\theta-\theta_r}{\theta_r}\right)(f'-f\ f'')+(\frac{1}{A_1A_3})f'''-\left(\frac{\theta'}{\theta-\theta_r}\right)f''-$$
$$\left(\frac{\theta-\theta_r}{\theta_r}\right)(\frac{A_4}{A_3})G(\theta)+\frac{A_6}{A_3}M^2\left(\frac{\theta'-\theta_r}{\theta_r}\right)\left(\frac{f'+mg}{1+m^2}\right)=0 \qquad (14)$$

$$\left(\frac{\square\square\square_r}{\square_r}\right)\square fg'\square fg'\square\square(\frac{1}{A_1A_3})g''\square\square\left(\frac{\square\square'}{\square\square\square_r}\right)g'\square\frac{A_6}{A_3}M^2\left(\frac{\square\square\square_r}{\square_r}\right)\left(\frac{mf'\square g}{1\square m^2}\right)\square 0 \qquad (15)$$

$$Rd((1\square(\square_w\square 1)\square)^3)\square')'\square\Pr Q\square\square\frac{Ec\Pr}{A_5}(f''^2\square g'^2)\square$$
$$\square\frac{EcA_6\Pr M^2}{A_5(1\square m^2)}(f'^2\square g^2)\square 0 \qquad (16)$$

$$C''\square Sc(fC'\square\square C)\square\square ScS_0\square'' \qquad (17)$$

Where □

$$A_1=(1-\varphi)^{2.5}\quad A_2=\frac{k_{nf}}{k_f},\quad A_3=1-\varphi+\varphi(\frac{\rho_s}{\rho_f}),A_4=1-\varphi+\varphi((\frac{(\rho\beta)_s}{(\rho\beta)_f}),A_5=1-\varphi+\varphi\frac{(\rho C_P)_s}{(\rho C_P)_f}$$

A_6 □□(1 3(1□□□)),□ □ s
(□ □2) □ f (19)

Modified setting are the

$$f'(\eta)=1+A_{11}f''(\eta),f(\eta)=0,g(\eta)=0,\theta(\eta)=1,C(\eta)=1\text{ at }\eta=0\qquad(18)$$

$$f'(\eta)\rightarrow 0,\ g(\eta)\rightarrow 0,\ \theta(\eta)\rightarrow 0,C(\eta)\rightarrow 0\text{ at }\eta\rightarrow\infty$$

dimensionless parameters are in the Eqs. (14)-(17) are sequence as □r □ Tr □T□ □□□ 1□ □ ,
T_w □T□□□□0(T_w □T□)□□

M □ □PBb02 , ,□□kb0 (Cw □C□) , Pr □ □Ckpv G□ g0□T(bT2w□T□) , N□□□CT(Cw□C□□) , Nr□ kk30 □ , S0 □Dms KpT ,

□ x (Tw□T) 4T□ □ C C

Sc□ □ , Q□ QH , Ec□ □2 , Rd □ 4□□T□3 ,m□ □Bo are viscosity, magnetic,
□□D □□Cpb (Tw □T□)Cpb 3□Rk f enc

chemical reaction parameters, Prandtl number Grashof number, Buoyancy ratio, thermal radiation, Soret parameter, Schmidt number , heat generation / absorption, Eckert number, radiation parameter and Hall parameter respectively.

3. NUMERICAL PROCEDURE

The coupled ordinary differential equations (14)-(17) have been numerically proved by 5thorder Runge-Kutta-Fehlberg unification format with mechanical grid generation format which ensures combining at a closer rate.

