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On various morphologies of propylene glycol-based SiO_2 nanofluid flow and heat transmission over a stretching cylinder

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Abstract

The Current study analyses the unsteady flow and heat transfer of SiO_2 nanoparticles based on propylene glycol over a stretching cylinder. The given partial differential equations (PDEs) are converted into a system of nonlinear ordinary differential equations and solved by using BVP4C in MATLAB. Graphical simulation is used to examine how different shaped SiO_2 nanoparticles affect flow and heat transfer rate along with other different parameters like Prandlt, Eckert, and biot numbers. Additionally, the Nusselt number and the skin friction coefficient are computed and numerically calculated. The research shows that different SiO_2 nanoparticle morphologies have faster flow and heat transmission rates.

Keywords: Axial stretching, Shape factor, Propylene based SiO_2-nanofluid; Heat transmission.

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1. Introduction

The creation of materials and technologies with novel or radically altered features using nanotechnology involves the manipulation or self-assembly of individual atoms, molecules, or molecular clusters into structures. Sulfide nano crystals were employed in stained glass windows for hair dyeing 2000 years ago by the Greeks and Romans. Different-sized gold nanoparticles are used in stained glass windows to create a variety of colors.

The class of fluids known as nanofluids, which includes particles with sizes ranging from 1 to 100 nm suspended in a base fluid, is thought to be a relatively new one. By adding various base fluids, such as water or propylene glycol, the thermal conductivity of nanofluids is increased.[1]

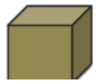
Metals or metal oxides, such as silver, copper, copper oxide, silica, and aluminium oxide, are colloidal nanomaterials with outstanding electrical, thermal, and structural properties. For the manufacture of nano fluids, various base fluids like water, ethylene glycol, and glycerol are employed. [2]

Nanofluid is used to improve the performance of engineering devices such automobiles, micro and minichannels, nuclear reactors, and thermal engineering systems[3-5]. Small amounts of nanoparticles have been shown to significantly boost the thermal conductivity of nanofluids [6]. Using ethylene glycol as a nano fluid and copper nanoparticles with a volume fraction of 0.3 nm results in an increase of 0.4 in effective thermal conductivity[7]. Additionally, alumina/water nanofluid with 1-4 percent alumina volume increased effective thermal conductivity by 0.1–0.3 [8]. The increase in energy absorbing capacity of nano fluid has also been calculated using the single phase coefficient of heat transfer. Further, if the flow is turbulent, the Nusselt Number rises by 0.3 compared to the assumption by taking into account the influence of heat conductivity and the increase in viscosity in circular tubes [9-13].

Table 1: Thermophysical properties of Propylene glycol base fluid and SiO_2 nanoparticle [14]

Nanoparticle / Base fluid	Density (kg/m3)	Thermal conductivity (W/m K)	Specific heat (J/kg K)	Electric conductivity (S/m)
SiO_2	2200	1.2	703	5.5×10^{-6}
$C_3H_8O_2$	938.5	0.684	4338	0.10×10^{-4}

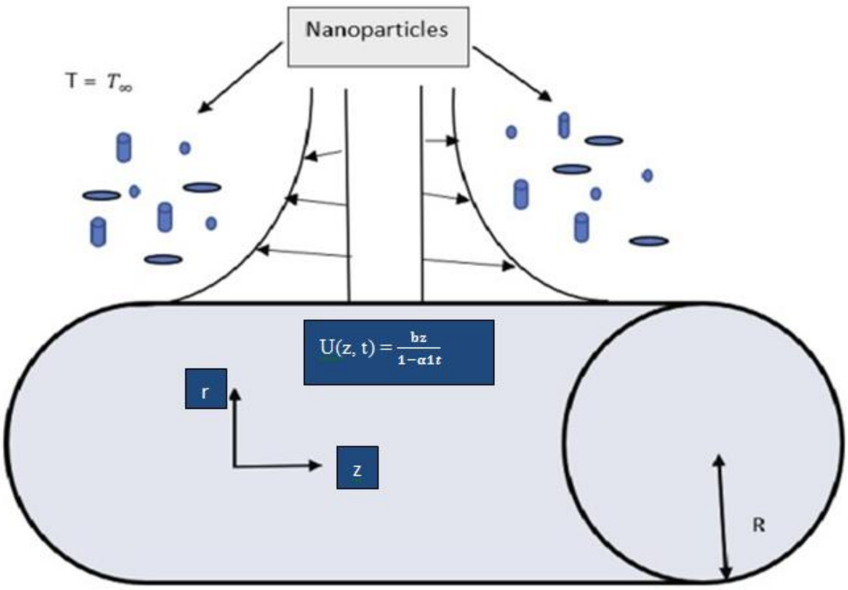
Table 2: Numerical values of viscosity and shape factor of nanoparticles [15]

Nanoparticles	Cylinder	Sphere	Blades	Platlets
Parameters				
A1	13.5	2.5	14.6	37.1
A2	904.4	6.5	123.3	612.6
M	4.82	3.0	8.26	5.72

Applications of heat transfer of nano fluid taking into account its flow across a stretching cylinder are now influencing many industries, such as insulating materials, roofing shingles, paper manufacture, condensation process, etc [16-19].
To fully comprehend the rate of heat transfer in both analytical and numerical investigations, slip condition plays a crucial role during the motion of nanofluids [20-25].
Thermal conductivity and heat transfer of nano fluid is explained by plucking the valuable contribution of Hamid and khan [26], Sheremet and Ramesh et al [27-31], Tiwari and Das, Maiga, Alawi, Dinarvand [32-35].

