IMPACT OF SLIP CONDITION ON CONVECTIVE MHD NON-NEWTONIAN FLOW, OVER A POROUS MEDIUM, IN OSCILLATING STATE INVOLVING SUCTION

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Abstract
The paper studies and analyses the result of convective MHD flow concerning viscous, incompressible fluid, over plate, semi- infinite, porous, oscillating, facing slip condition and affected by a transverse magnetic field. The governing equation reduced to ordinary differential equation is further solved with the help of perturbation method in which mat lab is also used. Tables and graphs are used to derive the values of skin-friction including velocity as well as temperature apart from other related factors. Variations due to the effect of various parameters of non-dimensional nature like permeability, magnetic and heat source along with numbers such as Grashof and Prandtl obtained. In the present exercise a problem concerning non-Newtonian, unsteady, electrically conducting MHD convective flow having velocity slip condition applied at the boundary is being considered for analytical solution. It will render help for future experiments and research with other non-Newtonian fluids to find impact of slip flow in inclined position.

Keywords used: Flow, Fluid, Convective, Non-Newtonian, oscillatory, suction, slip condition, medium, porous,

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1. Introduction

Appreciable utility of slip condition in manufacturing field has made it very important in this process. When applied at the boundary, increased velocity slip is developed which in turn results in increased heat transfer. The convective MHD flow has become a centre of attraction for many researchers due to its increased value in different fields. It plays vital role in chemical engineering , aerospace technology, food processing, polymer technology, paper industry, wire and fibre coating, heating and cooling chambers, purification of molten metals, solar power technology and many other technological fields like nuclear power plants, satellites and missiles as well. [1] Experimenter examined MHD flow in liquid film of such fluid involving heat transfer over unsteady stretching sheet with variable fluid properties. [2] Investigator delved an analysis involving heat transfer on magneto hydro dynamic flow concerning non-Newtonian fluid with slip condition applied at the wall, in porous medium. [3] Researchers investigated into unsteady MHD, oscillating fluid flow including heat transfer through a porous type medium under slip condition.[4] Investigators studied the convective oscillating MHD flow past a perpendicular pervious plate through a porous medium facing suction.[5] Investigators studied the slip condition effect on viscoelastic oscillating MHD forced convective flow through perpendicular channel having heat radiation.[6] The investigators examined the effect of heat transfer as well as radiation on an unsteady, MHD non-Newtonian fluid flow in a porous medium with slip condition.[7] The researchers examined the Chemically responding unsteady magneto hydrodynamic micro-polar fluid oscillatory flow with slip, in planer channel with varying attenuation. [8] Researchers studied Slip effect on chemically responding MHD oscillating fluid flow in a porous natured medium with heat as well as mass transfer.[9] Examined natural convection of Unsteady MHD rotating viscoelastic fluid due to oscillating free- sluice over an infinite perpendicular pervious plate. [10] Studied oscillatory MHD fluid flow through pervious channel saturated with pervious natured medium.[11] Examined Slip effect on viscoelastic MHD fluid flow through medium of pervious nature over oscillatory stretching sheet of porous nature. [12] Studied MHD Unsteady Non-Newtonian fluid flow in a previous natured saturated medium of pervious nature channel, with convective heating along with asymmetric Navier slip .[13] Examined the impact of slip of second-order on flow pertaining to casson liquid experiencing heat transfer, subjected to suction/ injection as well as convective boundary conditions.[14] Examined Impact of an oblique still position point on nano material micro-polar MHD flow in medium of porous nature over an oscillatory surface facing partial slip.[15] Performed experiment on Stoke’s Generalized flow as well as radiative model of heat transfer pertaining to non-Newtonian fluid through porous natured Darcy medium, subjected to conditions of Navier’s slip on the penetrable boundary of porous nature.[16] Examined impact of viscous type dissipation including Ohmic Heating on non-Newtonian, MHD steady, Mixed Convective, Fluid Flow Over porous natured, infinite perpendicular plate facing Hall and Ion-Slip Current.[17] examined the impact of chemical response as well as thermal prolixity over oscillatory convective MHD flow pertaining to viscoelastic fluid in porous natured medium facing slip condition.