4. SKIN FRICTION(C_f), NUSSELT(Nu) AND SHERWOOD(Sh) NUMBERS

The non dimensional Skin friction, rate of heat and mass transfer at the boundary □=0 are given by

Cf □ □□ w bv □ f □□(0), Nu□ b (Tq□ww □T□) , Sh □ D bv (Cmww □C□) □ □C□(0) (20) bx k v

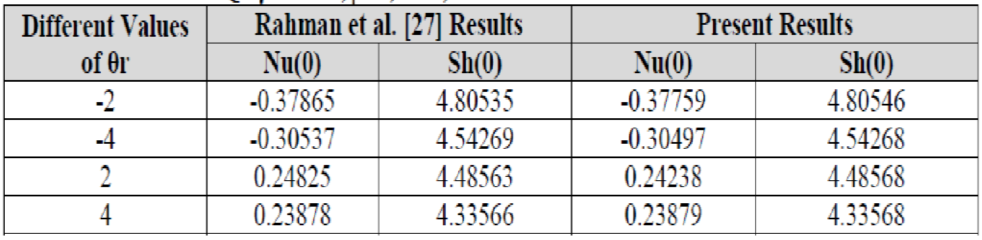
5. COMPARISON

The consequence values of References [36 & 27] the outcomes are in good concurrence given below.

Table 1a.Comparison of Nu and Sh at η=0 with Shit et al. [36] with S_0=0,Ec=0,ϕ=0,A=0,A11=0

M	Rd	γ	Q	θr	Shit et al.[36]Results		Present Results	
					Nu(0)	Sh(0)	Nu(0)	Sh(0)
0.5	1	0.5	0.5	-2	-0.6911	0.6267	-0.69047	0.62433
1.5	1	0.5	0.5	-2	-0.6973	0.6544	-0.69456	0.65236
0.5	3	0.5	0.5	-2	-12.3749	0.9279	-12.3699	0.91999
0.5	1	1.5	0.5	-2	-0.6952	1.0957	-0.6925	1.09124
0.5	1	-0.5	0.5	-2	-0.6964	0.4899	-0.69345	0.48787
0.5	1	0.5	1.5	-2	-0.6962	0.4247	-0.69235	0.41437
0.5	1	0.5	1.5	-2	-0.5970	0.4075	-0.59465	0.40529
0.5	1	0.5	1.5	-4	-0.6962	0.6256	-0.69566	0.62149

Table 1b Comparison of Nu and Sh at η=0 with Rahman et al. [27] with Pr=0.71, $m= S_0 = 0$, $Rd=Q=\gamma=Ec=0,\phi=0,A=0,A11=0$ for different values of θr



Different Values of θr	Rahman et al. [27] Results		Present Results	
	Nu(0)	Sh(0)	Nu(0)	Sh(0)
-2	-0.37865	4.80535	-0.37759	4.80546
-4	-0.30537	4.54269	-0.30497	4.54268
2	0.24825	4.48563	0.24238	4.48568
4	0.23878	4.33566	0.23879	4.33568

6. RESULTS AND FINDINGS

The combined effects of nonlinear thermal radiation, partial slip, dissipation, variable viscosity effects, Hall currents for hydromagnetic free convection, and heat and mass transfer in glycol-based Cuo nanofluids in the presence of stretched surfaces have been investigated. Heat
generation/absorption is discussed. The conclusion of this analysis are

The Hall-current(*m*): velocities of (*f* □)&(*g*), enhance, temperature (□) and concentration(C) reduce(Fig.2). With enlarge in *m*, skin-friction(Cf_x, Cfz), Nusselt(Nu) and Sherwood(Sh)Number grow in Ethylene Glycol-Cuo nanofluid.
An increase in the radiation parameter(Rd) enhances the (*f* □), (g), □ and reduces (C) (Fig.3). Cf_x, Cfz,Sh increase and Nu reduces with Rd.

Higher the dissipative heat larger *f* □, g, □ and smaller C in entire flow region (Fig.4). Cf_x, Cfz, Sh grow and Nu decay with Ec at the wall.

f □, g enhance and □, C reduce in the border line with upsurge in the nanoparticle
concentration(□)(Fig.5). Cf_x, Cfz,Nu,Sh increase on the wall with □.
f □, g decrease in the region (0,1) and enhance in the region(1,5) alongside upsurge in the θr. Among upsurge in the (θr), □ and C enhance in the boundary layer(Fig.6). Cf_x, Cfz,Sh decrease and Nu enhances with □r on □=0.

Higher temperature ratio(A) smaller the *f* □, g, □ and larger C (Fig.7). Cf_x, Cfz, Sh decrease and Nu enhances with A.

