Thermal Slip effects on the Heat transfer enhancement through Nanofluids with Applications in Automobile engines

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Abstract: I investigate the thermal slips effects on the heat transfer through nanofluids as coolant having applications in automobile engines. I observed three types of nanoparticles viz. Titanium dioxide (TiO_2), (CuO) Copper oxide and Aluminum oxide (Al_2O_3). (PDEs) formulated with the boundary conditions are expressed which governs the dynamics of the flow in a engine. Similarity transformations to converts the PDEs into non-linear (ODEs) by using Runge Kutta Fehlberg (RK-5) method to solved boundary value problem. Some physical parameters effect on the profiles of temperature and velocity fields at the boundary are investigated. We will investigate how the thermal slip effects in the car radiator. I achieve that the water based nan fluids with CuO nanoparticles have a heat transfer rate considerable higher than the titanium dioxide nanofluids and aluminum oxide.

Keywords: Applications of nanofluids; Heat Transfer; Better Performance of engine; Thermal Slip effects.

1. INTRODUCTION

In our daily life nanofluids play very important role to help industrial developments in the fields like HVAC, electronic, automotive, and mechanical. To the efficient of energy fluids thermal conductivity and heat transfer material. If nanoparticles mixed with fluid are generally specified by nanofluids. Not with standing, heat commercialized fluids is less as related to the other compact resources. The initial stage who directed learning on mixture and the colors of colloidal gold in 1857, which was Michael Faraday probably. Masuda et al. [1] presented in Early in 1990's, nanometer sized particles in predictable fluid the allied system are very constant when the evaluation of micrometer and millimeter size particle of nanofluid Choi [2] Investigate in Argonne National Laboratory of USA, using base fluids mixed with suspended nanometer particles named as nanofluids. By Addition of base fluid with nanoparticles to highly expands energy in process of the base liquid [3]. Currently nanotechnology produces less than 49nm materials with normal crystallite. When the elements are deferred in the base liquid the resultant of nanofluid some exclusive appearances which distinguish from the predictable two stages flow mixtures which have millimeter or micrometer particles. Lee et al. [4], Choi [1], Eastman [6] Masuda et al.[5], are well known for a researcher in refining the thermal conductivity of nanoparticles. Later Choi [1] many researcher [7-12] has been done the main quantity of nanofluids. Compact particles expand heat conduction in base fluid. Nanoparticles are auspicious coolants because of three assets i.e. their advanced thermal conductivity, advanced only one-point heat transfer, or advanced perilous heat flux. Researcher has verified that usually some procedures of nanoparticles of the instruction of 4.9 percent, then we can recover thermal conductivity of the liquid. This new class heat transfer fluids has shown several distinct assets with the massive improvements in thermal conductivity when related with the liquid [13], temperature and element size requirement [14-15] increase in critical heat flux Distinct and decreased friction coefficient (inorganic [16] and organic) and sorts of nan [17] drag reducing nanofluids, nanofluids by improved heat transfer. Here, we investigate thermal slip effects on the heat transfer enhancement through nanofluids. So we study nanofluids with three kinds of nanoparticles viz., Copper oxide (CuO), Aluminum oxide (Al_2O_3) Titanium dioxide (TiO_2).

2. PROBLEM FORMULATION

Here we have three types of nanoparticles viz., Copper-oxide (CuO), and Titanium (TiO_2), Alumina (Al_2O_3). Moreover, suppose that flow is an incompressible, steady, and laminar flow. The boundary layer 2D convectively intense having 'T_f' as a temperature of the fluid and with heat transfer amount of fluid is 'h_f', the magnetic field is B_0 Moreover we assume the following continuity, energy and momentum equations:

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

$$\bar{u}\ \frac{\partial \bar{u}}{\partial x}+\bar{v}\ \frac{\partial \bar{u}}{\partial y}=\frac{\mu_{naf}}{\rho_{naf}}\frac{\partial^2 \bar{u}}{\partial y^2}+\beta_{naf}\, g'(T-T_\infty)-\frac{\sigma_{nf}\beta_0^2\bar{u}}{\rho_{naf}} (\tag{2}$$

$$\bar{u}\ \frac{\partial T}{\partial x}+\bar{v}\ \frac{\partial T}{\partial y}=\frac{k_{naf}}{(\rho c_p)_{naf}}\frac{\partial^2 T}{\partial y^2}+\frac{\mu_{naf}}{(\rho c_p)_{naf}}\left(\frac{\partial \bar{u}}{\partial y}\right)^2+\frac{\sigma_{naf}\ \beta_0^2\bar{u}^2}{(\rho c_p)_{naf}} (\tag{3}$$

Using these boundary Conditions

$$\bar{u}\left(x,0\right)=U_0,\ \bar{v}\left(x,0\right)=0,\ -\gamma k_{naf}\frac{\partial T}{\partial y}\left(x,0\right)=h_f\left(T_f-T\left(x,0\right)\right), (\tag{4}$$

$$\bar{u}\left(x,\infty\right)=0, \qquad T\left(x,\infty\right)=T_\infty.$$

Here, in Eqs.3.1-3.4 $\bar{u}$ and $\bar{v}$ are the velocities of fluid particles, gravitational acceleration is denotes by g', ρ is the density, μ denotes kinematic viscosity, σ is the Boltzmann constant, and Specific heat constant is c_p ,thermal conductivity is denotes by k , naf abbreviate the term nanofluid, and γ is the thermal slip effect. If we consider that the particles are regularly spread so we can be calculated using these equations:

$$\rho_{naf}=\left(1-\varphi\right)\rho_f+\varphi\rho_s, \tag{5}$$

$$\beta_{naf}=\left(1-\varphi\right)\beta_f+\varphi\beta_s, \tag{6}$$

$$\mu_{naf}=\frac{\mu_f}{\left(1-\varphi\right)^{2.5}} \tag{7}$$

$$\left(\rho c_p\right)_{naf}=\left(1-\varphi\right)\left(\rho c_p\right)_f+\varphi\left(\rho c_p\right)_s (\tag{8}$$

$$\sigma_{naf}=\sigma_f\left[1+\frac{3\left(r-1\right)\varphi}{\left(r+2\right)-\left(r-1\right)\varphi}\right], \tag{9}$$

$$r=\frac{\sigma_s}{\sigma_f}, \tag{10}$$

$$\frac{k_{naf}}{k_f}=\frac{\left(k_s+2k_f\right)-2\varphi\left(k_f-k_s\right)}{\left(k_s+2k_f\right)+\varphi\left(k_f-k_s\right)}, \tag{11}$$

Where in above Eqs from 3.5-3.11, volume fraction of nanoparticles ϕ.So we have following similarity transformations

$$\eta=\left(a/\nu_f\right)^{1/2}y,\quad \psi=\left(a\nu_f\right)^{1/2}xf(\eta),\quad \theta(\eta)=\frac{T-T_\infty}{T_w-T_\infty}. \tag{12}$$

By using similarity transformations in above from Eqs. then we have

$$\begin{aligned}&f'''+(1-\varphi)^{2.5}\left(1-\varphi+\varphi\,\rho_s/\rho_f\right)ff''-(1-\varphi)^{2.5}\left(1-\varphi+\varphi\rho_s/\rho_f\right)f'^2-\\&Ha\left[1+\frac{3(r-1)\phi}{(r+2)-(r-1)\phi}\right](1-\varphi)^{2.5}f'+Gr(1-\varphi)^{2.5}\left(1-\varphi+\varphi\,\beta_s/\beta_f\right)\left(1-\varphi+\varphi\,\rho_s/\rho_f\right)\theta=0,\end{aligned} \tag{13}$$

$$\begin{aligned}&\varphi''+\frac{k_f}{k_{nf}}p_r\left(1-\varphi+\varphi\left(\rho c_p\right)_s/\left(\rho c_p\right)_f\right)f\theta'+\frac{k_fE_c\Pr}{k_{nf}(1-\varphi)^{2.5}}\left(f''\right)^2+\\&\left[1+\frac{3(r-1)\phi}{(r+2)-(r-1)\phi}\right]\frac{k_fHaEc\Pr}{k_{nf}}f'^2=0,\end{aligned} \tag{14}$$

Here, we get in above Eq.4 develops by

$$\begin{aligned}&f(0),\ \theta'(\infty)=0,\ f'(\infty)=0,\ f'(0)=1,\ \theta'(0)=-B_i\gamma\left[\theta(0)-1\right]\\&\text{at } \eta=0, \text{ and at } \eta\to\infty.\end{aligned} \tag{15}$$

Where in above primes characterize derivatives wither to η, Hartmann number is Ha ,Gasthof number is represents by Gr, Prandtl-number is denotes Pr, Eckert number is represents Ec, Bi is Biot number and stated as:

$$\begin{aligned}&Ha=\frac{\sigma_f\beta_0^{\,2}x}{\rho_fU_0},Gr=\frac{\beta_fg\left(T_f-T_\infty\right)}{U_0a},\Pr=\frac{\nu_f}{\alpha_f},\\&Ec=\frac{U_0^{\,2}}{Cp_f\left(T_f-T_\infty\right)},\ Bi=\frac{h_f}{k_f}\sqrt{\frac{\nu_fx}{U_0}}.\end{aligned} \tag{16}$$

The physical quantities, Nu is Nusselt number local and Coefficient C_f of skin friction which are:

$$C_f=\frac{\tau_w}{\rho_fU_0^{\,2}},\qquad Nu=\frac{xq_w}{k_f\left(T_f-T_\infty\right)}, \tag{17}$$

Where in Eq.17, q_w is surface heat flux τ_w is the surface skin friction are expressed as

$$\tau_w=\mu_{nf}\left.\frac{\partial u}{\partial y}\right|_{y=0},\quad q_w=-k_{nf}\left.\frac{\partial T}{\partial y}\right|_{y=0}. \tag{18}$$

We have find out the value of τ_w , q_w against Eq. 18 and putting these standards in above Eq. 1.17 then we have local Nusselt number local Nu_x and C_{fx} of skin-friction and are expressed as below

$$C_{fx} = \mathrm{Re}_x^{1/2} C_f = \frac{1}{(1-\varphi)^{2.5}} f''(0), \tag{19}$$