2 Analytical solution

2.1 Mathematical Presentation

In the problem under investigation, the impact of convective non-Newtonian incompressible, viscous, fluid flow conducting electrically over porous natured plate of semi-infinite natured in a porous natured medium with oscillating position, influenced by transverse magnetic field B_0 has been studied. Velocity u and velocity v have been taken along the x-axis and y- axis respectively, perpendicular to the plate. Considering induced magnetic field as negligible, Reynold number very smalll, pressure as constant, while relevent physical quantities to be functions of t and y with the Suction velocity at the plate as V_0 the continuity equation will be

$$\frac{\partial v}{\partial y}=0 \quad \ldots\ldots. \qquad (1)$$

Considering y=0, v=$-V_0$ boundary layer eq. will be

$$\frac{\partial u}{\partial t} - V_0\frac{\partial u}{\partial y} = (\nu + \alpha \frac{\partial}{\partial t})\frac{\partial^2 u}{\partial y^2} + g\beta(T - T_\infty) - \frac{V}{K_0}u - \frac{\sigma {B_0}^2 u}{\rho} \quad \ldots\ldots\ldots. \qquad (2)$$

$$\frac{\partial T}{\partial t} - V_0\frac{\partial T}{\partial y} = \mathrm{k}\ [1+ \alpha\ \frac{\partial}{\partial t}]\ \frac{\partial^2 T}{\partial y2} - \mathrm{S}[\ \mathrm{T} - T_\infty] \quad \ldots\ldots\ldots\ . \qquad (3)$$

so

$$y = 0: \quad u = U_0\ coswt + \mathrm{L}\ [\frac{\partial u}{\partial y}],\ \ \mathrm{T} = T_\infty + (T_\omega - T_\infty)\ e^{-i\omega t}\ ]$$

y→∞ :   u → 0,   T→ T_∞]   ………………   (4)
are allied boundary conditions.
k denotes thermal diffusivity, α is stress moduli, g gravitational force, density ρ, kinematic viscosity v, β denotes expansion coefficient of volumetric heat transfer, T_∞ denotes temperature of fluid distant from the plate, S heat source parameter, T for temperature.

Evolving the dimensionless quantities

$t' = U_0^2 \frac{t}{v}$, $V_0' = \frac{V_0}{u_0}$, $\omega' = \frac{v\omega}{U_0^2}$

$y' = U_0 \frac{y}{v}$, $u' = \frac{u}{U_0}$, $S' = \frac{vS}{U_0^2}$, $\alpha' = \alpha \frac{U_0^2}{v}$

$T' = \frac{T - T_\infty}{T_\omega - T_\infty}$, $M^{2'} = \frac{B_0 2}{U_0 2}(\frac{v\sigma}{\rho})$, $P_r' = \frac{v}{k}$

$G'_r = vg\beta \frac{T_\omega - T_\infty}{U_0^3}$, $K_p' = \frac{K_0 U_0^2}{V^2}$

Here P_r , G_r , M , stand for Prandtl number, Grashof number and Hartman numbers respectively.
(2), (3) and the equation of allied boundary condition (4) are reduce to,

$\frac{\partial u}{\partial t} - V_0 \frac{\partial u}{\partial y} = [1+ \alpha \frac{\partial}{\partial t}] \frac{\partial^2 u}{\partial y^2} + G_r T - [\frac{1}{K_p} + M^2]\, u$ …………   .(5)

$\frac{\partial T}{\partial t} - V_0 \frac{\partial T}{\partial y} = \frac{1}{P_r} [1+\alpha\frac{\partial}{\partial t}] \frac{\partial^2 T}{\partial y^2} - ST$ …………   (6)

(Dropping sign ′for convenience)
The conforming conditions of boundary are

$u = \cos wt + h\frac{\partial u}{\partial y}$, $T = e^{-i\omega t}$ at y = 0   …………   (7)

u→0,   Tω→ T_∞ as y→∞

Solving using necessary steps, non-linear partial equation (5), (6) in addition to boundary condition equation (7), we get,

$u = u_o e^{i\omega t} + u_1 e^{-i\omega t}$ …………   (8)

$T = T_0 e^{i\omega t} + T_1 e^{-i\omega t}$ …………   (9)

Where u_i , T_i (i = 0, 1) being functions of y only, u_0 u_1 , T_0, T_1 still to be determined .
Equating Harmonic and non-Harmonic terms and Placing the respective values of u and T in equations (5) and (6) from equations (8), (9)

Following Ordinary differential equations are obtained:-

$\frac{d^2u_0}{dy^2} + \frac{V_0}{1+\alpha i\omega}\frac{du_0}{dy} - \frac{[\frac{1}{K_p}+M^2+i\omega]}{1+\alpha I\omega} u_0 = \frac{-G_r T_0}{1+\alpha i\omega}$ …………   (10)