An increase in slip parameter (A11) upsurge in the area (0,1.0) and down in the remaining area. □ and C depreciate in the flow region(Fig.8) . Cf_x reduces Cfz, Nu and Sh enhance on □=0 with A11.

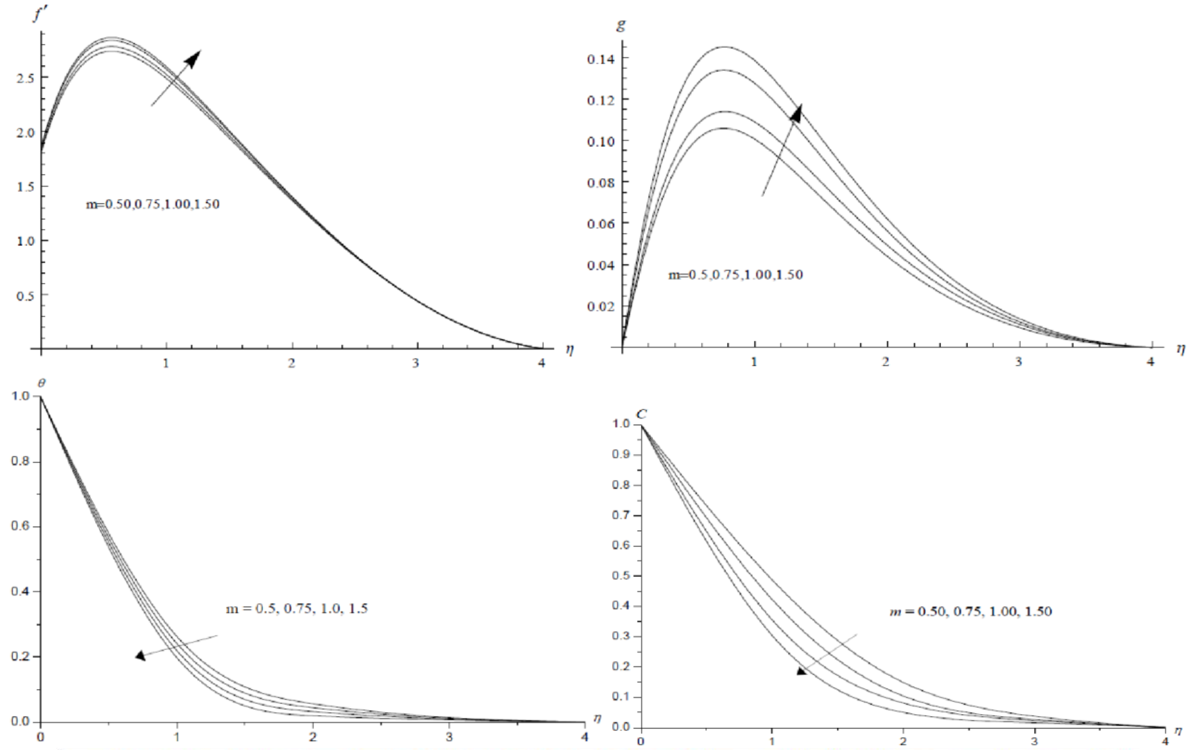


Fig. 2: Variation of [a]Primary velocity(f'), [b] Secondary velocity (g), [c]Temperature(θ), [d]nanoconcentration(C) with m
Rd=0.5, Ec=0.1, A=1.01, A11=0.2, θ_r=-2, ϕ=0.1