2. Mathematical Formulation:

The proposal given in this article is to investigate viscous fluid over a stretching cylinder of radius R and heat transfer of SiO_2 propylene glycol based nanofluid over a solid cylinder. Stretching of the cylinder is responsible for motion of the fluid along the axial direction z of the cylindrical coordinate system. $U(z,t) = \frac{\mathbf{bz}}{\mathbf{1-\alpha 1}t}$ is the surface velocity, where b and α_1 both are positive constants with dimension t^{-1} , T = $T_s = T_o - T_r\left[\frac{bz^2}{2\nu}\right][1 - \alpha 1t{-}32$ is the temperature of the stretching cylinder. T_r is the constant reference temperature.Stretching rate $\frac{\mathbf{bz}}{\mathbf{1-\alpha 1}t}$ increase with time. U(z,t) , Ts(z,t) , B(r,t) are taken in such a way such that it helps in formulating new similarity transformations. Law of Conservation of mass and momentum equation of PDEs into system of ODEs.



Velocity profile

$$\vec{V} = [u(r,z,t), o, w(r,z,t)]$$

Law of Conservation of mass:

$$\frac{\partial}{\partial r}(ru)+\frac{\partial}{\partial z}(rw)=0$$

Momentum Equation

$$\frac{\partial w}{\partial t}+u\frac{\partial w}{\partial r}+w\ \frac{\partial w}{\partial z}=\frac{v}{r}\frac{\partial}{\partial r}\left(r\frac{\partial w}{\partial r}\right)-\frac{1}{\rho}w\sigma\ \frac{\mathbf{B_0}^2}{(1-\alpha_1 t)}$$

Energy equation

$$\frac{\partial T}{\partial t}+u\frac{\partial T}{\partial r}+w\ \frac{\partial T}{\partial z}=\frac{v_{nf}}{C_p}\left(\frac{\partial w}{\partial r}\right)^2+\ \alpha_{nf}\left[\frac{r^2T}{\partial r^2}+\frac{1}{r}\left(\frac{\partial T}{rr}\right)\right]$$

Subject to the boundary condition

$W=U_w$, u= 0 and $T=T_S$ at r=R

w = 0, $T \rightarrow T_0$ as $r \rightarrow \infty$

Similarity transformation:

$$\Psi=(Uvz)^{\frac{1}{2}}\ Rf(\eta),\ \eta=\frac{r^2-R^2}{zR}\left(\frac{U}{vz}\right)^{\frac{1}{2}}$$

$$\theta(\eta)=\frac{T-T_o}{-T_{ref}\left[\frac{bz^2}{2v}\right](1-\alpha_1 t)^{\frac{-3}{2}}}$$

$$T=T_o-T_r\left[\frac{bz^2}{2v}\right][1-\alpha_1 t]^{-3/2}\ \theta(\eta)$$

Now above system of equations together with boundary conditions will become

$$[1+2C\eta]\epsilon_1 f'''+2C\epsilon_1 f''-\ [\epsilon_3 M+S]f'-\frac{S.\eta}{2}\ .f''+f.f''-(f')^2=\ 0$$

$$[1+2C\eta]\theta''+2C\theta'+\frac{P_r}{\epsilon_2}f\theta'-2\frac{P_r}{\epsilon_2}f'\theta-\frac{P_r}{2\epsilon_2}S[3\theta+\eta\theta']+[1+2C\eta]P_r\epsilon_2\left[\frac{\epsilon_1}{\epsilon_2}\right](f'')^2=0$$

Here

$$C=\sqrt{\frac{(1-\alpha_1 t)v_f}{bR^2}}\ ,\ \epsilon_1=\frac{1+A_1\emptyset+A_2\emptyset^2}{1-\emptyset+\emptyset\left(\frac{\rho_s}{\rho_f}\right)}\ ,\ \epsilon_2=\frac{\frac{k_{nf}}{k_f}}{1-\emptyset+\frac{\emptyset(\rho C_p)_3}{(\rho C_p)_f}}\quad ,\in_3=\frac{1-\emptyset+\emptyset\left(\frac{\sigma_s}{\sigma_f}\right)}{1-\emptyset+\emptyset\left(\frac{\rho_s}{\rho_f}\right)}$$

$$P_r=\frac{v_f(\rho C_p)_f}{K_f}\quad ,\quad E_c=\frac{bz^2}{C_p\Delta T(1-\alpha_{1t})^2}=\frac{U^2}{C_p\Delta T}\ ,\quad S=\frac{\alpha_1}{b}$$

$$\alpha_{nf}=\frac{k_{nf}}{(\rho C_p)_{nf}}\quad ,\ v_{nf}=v_f\in_1\quad ,\quad (\rho C_p)_{nf}=(1-\emptyset)(\rho C_p)_f+\emptyset(\rho C_o)_\rho$$

$$\frac{k_{nf}}{k_f}=\left[\frac{k_{s+(m-1)k_f+(m-1)(k_s-k_f)\emptyset}}{k_{s+(m-1)k_f-(k_s-k_f)\emptyset}}\right]$$

where ϕ is the volume-fraction of the nanofluid, A_1, A_2 are the coefficients of viscosity enhancement heat capacitance, K is the slip parameter, γ is the biot number, Ec is the Eckert number, M is the magnetic parameter, Pr is the Prandtl number and S is the unsteadiness parameter.