$\frac{d^2u_1}{dy^2} + \frac{V_0}{1-\alpha i\omega}\frac{du_1}{dy} - \frac{[\frac{1}{K_p}+M^2-i\omega]}{1-\alpha i\omega} u_1 = \frac{-G_r T_1}{1-\alpha i\omega}$ ……   …(11)

$\frac{d^2T_0}{dy^2} + \frac{V_0 P_r}{1+\alpha i\omega}\frac{dT_0}{dy} - \frac{P_r (S+i\omega)}{1+\alpha i\omega} T_0 = 0$ ………   (12)

$\frac{d^2T_1}{dy^2} + \frac{V_0 P_r}{1-\alpha i\omega}\frac{dT_1}{dy} - \frac{Pr(S-i\omega)}{1-\alpha i\omega} T_1 = 0$ …   (13)

The resultant boundary conditions are,

at y = 0 $u_0(0) = \frac{1}{2}$ +h $u_0'(0)$ $u_1(0) = \frac{1}{2}$ +h $u_1'(0)$ ………   (14)
at Y→∞ $u_0 = 0$ $u_1 = 0$ ……….   (15)
at y = 0 $T_0 = 0$ $T_1 = 1$ ………   . (16)
at Y→∞ $T_0 = 0$ $T_1 = 0$ ………   (17)

From equation (12) and (13), obtained ordinary differential equations (16) and (17) with prescribed boundary conditions which are solved as under:

$T_0 = 0$ ……   (18)
$T_1 = \exp(\ -D_2\, y)$ ………   (19)

Where $D_2 = \frac{P_1+\sqrt{{P_1}^2+4P_2}}{2}$ where $P_1 = \frac{v_0 P_r}{1-\alpha i\omega}$, $P_2 = \frac{P_r(S-i\omega)}{1-\alpha i\omega}$

By putting the equations (18) and (19) in equation (10) and (11) differential equations of second order are yielded

u_o and u_1 are given by :

$$\frac{d^2u_0}{dy^2}+\frac{V_0}{1+\alpha I\omega}\frac{du_0}{dy}-\frac{\frac{1}{k_p}+M^2+I\omega}{1+\alpha i\omega}u_0=0 \quad \ldots\ldots \quad (20)$$

$$\frac{d^2u_1}{dy^2}+\frac{V_0}{1-\alpha i\omega}\frac{du_1}{dy}-\frac{\frac{1}{K_p}+M^2-i\omega}{1-\alpha i\omega}u_1=\frac{-G_r\exp(-D_2y)}{1-\alpha i\omega} \quad \ldots\ldots \quad (21)$$

Using the boundary conditions of u_o and u_1 equations (20) and (21) are known and given by

$$u_0=\frac{\exp(-L_2y)}{2(1+hL_2)} \quad \ldots\ldots \quad (22)$$

$$u_1=\frac{\exp(-S_2y)}{2(1+hS_2)}+\frac{\text{Gr }(1+\text{h})\exp(-S_2y)}{(1+hS_2)(1-\alpha i\omega)({D_2}^2-R_1D_2-R_2)}-\frac{Gr\exp(-D_2y)}{(1-\alpha i\omega)({D_2}^2-R_1D_2-R_2)} \quad \ldots\ldots \quad (23)$$

Where $L_2=\frac{H_1+\sqrt{{H_1}^2+4H_2}}{2}$

Where $H_1 = \frac{V_0}{1+\alpha i\omega}$, $H_2=\frac{\frac{1}{k_p}+M^2+i\omega}{1+\alpha i\omega}$

$S_2=\frac{R_1+\sqrt{{R_1}^2+4R_2}}{2}$

Where $R_1 = \frac{V_0}{1-\alpha i\omega}$, $R_2=\frac{\frac{1}{k_p}+M^2-i\omega}{1-\alpha i\omega}$

Now substituting the values of u_o and u_1, T_0 and T_1 in equation (8) and (9)

$$u=\frac{1}{2}\left(\frac{\exp(-L_2y)}{(1+hL_2)}\right)e^{i\omega t}+\left(\frac{\exp(-S_2y)}{2(1+hS_2)}+\frac{\text{Gr }(1+\text{h})\exp(-S_2y)}{(1+hS_2)(1-\alpha i\omega)({D_2}^2-R_1D_2-R_2)}-\frac{Gr\exp(-D_2y)}{(1-\alpha i\omega)({D_2}^2-R_1D_2-R_2)}\right)e^{-i\omega t}\ldots \quad \ldots \quad (24)$$

$$\text{T}=\exp(-D_2y)\,e^{-i\omega t} \quad \ldots\ldots\ldots\ldots \quad (25)$$

Results Interpretation

Present study involves investigating the impact of convective incompressible, viscous flow pertaining to non-Newtonian fluid, conducting electrically over a plate of semi-infinite and porous nature, oscillating with transverse magnetic field acting on it. Solving the governing field equations the mathematical expressions regarding temperature as well as velocity are analytically evolved. The result obtained due to the impact of Gr, Kp, Pr, V0, S and M on velocity field u have been shown in figure 1 to 6, whereas the effect of Pr, Kp, S and V0 have been shown in figure 7 to 9.