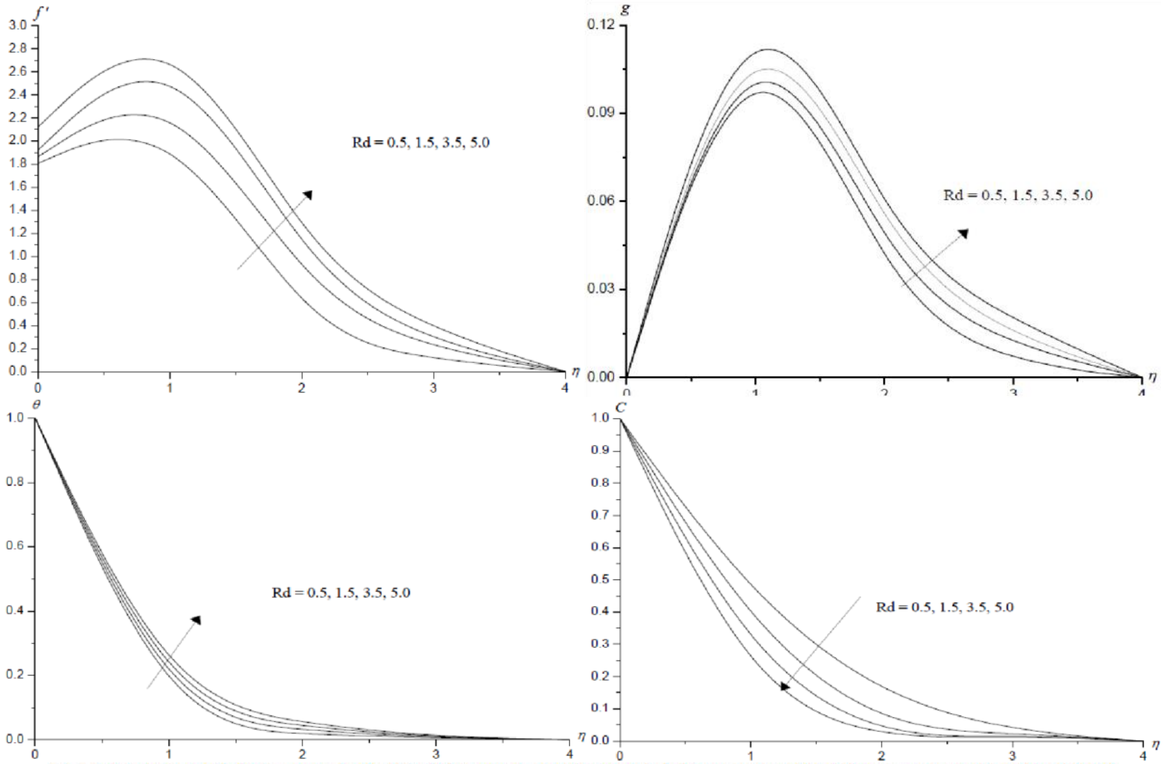


Fig. 3: Variation of [a]Primary velocity(f'), [b] Secondary velocity (g), [c]Temperature(θ), [d]nanoconcentration(C) with Rd
m = 0.5, Ec=0.1, A=1.01, A11=0.2, θ_r=-2, ϕ=0.1