So we have

$$[1+2C\eta]\epsilon_1 f'''+2C\epsilon_1 f''-[\epsilon_3 M+S]f'-\frac{s\eta}{2}f''+f.f''-(f')^2=0$$

$$[1+2C\eta]\theta''+2C\theta'+\frac{P_r}{\epsilon_2}[f.\theta'-2f'\theta-\frac{s}{2}(3\theta+\eta\theta')+E_c\,\epsilon_1(1+2cv)(f'')^2]=0$$

Related with boundary conditions

$f(0)=0$, $f'(0)=1$, $\theta(0)=1$

$f'(\infty)=0$, $\theta(\infty)=0$

3. Method of Solution:

For solving above system in mathematical form, the majority of scholars used various techniques as shooting, kellor boxes, Runge- Kutta, RK-2,4 Euler, and finite difference method. The BVP4C approach is suggested in this paper as a potential solution to the abovementioned systems. In publications, errors and convergence analysis in BVP4C are briefly explored. Analysis of [36] leads to the conclusion that BVP4C is an effective method with fewer errors that can be applied to both multi- and two-point BVPs. These features of BVP4C made it a revolutionary star in the disciplines of research. To solve the above system of equations numerically , we consider

$$y_1 = f$$
$$y_1' = y_2$$
$$y_2' = y_3$$
$$\theta = y_4$$
$$\theta' = y_5$$

4. Results and Discussion:

This section of research work is reserved for discussion of numerically computed results of the given equations using a reliable technique BVP4C in MATLAB. For a comprehensive study the multi-shaped nanoparticles of SiO_2 are dispersed in the propylene glycol base fluid are considered. The numerical results computed for velocity and temperature are illustrated and analyzed through graphs.

Impact of Significant physical Parameters on Velocity Profile

Impact of volumetric fractionϕ, unsteadiness parameter S, magnetic parameter M on velocity profile. Influence of volumetric fraction ϕ on velocity profile for different shaped nanoparticles of SiO_2.It is noted that nanofluid velocity increases for rising values ϕ for all shaped nanoparticles of SiO_2. It means that all type of nanoparticles of SiO_2 play a significant role to decrease the viscosity of regular Propylene glycol base fluid as a result fluid flow accelerates. The impact of magnetic parameter Mon velocity profile. It is observed that fluid flow decelerate for increasing values of M all shaped nanoparticles of SiO_2. The main reason behind this deceleration is that magnetic field acts like a drag force.
Furthermore, solutions of velocity and temperature fields are discussed in table (3, 4) and figure (1-8).

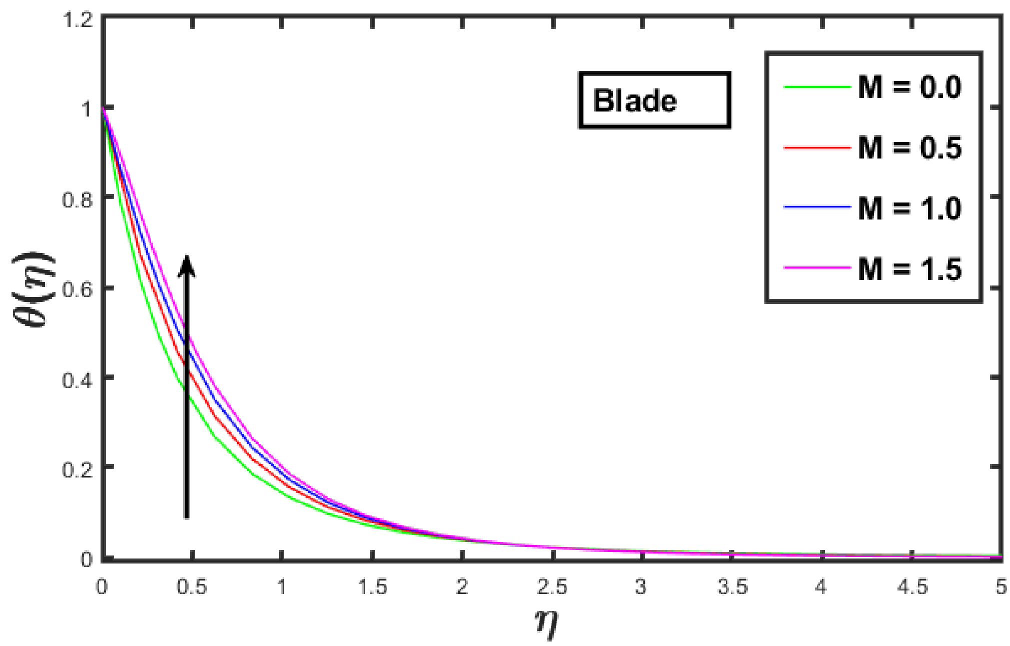


Figure: 1 represents the impact of M on temperature field for Blade shaped nano particles by taking M = 0.0, 0.5, 1.0 and 1.5 respectively while other parameters are fixed i.e K = 0.5 , S = 0.3 , ϕ = 0.08 and Ec = 1.0. The graph shows clear increase of temperature field by increasing value of M using Blade shaped nano particles.