$$Nu_x = \mathrm{Re}_x^{-1/2} Nu = -\frac{k_{naf}}{k_f}\theta'(0), \tag{20}$$

And the local Reynolds-number is

$$\mathrm{Re} = \frac{\text{Inertial Forces}}{\text{Viscous Forces}}.$$

3. Numerical Result and Discussion

To clarify the set of non-linear equations imperiled to boundary conditions in Eq.15 are existing or conferred. Mathematical tests are completed as changing the different principles of related physical parameters computational researches the mathematical methods of many physical parameters are attained with in Eeqs. (1-11) and the thermophysical assets from the -conductivity these properties from the K.C.K. Vijayakumar and S. Senthil raja [19], for expansion coefficient of water are taken Table 1.1. Here we have nanoparticles, Copper oxide (CuO), Titanium oxide (TiO_2), Aluminum Oxide(Al_2O_3) mixed with water as the base liquid are measured. Table II which shows that the thermophysical assets of water onward to nano particles CuO, TiO_2 and Al_2O_3. For Al_2O_3 density, thermal conductivity k and specific heat constant (c_p) from book [18] as the density of water, specific heat and thermal from [20], the water electrical conductivity (σ) from [21]. For 99.6% of Aluminum quantity of thermal expansion γ from [22]. The electrical conductivity of Al_2O_3 is reserved by *D.* Giancoli [23]. The thermal conductivity, specific heat, density, electrical conductivity amount of thermal extensions for TiO_2 thermal expansion coefficient and the electrical- conductivity for CuO are reversed by book of *R. A.* Segway [24].From figures (1- 8) are shown the things of different physical- parameters on the profiles of temperature. In Fig. 1.1 assessment of heat transfer amount of water with copper oxide is accessible. we have three dissimilar absorption factors of Bi nanoparticles with the different value of γ. Furthermore, the temperature increasingly decreases as the nano-particle absorption of Bi is improved in the nano fluids. In Fig. 2 we observed that if we are increasing the values of Gr it mains to rises in temperature profile. In Fig. 3 shows by rises the Gr and temperature profile is also increasing. Fig. 4 shows that the thermic boundary layer is rises when Hartmann number Ha will be rises. Fig.1.5 show the effects of different nano fluids i.e. Copper oxide CuO, titanium oxide TiO_2 aluminum oxide Al_2O_3 on the profile of temperature boundary layer thickness. We have seen that the nanofluids built on CuO nanoparticles get a more heat transfer amount other than two nanofluids i.e. TiO_2 and Al_2O_3 .However, the rate of heat transfer Al_2O_3 and TiO_2 nanofluids is nearly same. And we can easily see that if we are increasing the values of Bi then the temperature profile will be decreases. In Fig. 6 show the effects of different nanofluids i.e. Copper oxide, TiO_2 and Al_2O_3 on the temperature boundary layer thickness. It is showed that the nanofluids constructed CuO nanoparticles have more heat transfer amount other two nano fluids i.e. Titanium oxide TiO_2 or Aluminum oxide Al_2O_3. However, the amount of heat transfer Aluminum oxide Al_2O_3 and Titanium oxide TiO_2 is nearly similar when the thermal slip effect γ will be increases. In Fig.7 show the effects of distant nanofluids i.e. TiO_2 and Al_2O_3 on the temperature boundary thickness. When the Gr increases then the Copper oxide nanoparticles have a more heat transfer rate other two nanofluids i.e. CuO, TiO_2 and Al_2O_3. In Fig. 8 show the effects nanofluids CuO,

TiO_2 and Al_2O_3 on the temperature it can be show that when Ha rises then temperature profile of the fluid will be increases and clearly shows that the CuO nanoparticles have a more heat transfer amount as related to the particles TiO_2 and Al_2O_3 .The velocity profile in Fig. 9 it can be seen γ vary with aluminum material. If the values of γ is increases the velocity of fluid will be increases. velocity profile show that in Fig.1.10 Ha is varying with aluminum material then the value of Ha is increases we can see that the material Al_2O_3 (Aluminum oxide) will be decreases and viscous dissipation is fixed. The velocity of the fluid show that in Fig 1.11 copper oxide with water varying Bi so it can be seen that when the Bi is increases the copper oxide of nano particles is decreases. In Fig. 12 we can see that the velocity profile of the copper oxide with varying γ. If the γ increases, then the copper oxide of the nano particles is also increasing. The velocity profile in Fig. 13 shows that the nanofluids founded on copper slow velocity as related to other two nanofluids particles TiO_2 and Al_2O_3 .copper oxide nano particles enhance the viscosity of the CuO water the velocity of CuOwater nanofluids will be decreases. In Fig. 14 shows that the velocity profile shows that in TiO_2 material with varying γ, then the γ in rises the velocity of the material is also rises. The velocity of fluid shows in Fig. 15 TiO_2 (titanium oxide) material with varying Ha so it can be seen that the material TiO_2 (titanium oxides) is decreases when the Ha is increases. In Fig. 16 shows i.e. CuO, TiO_2 and Al_2O_3 on velocity profile. We have observed that the based on Copper oxide nanoparticles get a low heat transmission amount in velocity profile than the more two nanofluids so it can be seen that increasing Ha the fluid velocity decreases. In Fig. 17 show that the effects of different nanofluids Copper oxide CuO, TiO_2 , Al_2O_3 on velocity profile. Observed that in velocity profile the nanofluids based on copper oxide nanoparticles have a less heat transfer rate than other two nanofluids when the Ha will be increases.