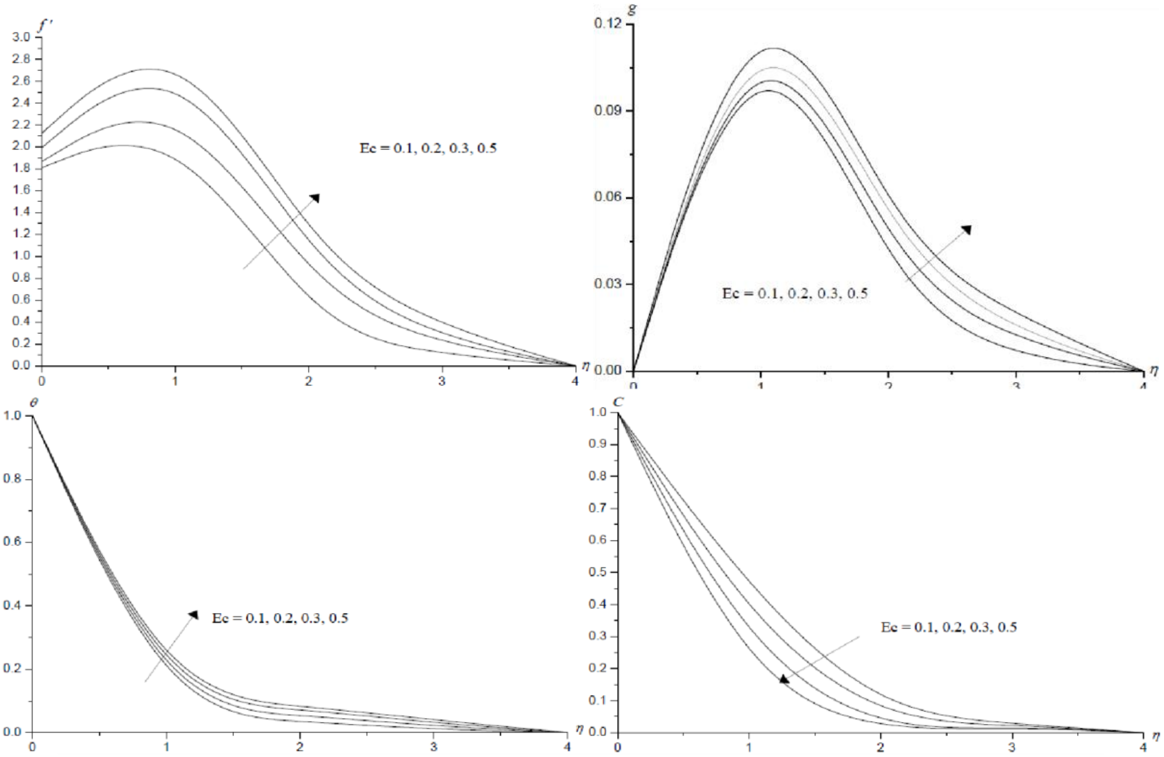


Fig. 4: Variation of [a]Primary velocity(f'), [b] Secondary velocity (g), [c]Temperature(θ), [d]nanoconcentration(C) with *Ec*
$m = 0.5$, Rd=0.5, A=1.01, A11=0.2, θ_r=-2, ϕ=0.1

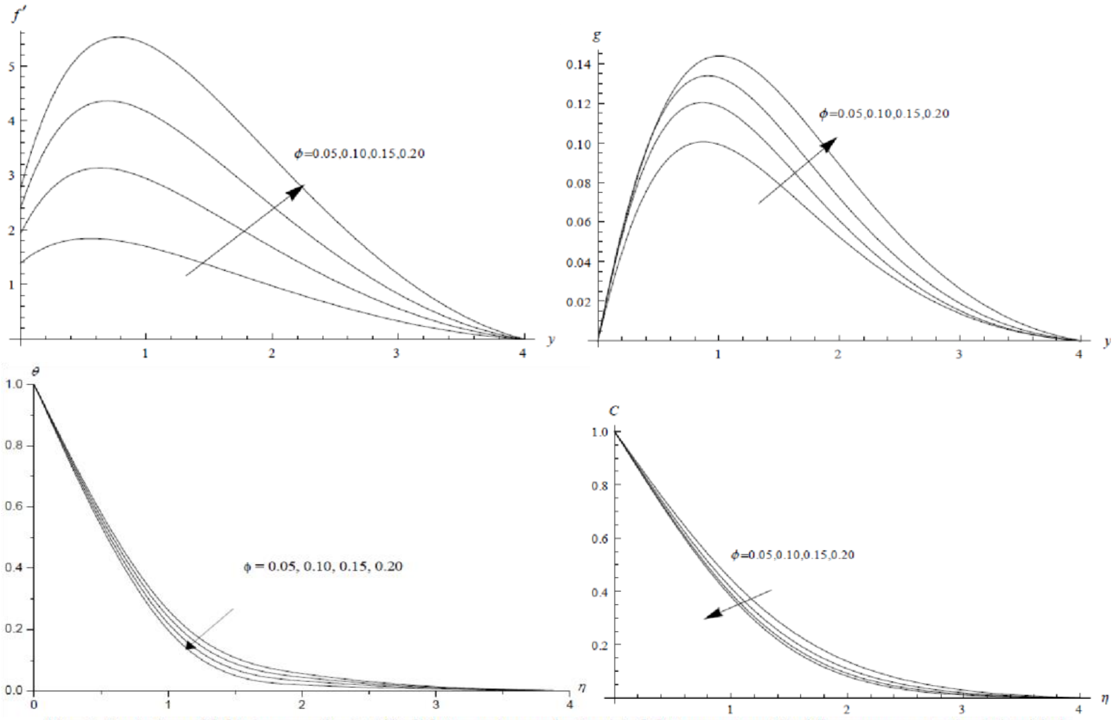


Fig. 5: Variation of [a]Primary velocity(f'), [b] Secondary velocity (g), [c]Temperature(θ), [d]nanoconcentration(C) with ϕ
$m = 0.5$, Rd=0.5, Ec=0.1, A=1.01, A11=0.2, θ_r=-2