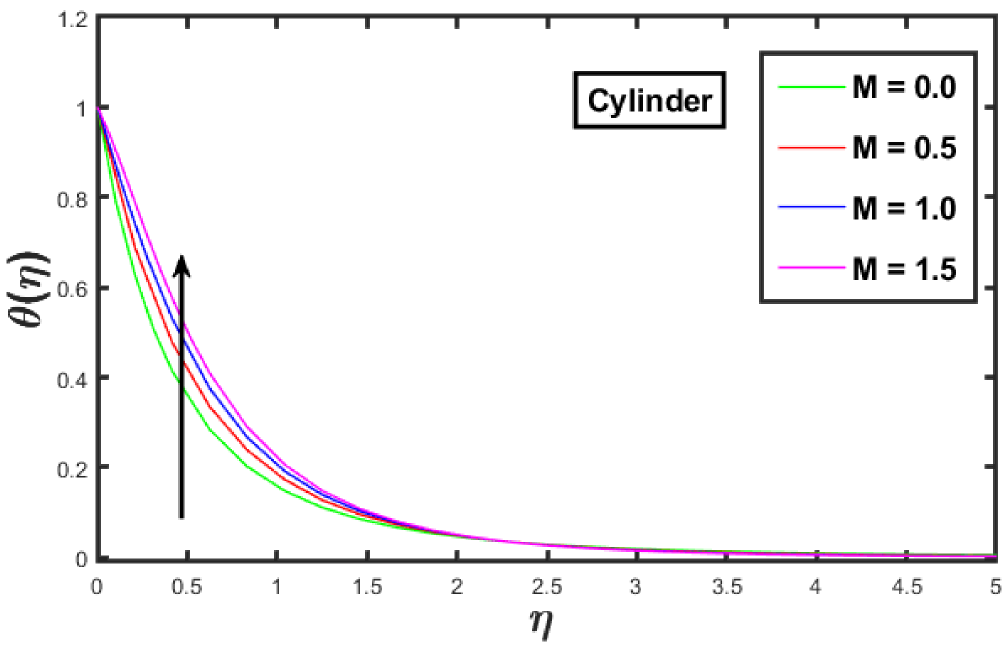


Figure: 2 represents the impact of M on temperature field for Cylinder shaped nano particles by taking M = 0.0, 0.5, 1.0 and 1.5 respectively while other parameters are fixed i.e K = 0.5 , S = 0.3 , ϕ = 0.08 and Ec = 1.0. The graph shows clear increase of temperature field by increasing value of M using Cylinder shaped nano particles.

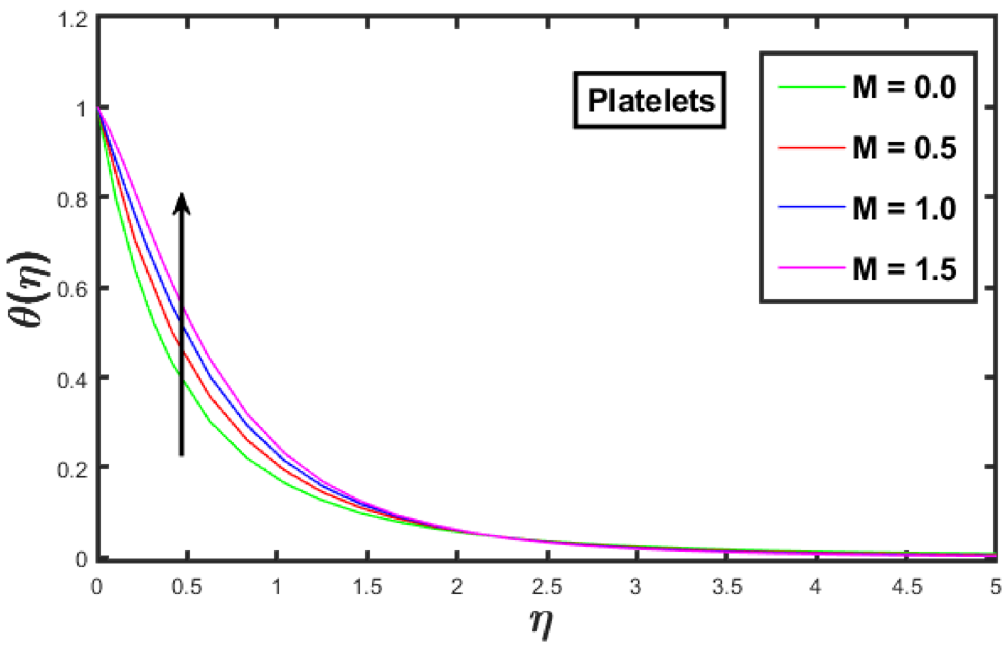


Figure: 3 represents the impact of M on temperature field for Platlet shaped nano particles by taking M = 0.0, 0.5, 1.0 and 1.5 respectively while other parameters are fixed i.e K = 0.5 , S = 0.3 , ϕ = 0.08 and Ec = 1.0. The graph shows clear increase of temperature field by increasing value of M using Platlet shaped nano particles.