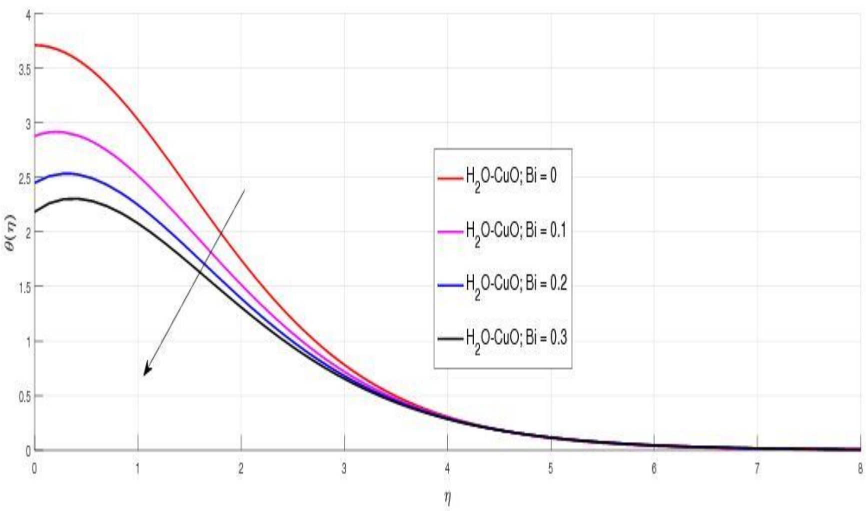

Figure. 1. Temperature profile with varying Bi

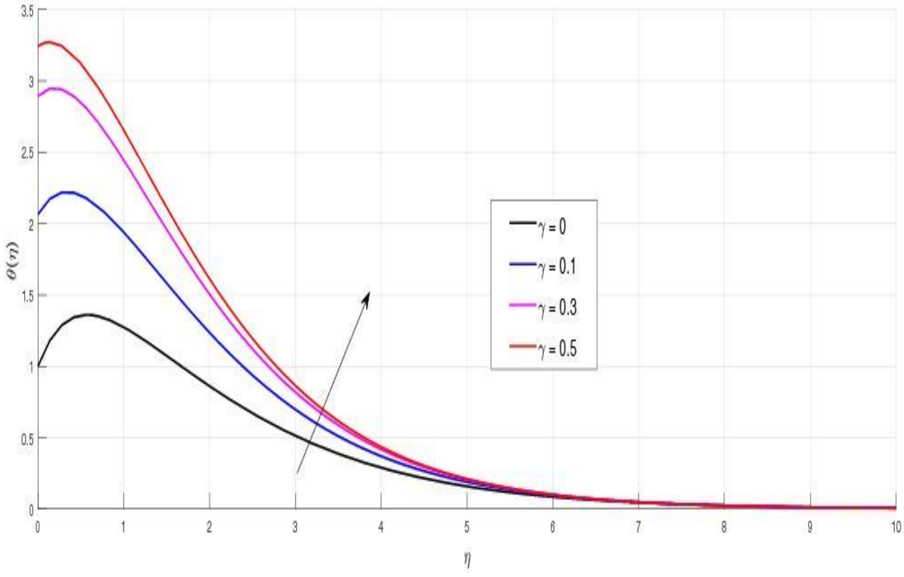

Figure. 2. Temperature profile with varying γ

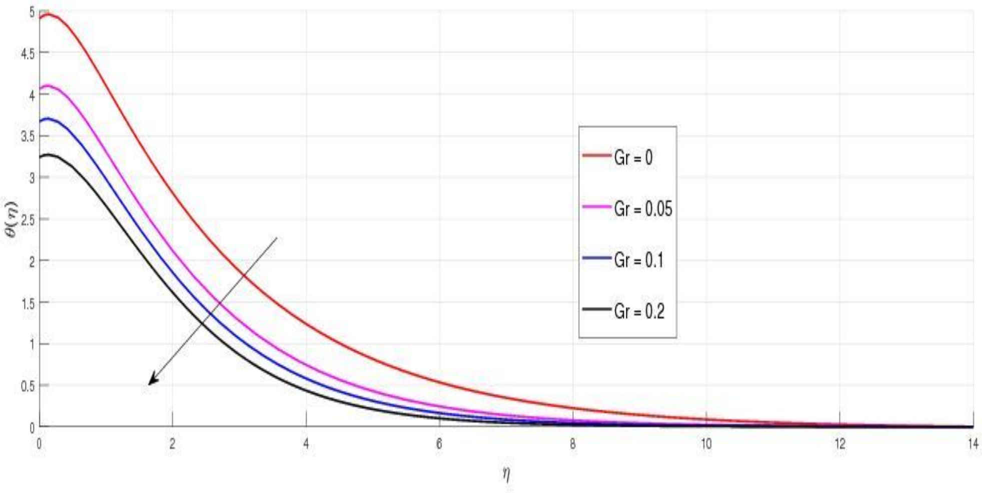

Figure. 3. Temperature profile with varying Gr

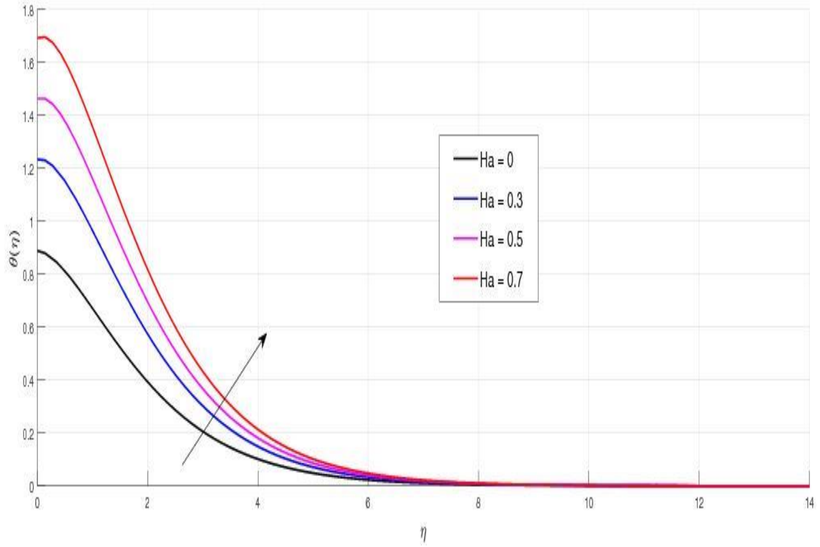

Figure. 4. Temperature profile with varying Ha

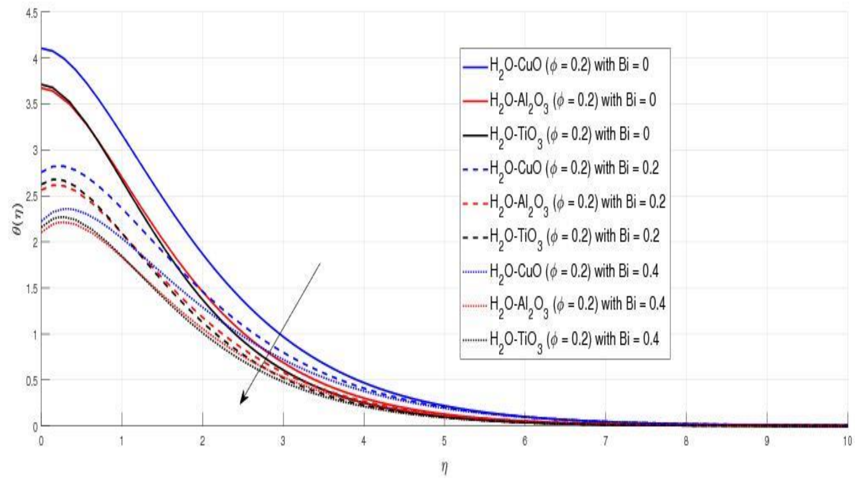