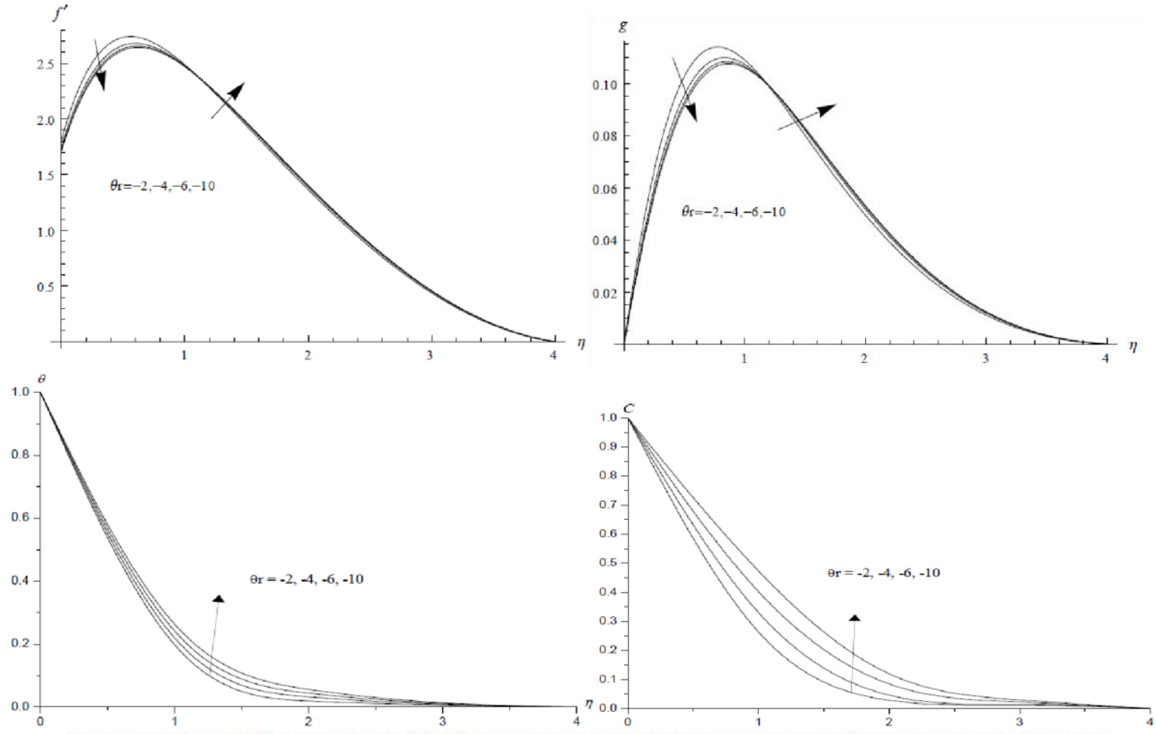


Fig. 6: Variation of [a]Primary velocity(f'), [b] Secondary velocity (g), [c]Temperature(θ), [d]nanoconcentration(C) with θ_r
m = 0.5, Rd=0.5, Ec=0.1, A=1.01, A11=0.2, ϕ=0.1