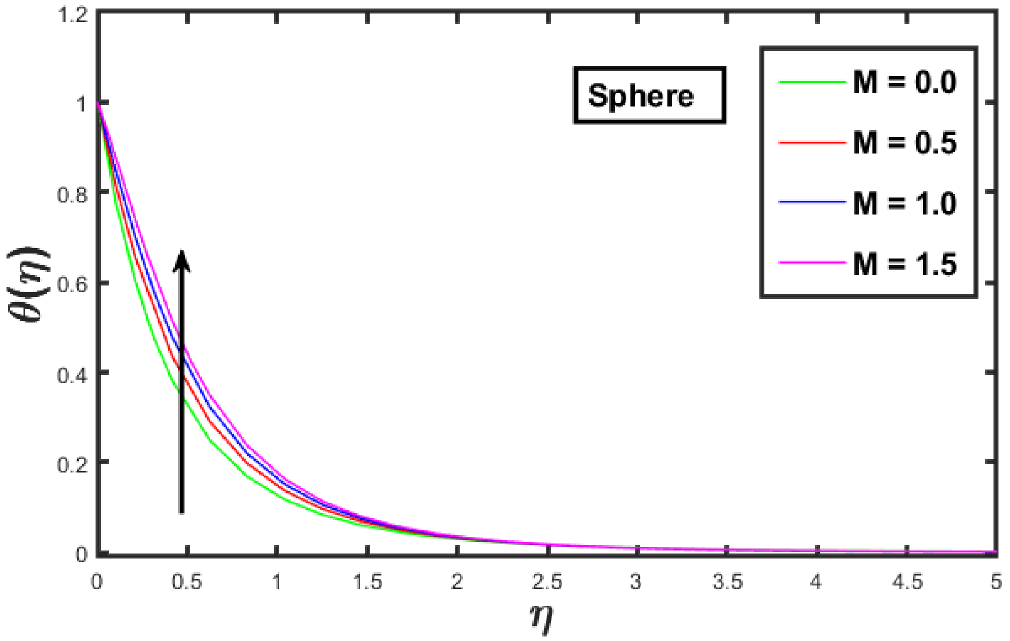


Figure: 4 represents the impact of M on temperature field for Sphere shaped nano particles by taking M = 0.0, 0.5, 1.0 and 1.5 respectively while other parameters are fixed i.e K = 0.5 , S = 0.3 , ϕ = 0.08 and Ec = 1.0. using Sphere shaped nano particles.

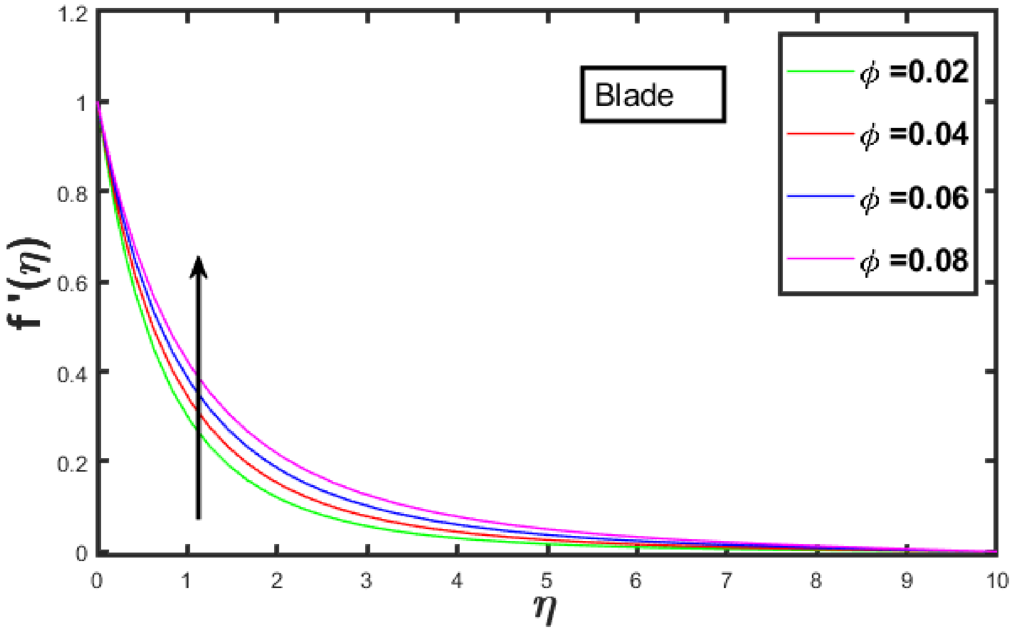


Figure: 5 represents the impact of M on Velocity field for Blade shaped nano particles by taking ϕ = 0.02, 0.04, 0.06 and 0.08 respectively while other parameters are fixed i.e K = 0.5 , S = 0.3 , M = 1.0 and Ec = 1.0. The graph shows clear increase of temperature field by increasing value of ϕ using Blade shaped nano particles.