Figure. 5. Temperature profile for different water based nanofluids with varying Bi

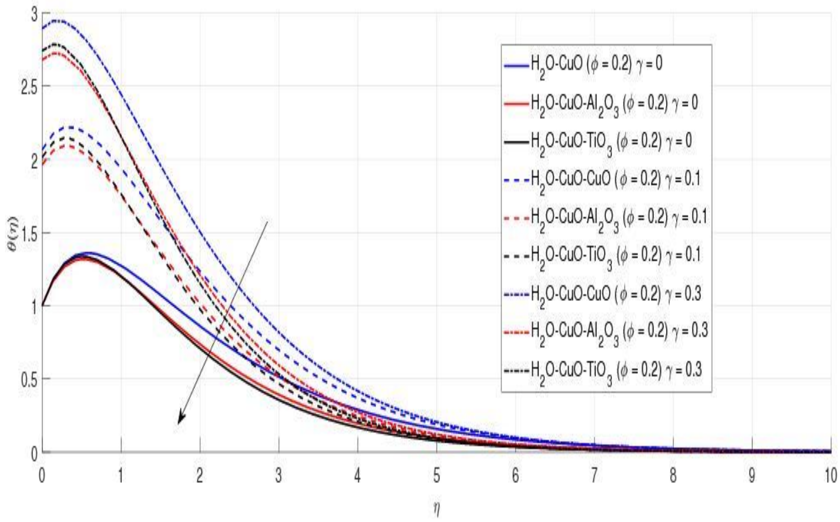

Figure. 6. Temperature profile for different water based nanofluids with varying γ

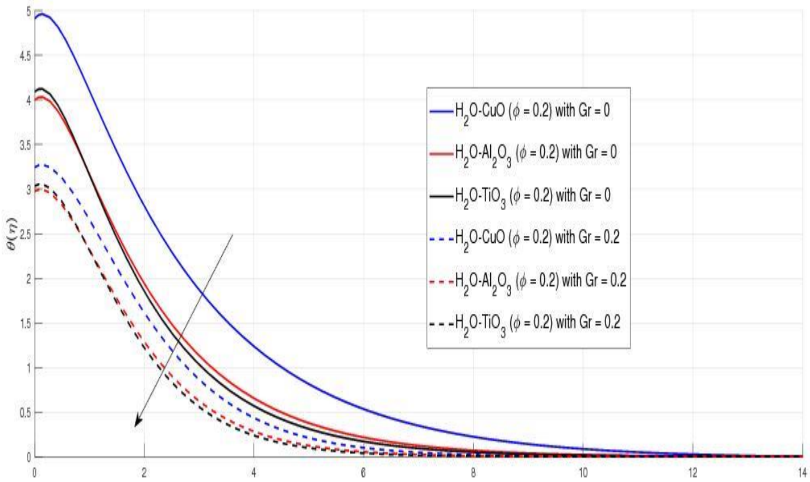

Figure. 7. Temperature profile for different water based nanofluids with varying Gr

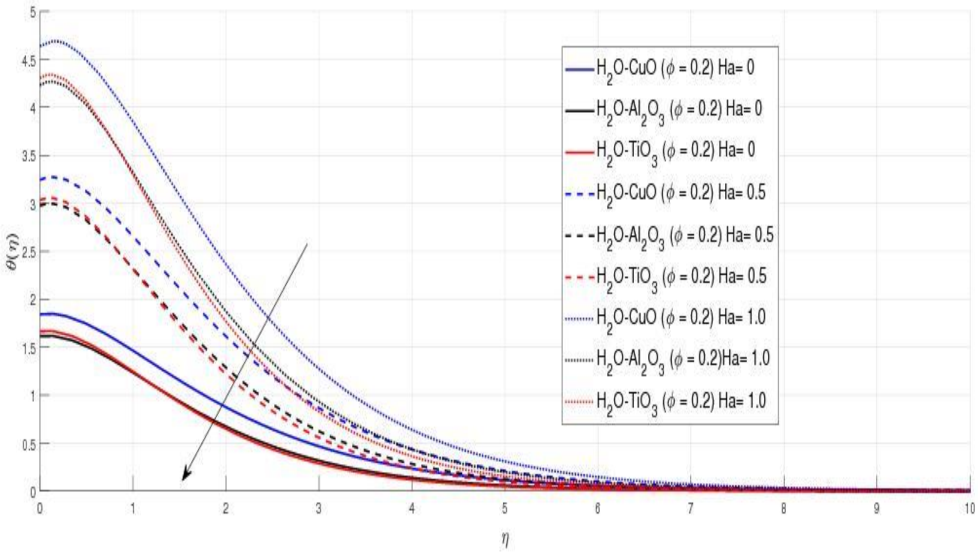

Figure. 8. Temperature profile for different water based nanofluids with varying Ha