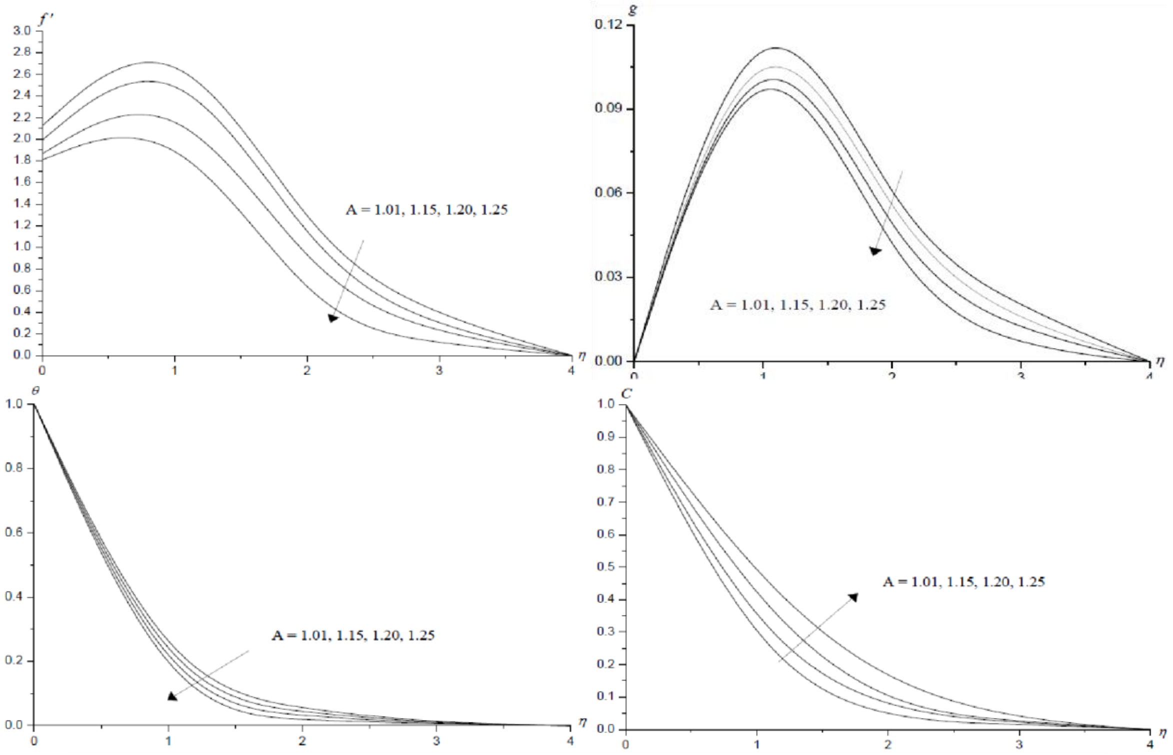


Fig. 7: Variation of [a]Primary velocity(f'), [b] Secondary velocity (g), [c]Temperature(θ), [d]nanoconcentration(C) with A
m = 0.5, Rd=0.5, Ec=0.1, A11=0.2, θ_r=-2, ϕ=0.1