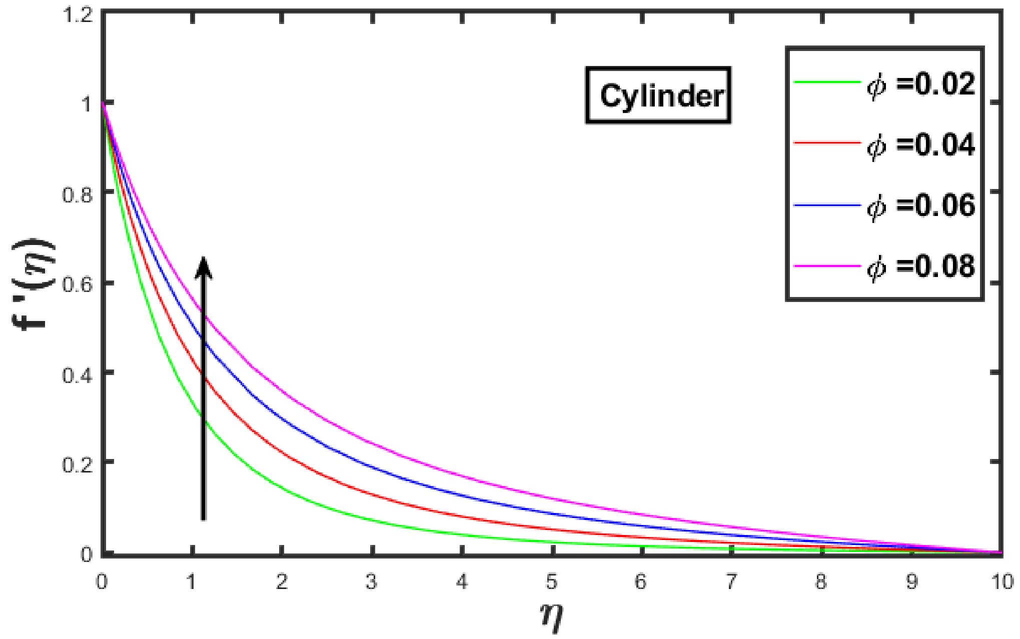


Figure: 6 represents the impact of M on Velocity field for Cylinder shaped nano particles by taking ϕ = 0.02, 0.04, 0.06 and 0.08 respectively while other parameters are fixed i.e K = 0.5 , S = 0.3 , M = 1.0 and Ec = 1.0. The graph shows clear increase of temperature field by increasing value of ϕ using Cylinder shaped nano particles.

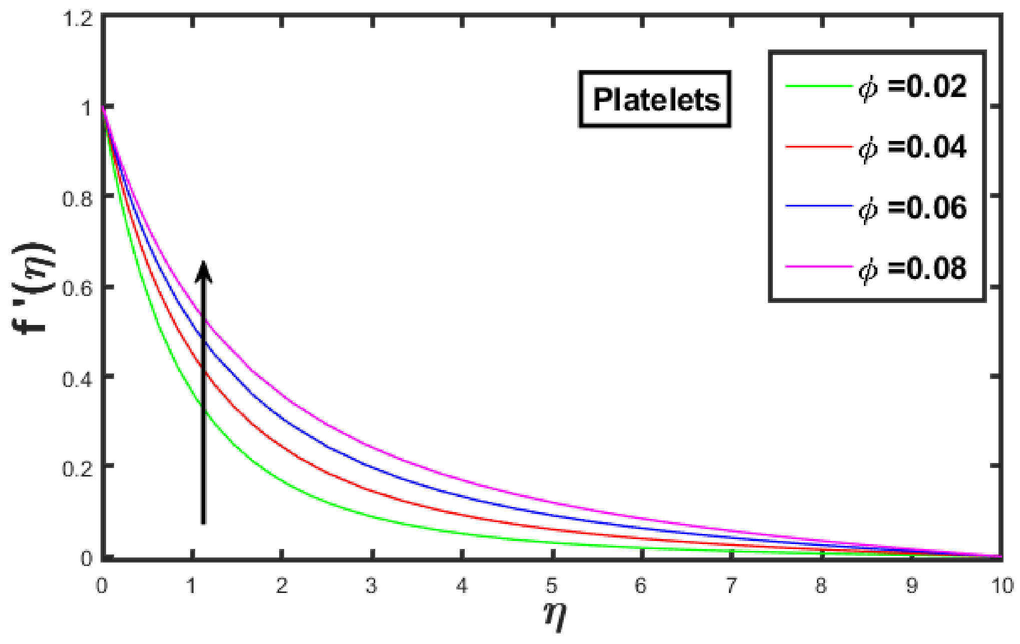


Figure: 7 represents the impact of M on Velocity field for Platelet shaped nano particles by taking ϕ = 0.02, 0.04, 0.06 and 0.08 respectively while other parameters are fixed i.e K = 0.5 , S = 0.3 , M = 1.0 and Ec = 1.0.

The graph shows clear increase of temperature field by increasing value of ϕ using Platelet shaped nano particles.

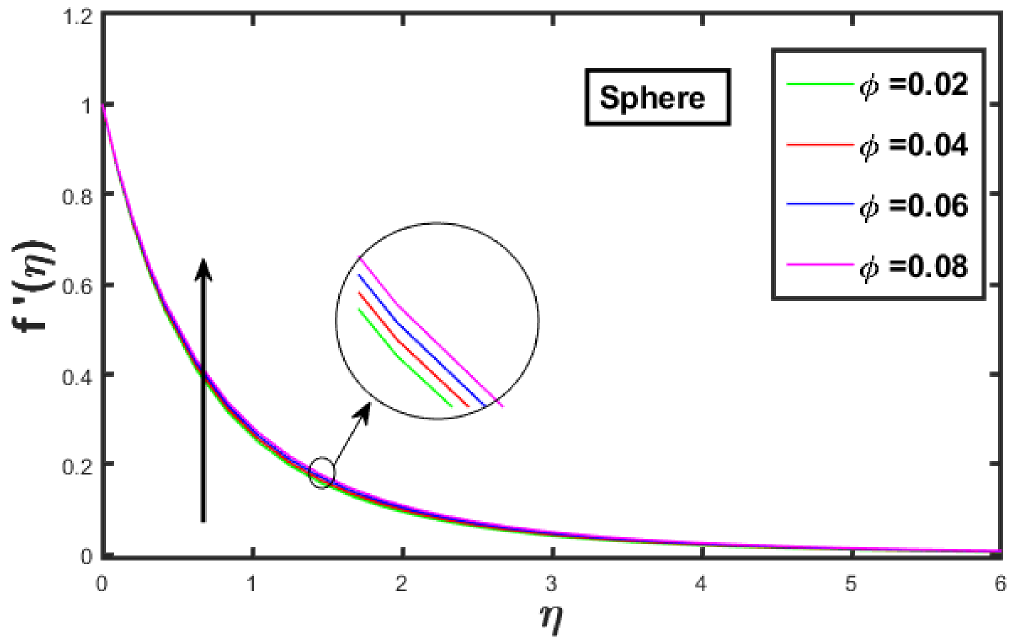


Figure: 8 represents the impact of M on Velocity field for Sphere shaped nano particles by taking ϕ = 0.02, 0.04, 0.06 and 0.08 respectively while other parameters are fixed i.e K = 0.5 , S = 0.3 , M = 1.0 and Ec = 1.0. The graph shows clear increase of temperature field by increasing value of ϕ using Sphere shaped nano particles.