Figure-1, varying values of thermal buoyancy force parameter Gr have been used for plotting velocity field. Velocity increases due to increase in Gr. Finally it is reduced to zero towards the boundary. Figure-2, varying values of permeability parameter Kp have been taken for plotting velocity field shown to be plotted against y. Increase in y causes increase in velocity which becomes zero finally. Figure-3, varying Pr values have been used for plotting velocity field, plotted against y. The increase in y produces decreasing trend in velocity which becomes zero finally. Figure-4, varying suction velocity values have been taken for plotting velocity field, shown against y in the figure. When y gets increase velocity tends to reduce and becomes zero finally. Figure-5, varying heat source values are taken for plotting velocity as shown in figure .Velocity faces decrease with increase in the value of y to become zero at the end. Figure-6 it shows plotting of velocity field with different values of magnetic field as shown in the figures. When magnetic field increases, flow is reduced there by decreasing the velocity which finally becomes zero at the boundary. Figure-7, in order to plot temperature field varying values of Prandtl number have been used. Its increase causes decrease in temperature which is reduced to zero at the boundary. Figure-8, temperature Tis plotted against y taking varying values pertaining to S parameter. y increases, temperature decreased to become zero at the boundary. Figure-9, temperature T is plotted in the direction against y on the basis of varying values of VO, the suction velocity and it reduces with increase in y. It becomes zero when it approaches the boundary.

Table-1. It contains the value of C_f the Skin-friction. Due to heat source parameter S increase skin-friction decreases. It also decreases when Prandlt number, Suction parameter and magnetic parameter increase. But increase in Gr and permeability parameters, skin-friction gets increase.

Table-2. This shows the status of Nusselt number with respect to heat source parameter, the increase in this parameter brings about decrease in Nusselt number, which also decreases when suction velocity and prandtl number increase but there is no change occurs when permeability parameter Kp increases.

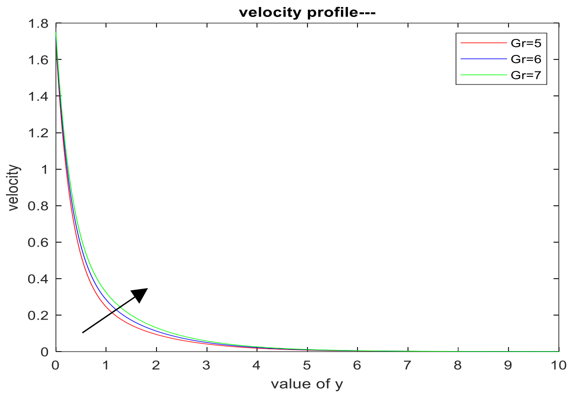

Figure -1 at Kp=0.1,M=0.5,alpha=0.1,exp=2.7183,w=pi/4;S=0.5,Pr=0.71, V0=0.5,h=0.2,t=0.5,phi=pi/6,Gr=5. **Grashof number causes variation in velocity**

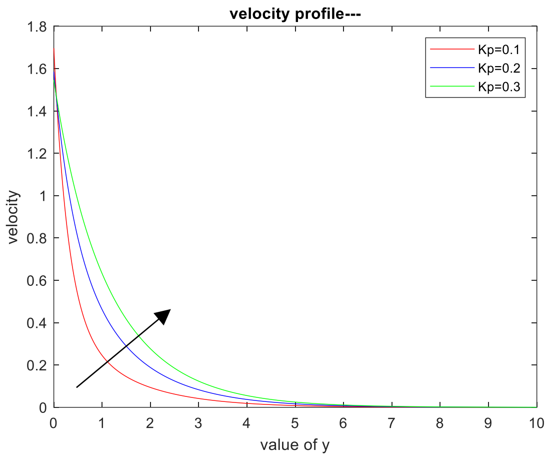

Figure -2 at Kp=0.1,M=0.5,alpha=0.1,exp=2.7183,w=pi/4;S=0.5,Pr=0.71, V0=0.5,h=0.2,t=0.5,phi=pi/6,Gr=5. **The velocity varies with Permeability**