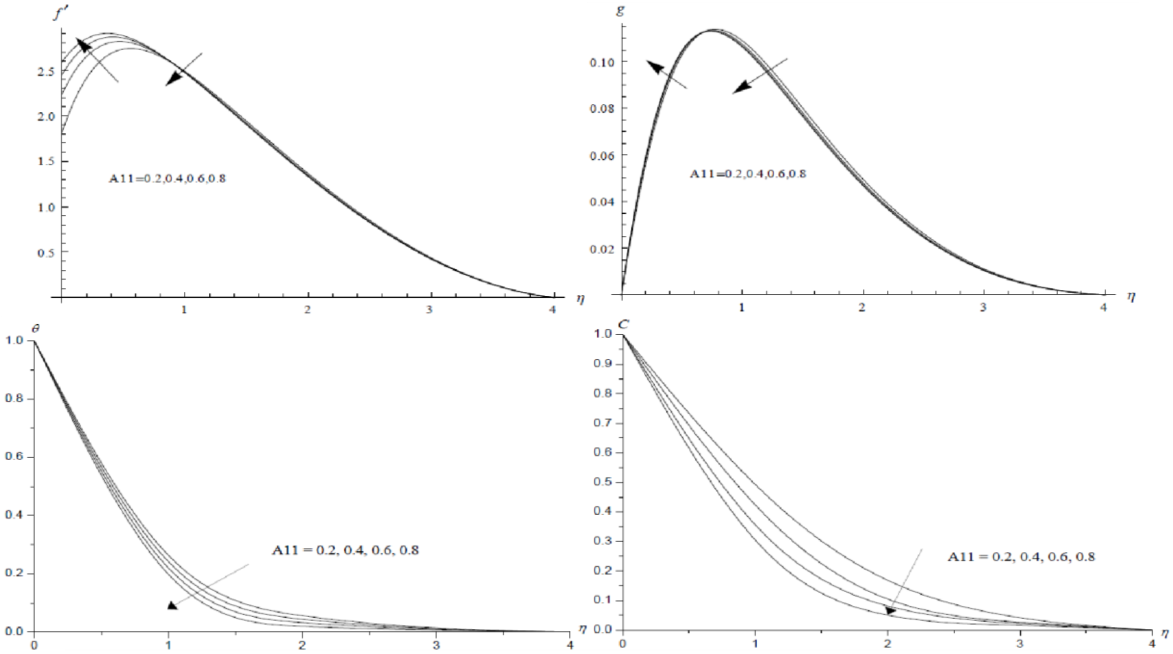


Fig. 8: Variation of [a]Primary velocity(f'), [b] Secondary velocity (g), [c]Temperature(θ), [d]nanoconcentration(C) with A11
m = 0.5, Rd=0.5, Ec=0.1, A=1.01, θ_r=-2, ϕ=0.1

Table–2 Skin Friction(Cf$_{x,z}$), Nusselt(Nu) and Sherwood(Sh) Numbers at □ = 0

Parameter		Cfx(0)	Cfz(0)	Nu(0)	Sh(0)	Parameter		Cfx(0)	Cfz(0)	Nu(0)	Sh(0)
m	0.5	4.04492	0.328518	0.248042	0.608825	□$_□$	-2	4.04492	0.328518	0.248042	0.608825
	0.75	4.13846	0.353634	0.248043	0.613222		-4	3.73872	0.290692	0.248043	0.602503
	1	4.25982	0.386476	0.248055	0.618924		-6	3.62549	0.277399	0.248043	0.600032
	1.5	4.31683	0.405194	0.248103	0.621598		-10	3.56642	0.270606	0.248043	0.598713
Rd	0.5	4.04492	0.328518	0.248042	0.608825	A	1.01	4.04492	0.328518	0.248042	0.608825
	1.5	4.04692	0.328616	0.246757	0.609298		1.15	4.0449	0.328517	0.248063	0.608819
	3.5	4.04785	0.328663	0.246143	0.609524		1.2	4.04486	0.328516	0.248089	0.608811
	5	4.04834	0.328687	0.245833	0.609639		1.25	4.04484	0.328515	0.248105	0.608806
Ec	0.1	4.04492	0.328518	0.248042	0.608825	A11	0.2	4.04492	0.328518	0.248042	0.608825
	0.2	4.04506	0.328525	0.247923	0.608865		0.4	2.93188	0.346196	0.248051	0.624144
	0.3	4.04523	0.328532	0.247805	0.608904		0.6	2.33497	0.354957	0.248054	0.631805
	0.5	4.04534	0.328538	0.247691	0.608942		0.8	1.93708	0.360557	0.248056	0.636725
□	0.05	1.92748	0.260771	0.248041	0.505712						
	0.1	4.60472	0.304916	0.248618	0.650264						
	0.15	6.90033	0.315601	0.249035	0.761482						
	0.2	8.65629	0.300779	0.249361	0.798965.						

7. CONCLUSIONS

Axial and secondary velocities elevate with rise Hall parameter(m), Eckert number(Ec), Radiation(Rd), Nanoparticle concentration (□) and Slip parameter(A11), depreciate with viscosity parameter(□$_r$), Temperature ratio (A). Temperature(□) and nanoconcentration(C) experience depreciation with rising values of m, Rd,□, A, A11 and upsurge with viscosity parameter(□$_r$). Higher dissipation larger the temperature and nanoconcentration in the flow region. Skin friction(□) increases with m, Rd, □ and decreases with □$_r$, A, A11, Nusselt Number(Nu) reduces with Ec, Enhances with higher values of Rd,□$_r$, □, A, A11. Sh upsurge on η=0 by means of rising values of □ & A11.

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