Table 3: Numerical values of skin-friction coeffcient of multi-shape nanoparticles

K	Phi	Ec	S	M	sphere	Cylinder	blade	Platelet
0.5	0.02	1.0	0.3	1.0	-1.6757832	-2.1272397	-1.9111774	-2.3709318
-	0.04	-	-	-	-1.7330343	-2.9896493	-2.2424432	-3.2510739
-	0.06	-	-	-	-1.7938827	-4.0627124	-2.6068329	-4.2316768
-	0.08	-	-		-1.8581577	-5.3004602	-2.9987578	-5.3088485
-	-	-	-	0.0	-1.2719793	-1.6229155	-1.4543973	-1.8143759
-	-	-	-	0.5	-1.490298	-1.8952504	-1.7012532	-2.1145454
-	-	-	-	1.0	-1.6757832	-2.1272397	-1.9111774	-2.3709318
-	-	-	-	1.5	-1.8402061	-2.3328059	-2.0972002	-2.5981987

Table 4: Numerical values of Nusselt number of multi-shape nanoparticles

K	phi	Ec	S	M	Sphere	Cylinder	Blade	Platelet
0.5	0.02	1.0	0.3	1.0	1.5385163	1.2721682	1.3978275	1.1381833
-	0.04	-	-	-	1.5648209	0.90233308	1.2806772	0.78017119
-	0.06	-	-	-	1.5883489	0.50590055	1.1644155	0.43511613
-	0.08	-	-	-	1.6094517	0.088905918	1.0514986	0.086115226
-	-	-	-	0.0	2.5414549	2.3851236	2.461304	2.301599
-	-	-	-	0.5	2.0113645	1.8008983	1.9012195	1.6930965
-	-	-	-	1.0	1.5385163	1.2721682	1.3978275	1.1381833
-	-	-	-	1.5	1.1048287	0.78363093	0.93431242	0.62347619

5. Conclusion

Exploring the dependence of physical parameters on velocity and temperature profiles through graphs, in depth. Following are the conclusions of the current study:

- volume-fraction ϕ is directly related with both velocity and temperature field for all shapes of nano particle
- velocity of fluid flow and heat transfer rate increase with magnetic parameter M.
- impact of volume-fraction ϕ have constant behavior for blade,cylinder,sphere and platelets.
- Influence of magnetic parameter M have also the constant increasing behavior for all considered shapes of nano particals

References

[1]. N.Funda, A.k.Azem, I.Birlik, R.Yigit, M.Erol, S.Yildirim, E.Celik, Preparation and characterization of SiO_2 Nanofluid by Flame Spray system for Machining process, AKÜ FEMÜBİD 14 (2014) OZ5775 (471-478).

[2]. Wen et al., Review of nanofluids for heat transfer applications, Particuology, 7 (2) (2009) 141-150

[3]. R.Saidur, K.Y.Leong and H.A.Mohammad, A review on applications and challenges of nanofluids, Renewable and Sustainable Energy Reviews, 15 (3) (2011) 1646-1668.

[4]. Hung et al., Heat transfer enhancement in microchannel heat sinks using nanofluids, Int. J. Heat Mass Transf., 55 (9-10) (2012) 2559-2570

[5]. C.J.Ho, W.C.Chen and W.M.Yan, Correlations of heat transfer effectiveness in a minichannel heat sink with water-based suspensions of Al_2O_3 nanoparticles and/or MEPCM particles, Int. J. Heat Mass Transf., 69 (2014) 293-299

[6]. D.Y.Tzou, Thermal instability of nanofluids in natural convection, Int. J. Heat Mass Transf., 51 (2008) 2967-2979.

[7]. J.A.Eastman, S.U.S.Choi, S.Li, W.Yu, L.J.Thompson, Anomalously increased effective thermal conductivities of ethylene glycol- based nanofluids containing copper nanoparticles, Appl. Phys. Lett. 6 (2001) 718–720

[8]. S.K.Das, N.Putra, P.Thiesen, W.Roetzel, Temperature dependence of thermal conductivity enhancement for nanofluids, ASME J. Heat Transfer 125 (2003) 567–574

[9]. B.C.Pak, Y.Cho, Hydrodynamics and heat transfer study of dispersed fluids with submicron metallic oxide particles, Exp. Heat Transfer 11 (1998) 151–170

[10]. Y.Xuan, Q.Li, Investigation of convective heat transfer and flow features of nanofluids, ASME J. Heat Transfer 125 (2003) 151–155.

[11]. Y.Xuan, W.Roetzel, Conceptions for heat transfer correlation of nanofluids, Int. J. Heat Mass Transfer 43

[12]. S.Ma¨ıga, C.T.Nguyen, N.Galanis, G.Roy, Heat transfer behaviors of nanofluids under in a uniformly heated tube, Superlattices Microstruct. 35 (2004) 543–557.