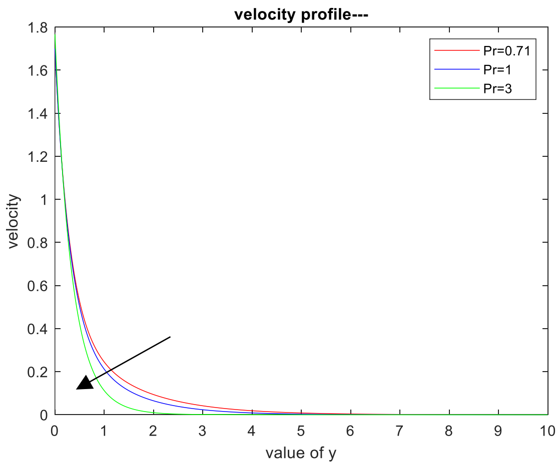

Figure -3 at Kp=0.1,M=0.5,alpha=0.1,exp=2.7183,w=pi/4;S=0.5,Pr=0.71, V0=0.5,h=0.2,t=0.5,phi=pi/6,Gr=5. **With Prandtl number velocity varies**

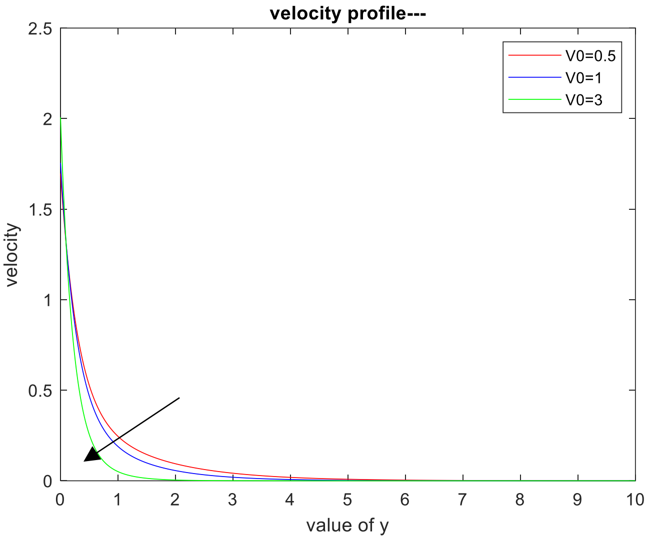

Figure -4 at Kp=0.1,M=0.5,alpha=0.1,exp=2.7183,w=pi/4;S=0.5,Pr=0.71, V0=0.5,h=0.2,t=0.5,phi=pi/6,Gr=5. **With suction velocity varies.**

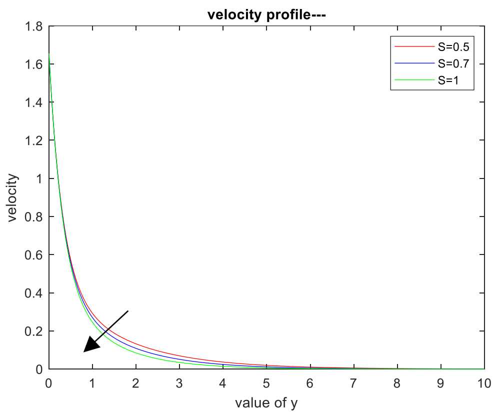

Figure -5 at Kp=0.1,M=0.5,alpha=0.1,exp=2.7183,w=pi/4;S=0.5,Pr=0.71, V0=0.5,h=0.2,t=0.5,phi=pi/6,Gr=5,**the velocity varies with heat source parameter.**