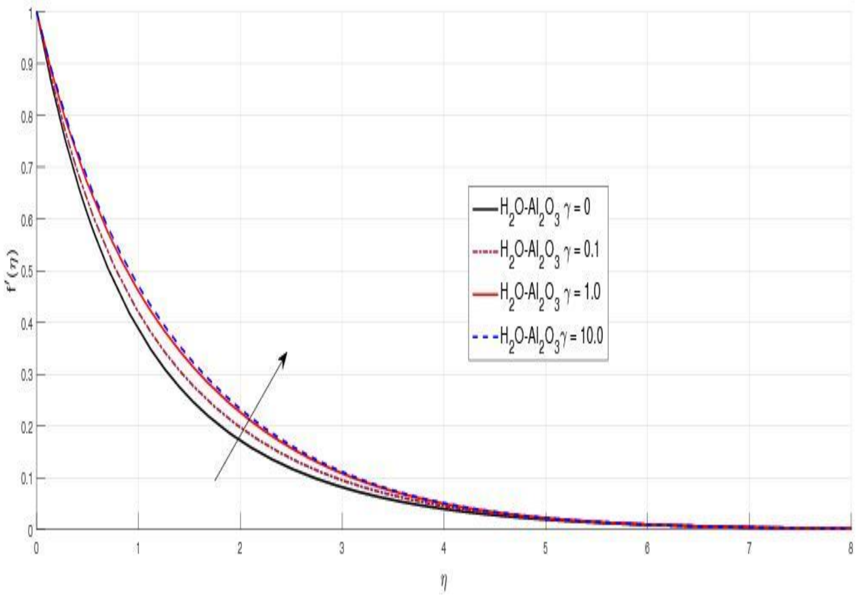

Figure. 9. Velocity profile for different water based nanofluids with varying γ

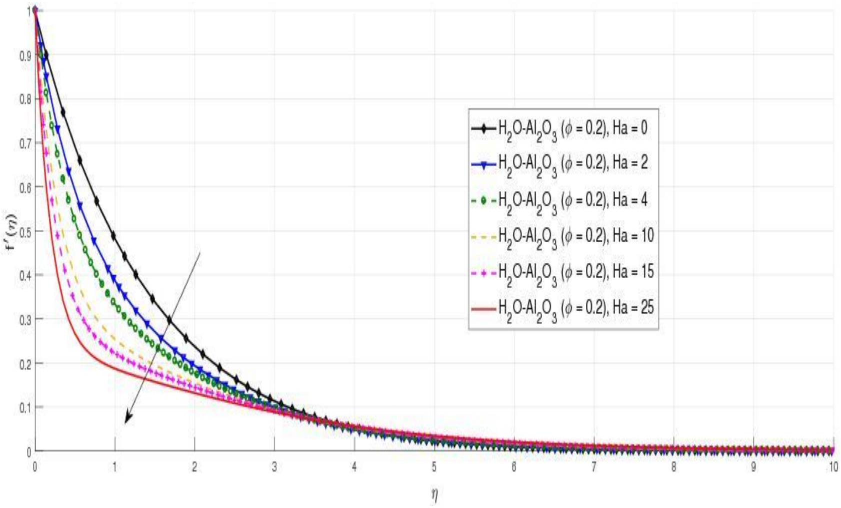

Figure. 10. Velocity profile for aluminum with varying Ha

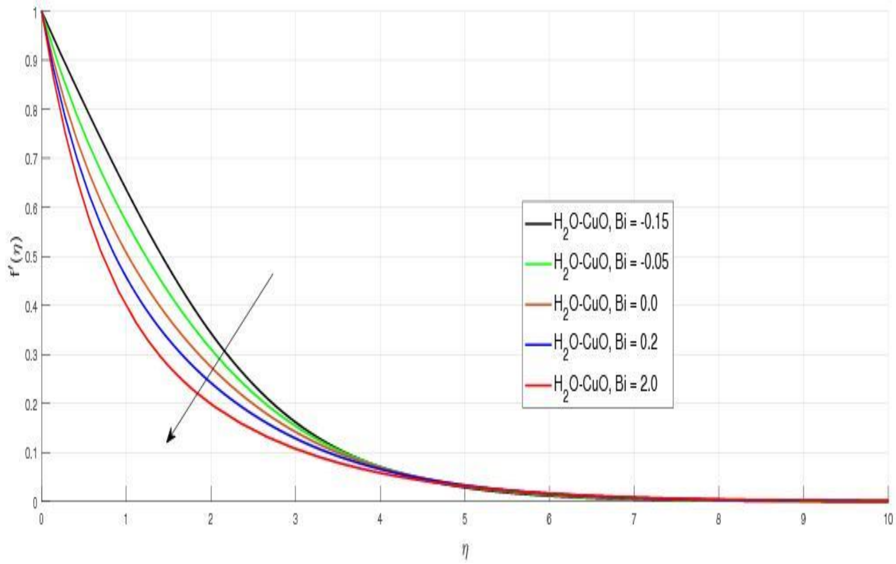