[13]. J.Buongiorno, Convective transport in nanofluids, ASME J. Heat Transfer 128 (2006) 240–250.

[14]. S.R.Vajjha and K.D.Debendra, Experimental determination of thermal conductivity of three nanofluids and development of new correlations, Int. J. Heat Mass Transf., 52 (21-22) (2009) 4675-4682

[15]. E.V.Timofeeva, J.L.Routbort and D.Singh, Particle shape effects on thermophysical properties of alumina nanofluids, Journal of Applied Physics, 106 (1) (2009) 014304.

[16]. Fakour et al., Nanofluid thin film flow and heat transfer over an unsteady stretching elastic sheet by LSM, Journal of Mechanical Science and Technology, 32 (1) (2018) 177-183.

[17]. Lin et al., MHD pseudo-plastic nanofluid unsteady flow and heat transfer in a finite thin film over stretching surface with internal heat generation, Int. J. Heat and MassTransf., 84 (2015) 903-911.

[18]. G.K.Ramesh et al., Interaction of Al_2O_3-Ag and Al_2O_3-Cu hybrid nanoparticles with water on convectively heated moving material, Multidiscipline Modeling in Materials and Structures, http://doi.org/10.1108/MMMS-11-2019-0191.

[19]. G.K.Ramesh, Influence of shape factor on hybrid nanomaterial in a cross flow direction with viscous dissipation, Physica Scripta, 94 (10) (2019) 105224

[20]. A.Hussanan, M.Z.Salleh and I.Khan, Microstructure and inertial characteristics of a magnetite ferrofluid over a stretching/shrinking sheet using erective thermal conductivity model, Journal of Molecular Liquids, 255 (2018) 64-75.

[21]. K.L.Hsiao, Micropolar nanofluid flow with MHD and viscous dissipation erects towards a stretching sheet with multimedia feature, Int. J. Heat Mass Transf., 100 (2016)316-323.

[22]. K.Hooman and A.Ejlali, Effects of viscous heating, fluid property variation, velocity slip, and temperature jump on convection through parallel plate and circular microchannels, Int. Communi. in Heat Mass Transfer., 37 (1) (2010) 34-38.

[23]. Hussanan et al., Slip effects on unsteady free convective heat and mass transfer flow with Newtonian heating, Thermal science, 26 (6) (2016) 1852-1939.

[24]. A.Hamid, Hashim and M.Khan, Heat generation obsorption and velocity slip erectson unsteady axisymmetric flow of Williamson magneto-nanofluid, Modren Physics Let- ters B, 33 (2019) 1950432.

[25]. Iqbal et al., Magnetohydrodynamic thin film deposition of Carreau nanofluid over an unsteady stretching surface, Applied Physics A, 126 (2) (2020), doi:10.1007/s00339- 019-3204-6.

[26]. A.Hamid and M.Khan, Multiple solutions for MHD transiant flow of Wiliamson nanofluids with convective heat transport, J. Tiwan Inst. Chem. Engrs., 103 (2019) 126–137.

[27]. M.A.Sheremet, T.Grosan and I.Pop, Free convection in a square cavity filled with a porous medium saturated by nanofluid using Tiwari and Das' nanofluid model, Transp. Porous Media, 106 (2015) 595-610.

[28]. G.K.Ramesh and B.J.Gireesha, Influence of heat source/sink on a Maxwell fluid overs a stretching surface with convective boundary conditions in the presence of nanoparti- cles, Ain Shams Engineering Journal, 5 (3) (2014) 991-998.

[29]. G.K.Ramesh, B.J.Gireesha and R.S.R.Gorla, Boundary layer flow past a stretching sheet with fluid-particle suspension and convective boundary condition, Heat and Mass Transfer, 51 (2015) 1061-1066.

[30]. G.K.Ramesh, B.J.Gireesha and R.S.R.Gorla, Study on Sakiadis and Blasius flows of Williamson fluid with convective boundary condition, Nonlinear Engineering Journal, 4 (4) (2015) 215-221.

[31]. G.K.Ramesh et al., Magnetohydrodynamic nanoliquid due to unsteady contracting cylinder with uniform heat generation/absorption and convective condition, Alexandria Engineering Journal, 57 (4) (2018) 3333-3340.

[32]. Alawi et al., Thermal conductivity and viscosity models of metallic oxides nanofluids, Int. J. Heat Mass Transf., 116 (2018) 1314-1325.

[33]. Maiga et al., Heat transfer enhancement by using nanofluids inforced convection flow, Int. J. Heat Fluid Flow, 26 (4) (2005) 530-546.

[34]. R.J.Tiwari and M.K.Das, Heat transfer augmentation in a two-sided lid-driven differentially heated square cavity utilizing nanofluids, Int. J. Heat Mass Transf., 50 (9-10) (2007) 2002-2018.

[35]. S.Dinarvand, R.Hosseini, M.Abulhasansari and I.Pop, Buongiorno's model for double-diffusive mixed convective stagnation-point flow of a nanofluid considering diffusio-phoresis effect of binary base fluid, Adv. Powder Technol., 26 (2015) 1423–1434.

[36]. S.Bibi, Z.Elahi, and A.Shahzad, Impacts of different shapes of nanoparticlea on SiO2 nanofluid flow and heat transfer in a liquid film over a stretching sheet, Physica Scripta, Volume 95, Number 11,(2020).