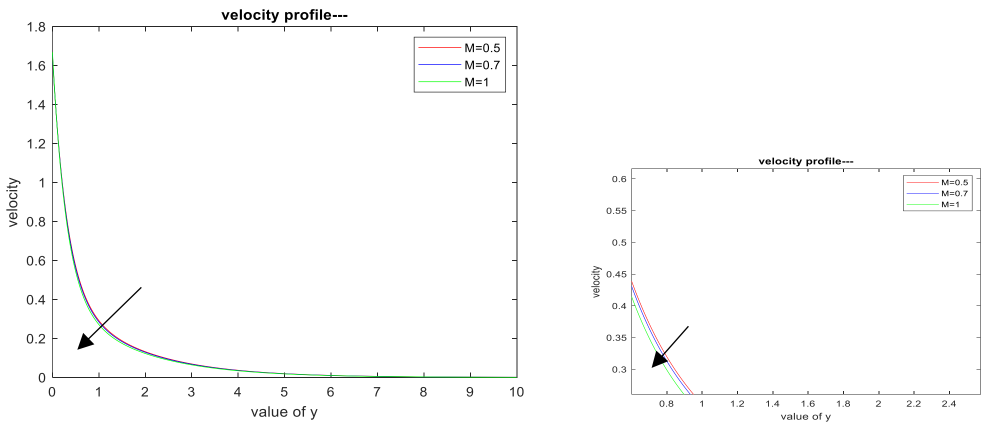

Figure -6 at Kp=0.1,M=0.5,alpha=0.1,exp=2.7183,w=pi/4;S=0.5,Pr=0.71, V0=0.5,h=0.2,t=0.5,Gr=5. **The velocity varies with Magnetic field parameter**

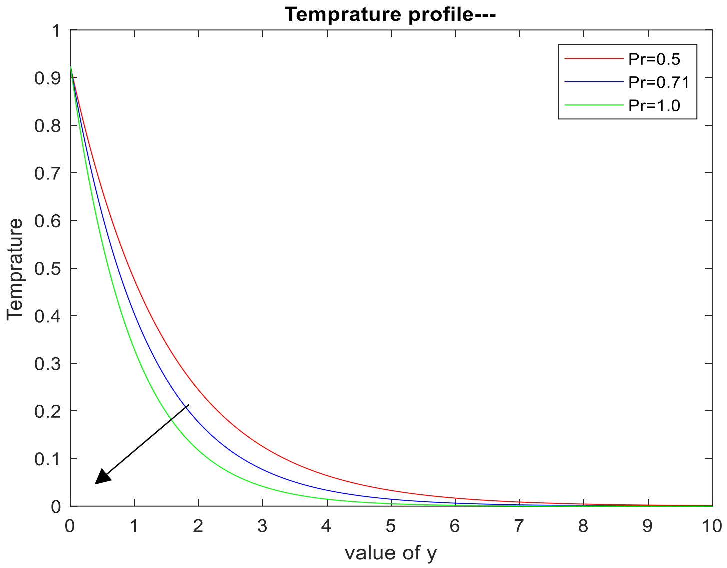

Figure -7 at Kp=0.1,M=0.5,alpha=0.1,exp=2.7183,w=pi/4;S=0.5,Pr=0.71, V0=0.5,h=0.2,t=0.5,phi=pi/6,Gr=5 **Prandtl number brings about variation in temperature .** .

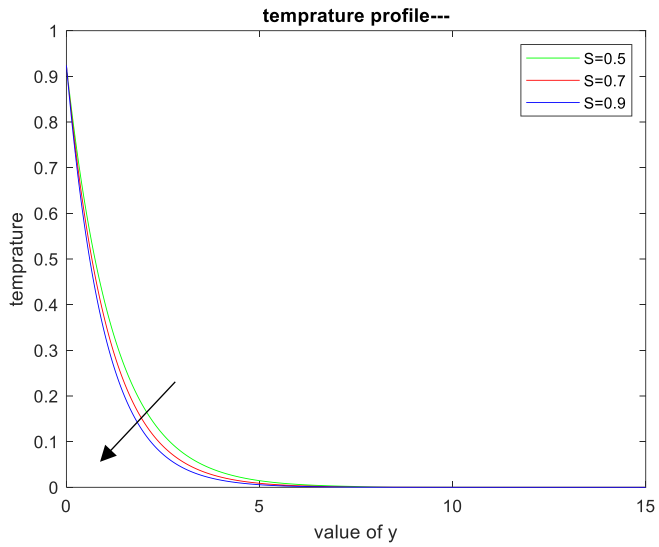

Figure -8 at Kp=0.1,M=0.5,alpha=0.1,exp=2.7183,w=pi/4;S=0.5,Pr=0.71, V0=0.5,h=0.2,t=0.5,phi=pi/6,Gr=5. **Temperature varies with heat source parameter**