Figure. 11. Velocity profile for copper oxide with varying Bi

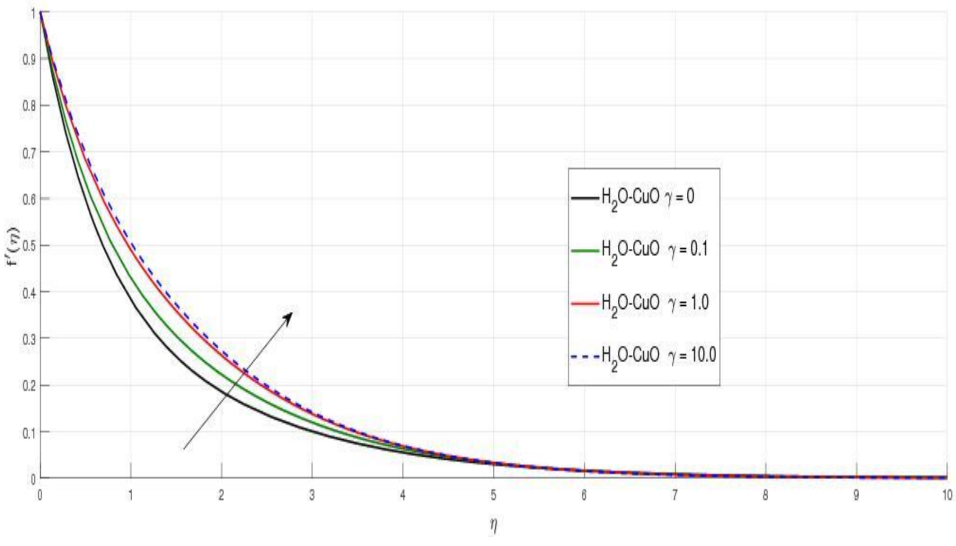

Figure. 12. Velocity profile forcopper oxide with varying γ

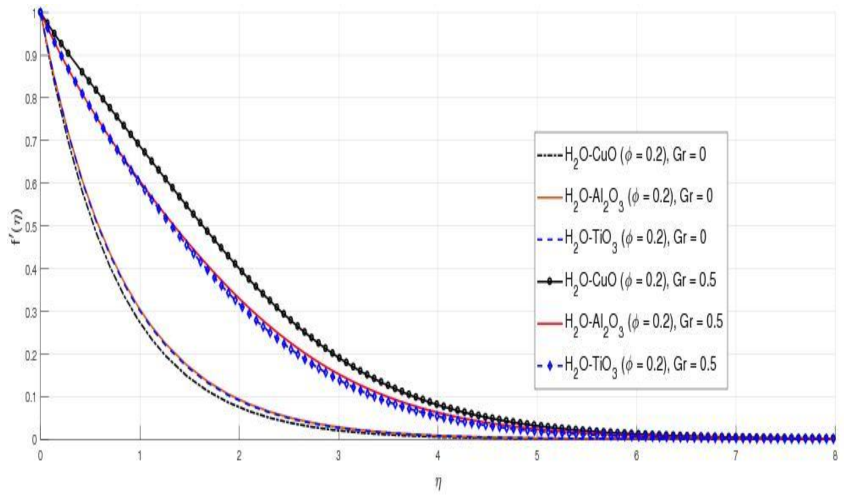

Figure. 13. Velocity profile for different water based nanofluids with varying Gr