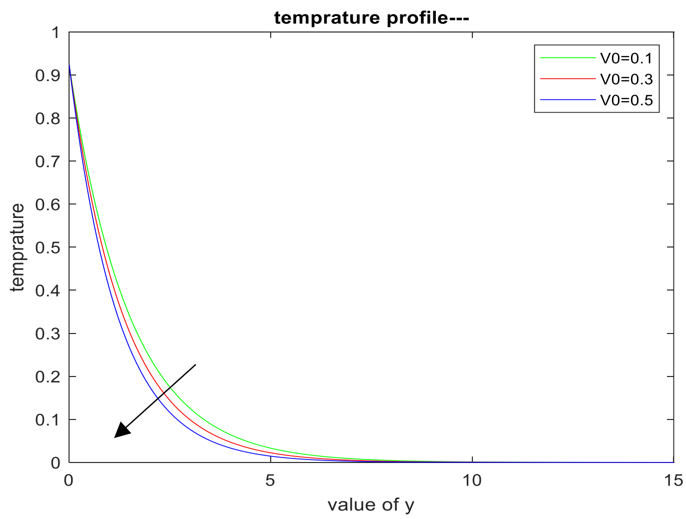

Figure -9 at Kp=0.1,M=0.5,alpha=0.1,exp=2.7183,w=pi/4;S=0.5,Pr=0.71, V0=0.5,h=0.2,t=0.5,phi=pi/6,Gr=5. **The temperature varies with suction velocity**

C_f at the plate

It is derived as under:

$$C_f = [\frac{\partial u}{\partial y}]_{y=0} = \frac{1}{2} \left(\frac{\exp(-L_2 y)(-L_2)}{(1+hL_2)}\right)e^{i\omega t} + \left(\frac{\exp(-S_2 y)(-S_2)}{2(1+hS_2)} + \frac{\mathrm{Gr}\,(1+h)\exp(-S_2 y)(-S_2)}{(1+hS_2)(1-\alpha i\omega)(D_2{}^2 - R_1 D_2 - R_2)} - \frac{Gr\exp(-D_2 y)(-D_2)}{(1-\alpha i\omega)(D_2{}^2 - R_1 D_2 - R_2)}\right)e^{-i\omega t}$$

Table 1. Displays computed values of C_f

S	Gr	Pr	Kp	V0	M	C_f
0.5	5	0.71	0.1	0.5	0.5	- 4.6485
0.7	5	0.71	0.1	0.5	0.5	- 4.6873
1.0	5	0.71	0.1	0.5	0.5	- 4.7362
0.5	6	0.71	0.1	0.5	0.5	- 4.4967
0.5	7	0.71	0.1	0.5	0.5	- 4.3449
0.5	5	1	0.1	0.5	0.5	-4.7226
0.5	5	3	0.1	0.5	0.5	-5.2178
0.5	5	0.71	0.2	0.5	0.5	-2.4523
0.5	5	0.71	0.3	0.5	0.5	-1.4928
0.5	5	0.71	0.1	1.0	0.5	-5.3477
0.5	5	0.71	0.1	3.0	0.5	-9.0168
0.5	5	0.71	0.1	0.5	0.7	-4.7408
0.5	5	0.71	0.1	0.5	1.0	-4.9345

Coefficient of heat transfer

It is given by: $Nu = [\frac{\partial T}{\partial y}]_{y=0}$ = $(-D_2)\exp(-D_2 y)\, e^{-i\omega t}$

Table 2. Values of Nu are tabulated

S	Pr	V0	Kp	Nu
0.5	0.71	0.5	0.1	-0.7670
0.7	0.71	0.5	0.1	-0.8596
0.9	0.71	0.5	0.1	-0.9413
0.5	0.5	0.5	0.1	-0.6162
0.5	1.0	0.5	0.1	-0.9570
0.5	0.71	0.3	0.1	-0.6876
0.5	0.71	0.1	0.1	-0.6152
0.5	0.71	0.5	0.2	-0.7670
0.5	0.71	0.5	0.3	-0.7670

Conclusion

This paper analytically examined the effect of non-Newtonian, viscous fluid, convective flow through medium of porous natured, over semi-infinite type plate in oscillatory position, while being affected by transverse magnetic field . Perturbation method is deployed for reducing related governing equations into ordinary differential equation which are further numerically solved to get the velocity and temperature. The analytical solution of the problem, computation of required values of Nu, C_f, and comparison of different values of Pr, M, Gr and skin friction by the use of graphs and tables yielded the result:

- Due to heat source parameter S increase skin-friction decreases.
- Skin-friction also decreases when Prandlt number, Suction parameter and magnetic parameter increase. But increase in Gr and permeability parameters, skin-friction gets increase.
- Increase of S, the heat source parameter reduces Nusselt number.
- Increase of suction velocity and Prandtl number also reduces Nusselt number but no change is affected due to increase in Kp, permeability parameter.
- Ratio of thermal diffusivity and momentum diffusivity is signified by Prandtl number and it can be used to increase the cooling effect in conducting flows.

REFERENCES

1. Mahmoud, M. A., & Megahed, A. M. (2009). MHD flow and heat transfer in a non-Newtonian liquid film over an unsteady stretching sheet with variable fluid properties. Canadian Journal of Physics, 87(10), 1065-1071.
2. Khan, M., & Rahman, S. (2009). Heat transfer analysis and magnetohydrodynamic flow of a non-Newtonian fluid through a porous medium with slip at the wall. Journal of Porous Media, 12(3).
3. Hamza, M. M., Isah, B. Y., & Usman, H. (2011). Unsteady heat transfer to MHD oscillatory flow through a porous medium under slip condition. International Journal of Computer Applications, 33(4), 12-17.
4. Moniem, A. A., & Hassanin, W. S. (2013). Solution of MHD Flow past a Vertical Porous Plate through a Porous Medium under Oscillatory Suction. Applied Mathematics, 4, 694-702.
5. Singh, K. D. (2013). Effect of slip condition on viscoelastic MHD oscillatory forced convection flow in a vertical channel with heat radiation. International Journal of Applied Mechanics and Engineering, 18(4).
6. Gbadeyan, J. A., & Dada, M. S. (2013). On the influence of radiation and heat transfer on an unsteady MHD non-Newtonian fluid flow with slip in a porous medium. Journal of Mathematics Research, 5(3), 40.
7. Bakr, A. A. (2014). Chemically reacting unsteady magnetohydrodynamic oscillatory Slip flow of a micropolar fluid in a planer channel with varying concentration. American Journal of Applied Mathematics, 2(4), 141-148.
8. Daniel, S., Tella, Y., & Joseph, K. M. (2014). Slip Effect on MHD Oscillatory flow of fluid in a porous medium with heat and mass transfer and chemical reaction. Asian Journal of Science and Technology, 5(3), 241-254.
9. Singh, J. K., Seth, G. S., & Begum, S. G. (2017). Unsteady MHD natural convection flow of a rotating viscoelastic fluid over an infinite vertical porous plate due to oscillating free-stream. Multidiscipline Modeling in materials and Structures. Multidiscipline Modeling in Materials and Structures, 14(2), 236-260. https://doi.org/10.1108/MMMS-06-2017-0054.
10. Falade, J. A., Ukaegbu, J. C., Egere, A. C., & Adesanya, S. O. (2017). MHD oscillatory flow through a porous channel saturated with porous medium. Alexandria engineering journal, 56(1), 147-152.
11. Ali, N., Khan, S. U., Sajid, M., & Abbas, Z. (2017). Slip effects in the hydromagnetic flow of a viscoelastic fluid through porous medium over a porous oscillatory stretching sheet. Journal of porous media, 20(3).
12. Rundora, L., & Makinde, O. D. (2018). Unsteady MHD Flow of Non-Newtonian Fluid in a Channel Filled with a Saturated Porous Medium with Asymmetric Navier Slip and Convective Heating. Appl. Math, 12(3), 483-493.
13. Majeed, A., Zeeshan, A., Mahmood, T., Rahman, S. U., & Khan, I. (2019). Impact of magnetic field and second-order slip flow of casson liquid with heat transfer subject to suction/injection and convective boundary condition. Journal of Magnetics, 24(1), 81-89.
14. Nadeem, S., Ullah, N., & Khan, A. U. (2019). Impact of an oblique stagnation point on MHD micropolar nanomaterial in porous medium over an oscillatory surface with partial slip. Physica Scripta, 94(6), 065209.
15. Aziz, T. (2021). Generalized stokes' flow and radiative heat transfer model of a non-Newtonian fluid in a darcy porous medium subject to Navier's slip conditions on the penetrable porous boundary: Group theoretical and compatibility analysis. Applied Mathematics and Computation, 400, 126048.
16. Rajakumar, K. V. B., Umasankara Reddy, M., & Balamurugan, K. S. (2021). Influence of Ohmic Heating and Viscous Dissipation on Steady MHD Non-Newtonian Mixed Convective Fluid Flow Over an Infinite Vertical Porous Plate with Hall and Ion-Slip Current. In Advances in Fluid Dynamics (pp. 159-169). Springer, Singapore.
17. Das, N., Taid, B. K., & Ahmed, N.(2022) Impact of thermal diffusion and chemical reaction on oscillatory MHD convective flow of a viscoelastic fluid through a porous medium in a slip flow regime. Heat Transfer.