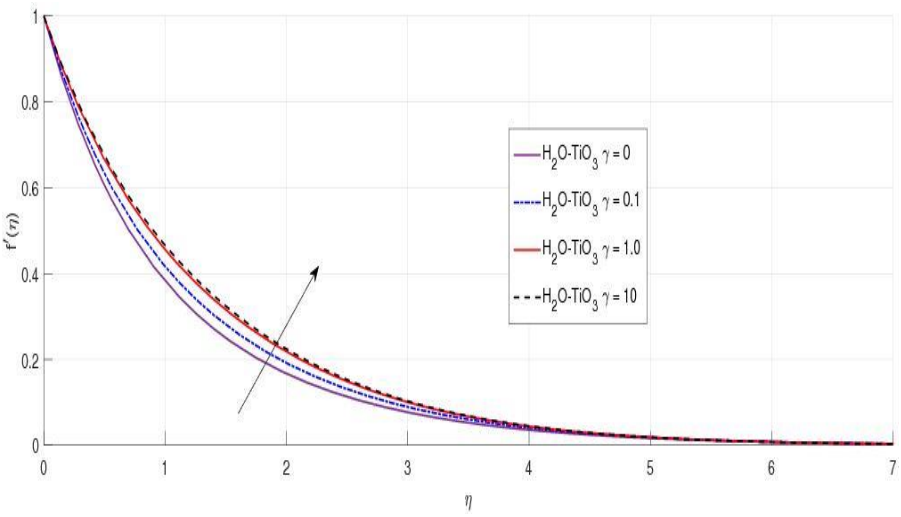

Figure. 14. Velocity profile for Titanium with varying γ

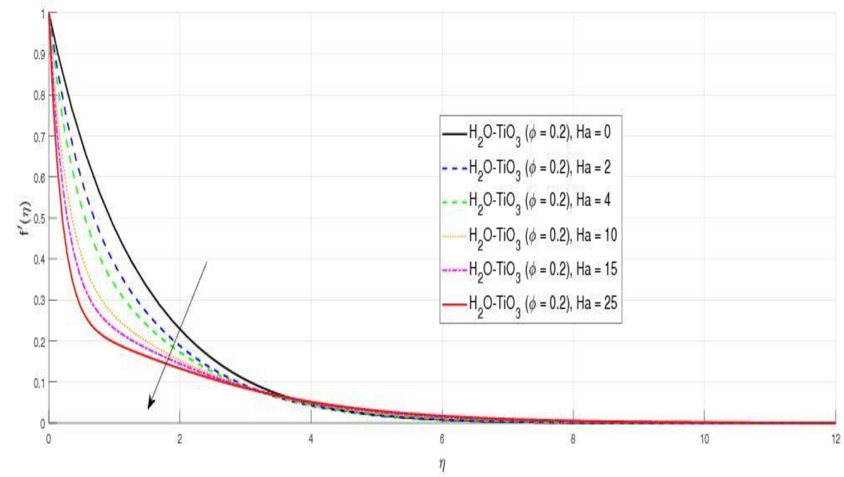

Figure. 15. Velocity profile for Titanium with varying Ha

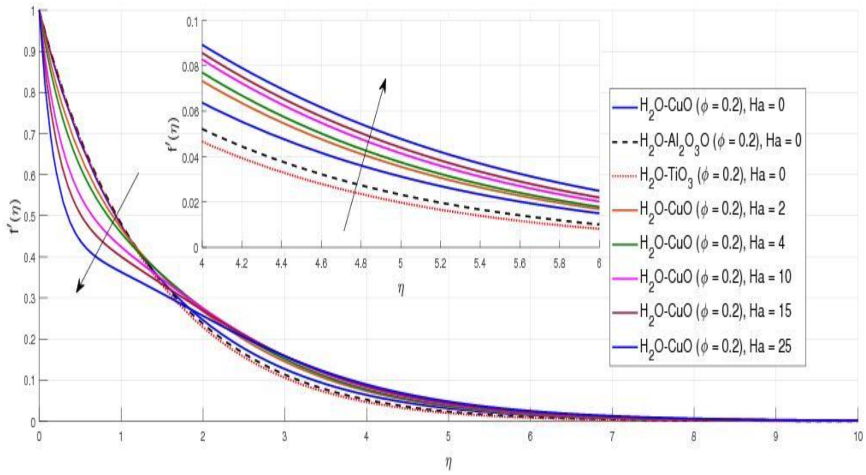

Figure. 16. Velocity profile for different nanofluids with varying Ha

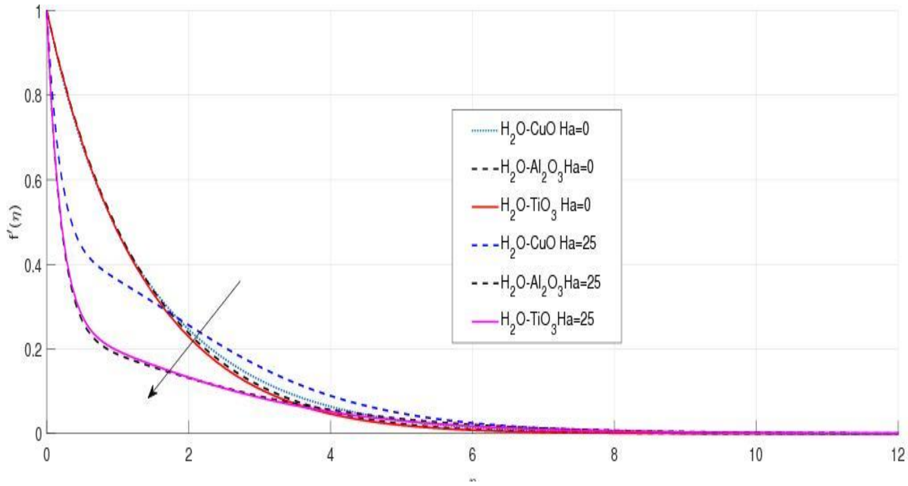

Figure. 17. Velocity profile for nanofluid with varying Ha

TABLE. 1 Local skin- friction oefficient and Nu for CuO water nanofluid with different nanoparticle factor ϕ.

4. CONCLUSION

Firstly, we investigate thermal slip effects on the heat transfer rate through nanofluids as coolant having applications in automobile engines.in this respect the mathematical models descripted in the form of PDEs along with prescribed boundary conditions. Thermal slip boundary is introduced, and nanofluid flow dynamics is using bvp4c MATLAB through system of coupled nan linear ODEs obtained after the application of suitable transformations. Some points are briefly below:

we observed that increasing thermal slip effects leads to an increasing in temperature. It is clearly show that the nanofluids based on CuO particle have a more heat transfer percentage than the other two nano-fluids. Larger the concentration of the γ base fluid higher is the heat transfer rate of $CuO-\text{water}$ nanofluid. Temperature gradually reduces as the nanoparticle concentration of Biot number (*Bi),* Eckert number (*Ec)* is increased in the nanofluids. Moreover, the result of different nanofluids copper oxide, TiO_2 and Al_2O_3 on the boundary layer. It is shown that the nano-fluids based on

ϕ	k_{nf}	Nu	$Re_x^{1/2} C_f$
0	0.628	0.084138154	0.993989767
0.05	0.72141	0.085608603	1.18560452
0.1	0.82458	0.086968704	1.381935016
0.15	0.9391	0.091634371	1.58355532
0.2	1.06696	0.095644211	1.79198143

Copper-oxide CuO have a more heat transfer rate than the other two nano-fluids. However, heat-transfer rate of Al_2O_3 and TiO_2 built nanoparticles is practically similar when the thermal slip effects will be increases.

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