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Heat Absorption and Magneto hydro dynamic (MHD) Effects on Jeffery Fluid Flow past a Vertical Porous Plate with Variable Suction

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ABSTRACT
Heat absorption and magneto hydrodynamic (MHD) effects on Jeffery fluid flow past a vertical porous plate with variable suction has been studied. The fundamental governing equations for this investigation are solved numerically using a regular perturbation technique. The velocity, temperature and concentration profiles within the boundary layer are presented graphically and discussed. Also, the expressions for the skin-friction coefficient, rate of heat and mass transfer coefficients were derived.

Key word:-magnetohydrodynamic(MHD), suction, temperature, porous medium,fluid,Jeffery fluid flow

I. INTRODUCTION

Magnetohydrodynamics MHD is the science of motion of electrically conducting fluids in presence of magnetic field. It concerns with the interaction of magnetic field with the fluid velocity of electrically conducting fluid. MHD generators, MHD pumps and MHD flow meters are some of the numerous examples of MHD principles. Dynamo and motor are classical examples of MHD principle. Convection problems of electrically conducting fluid in presence of magnetic field have got much importance because of its wide applications in Geophysics, Astrophysics, Plasma Physics, Missile technology, etc. MHD principles also find its applications in Medicine and Biology. Magnetohydrodynamics has many industrial applications such as physics, chemistry and engineering, crystal growth, metal casting and liquid metal cooling blankets for fusion reactors (Vajraveluetal., 1997).

Flow through a porous medium has numerous engineering and geophysical applications for example, in chemical engineering for filtration and purification process; in agricultural engineering to study the underground water resources; in petroleum technology to study the movement of natural gas, oil and water through the oil reservoirs (Alamet al. 2006).

Heat and mass transfer in porous medium are known to have applications in industrial, chemical engineering, nuclear reactors, geophysical and in petroleum industries. Recent development in binary flow of mixtures and the determination of molecular weights separation of isotopes, food processing and filtration process lead to increased investigations understanding such flow (Alamet al. 2006).

There are industrial applications of flow of electrically conducting fluid in the field of geothermal system, nuclear reactor, filtration etc., where the conducting fluid flows through a porous medium which also rotates about an axis.

There is one sub-class of non-Newtonian fluids called Jeffery fluid, the fluid model is capable of describing the characteristics of relaxation and retardation times (Hayat et al., 2008).

Jeffery fluid flow problems are useful in nuclear engineering in connection with the cooling of reactors, in the case of flow past a semi-finite vertical plate under the action of transverses magnetic field and in the presence of suction (Rajuet al. 2018).

II. LITERATURE REVIEW

Magnetohydrodynamics (MHD) is the science of motion of electrically conducting fluids in presence of magnetic field. It concerns with the interaction of magnetic field with the fluid velocity of electrically conducting fluid. MHD generators, MHD pumps and MHD flow meters are some of the numerous examples of MHD principles. Dynamo and motor are classical examples of MHD principle. Convection problems of electrically conducting fluid in presence of magnetic field have got much importance because of its wide applications in Geophysics, Astrophysics, Plasma Physics, Missile technology, etc. MHD principles also find its applications in Medicine and Biology. Magneto hydrodynamics has many industrial applications such as physics, chemistry and engineering, crystal growth, metal casting and liquid metal cooling blankets for fusion reactors. The convective heat transfer over a stretching surface with applied magnetic field was presented by Vajraveluet al. (1997).

Omokhualeet al. (2016) studied effect of Heat Absorption on Steady/Unsteady MHD Free Convection Heat and Mass Transfer Flow Past an Infinite Vertical Permeable Plate with Mass Absorption and Variable Suction. Omokhuale et al. (2016) analyzed effect of Chemical Absorption and Time Dependent Suction on Jeffery Fluid Flow Past an Infinite Vertical Plate with Heat Mass Transfer. Omokhuale et al. (2016) presented effect of Heat Absorption on Steady/Unsteady MHD Free Convection Heat and Mass Transfer Flow Past an Infinite Vertical Permeable Plate with Mass Absorption and Variable Suction.

Sandeep and Sulochana (2007) proposed a new mathematical model for investigating the momentum and the heat transfer behavior on Jeffery, Maxwell and Oldroyd-B Nano-fluid over a stretching surface in the presence of transverse magnetic field, non-uniform heat source, thermal radiation and suction effects. Singh and Takhar (2007) have investigated the effects of heat and mass transfer on the three dimensional flow of viscous fluid along an infinite porous vertical plate with periodic suction velocity. Hayat et al. (1998) have analyzed the periodic unsteady flow of a non-Newtonian fluid. Ogulu and Prakash (2006) discussed the heat transfer of unsteady magneto hydrodynamic flow past an infinite vertical moving plate with variable suction. Uwanta (2009) analyzed mass transfer of free convective flow over a vertical plate with heat sink and jumped wall temperature. Das et al., (2010) investigate numerically the influence of melting heat transfer and thermal radiation on MHD stagnation point flow of an electrically conducting non-Newtonian fluid (Jeffery fluid) over a stretching sheet with partial surface slip. His analysis revealed that the fluid temperature is higher in case of Jeffery fluid than that Newtonian fluid. Abdul Gaffaret al., (2011) examined the non-linear steady state boundary layer flow, heat and mass transfer of an incompressible non-Newtonian Jeffery fluid past a semi-infinite vertical plate. He stated that this model application in metallurgical material processing, chemical engineering flow control etc. in many industrial applications, external magnetic field is used to control construction of materials, fields such as hot rolling, paper production, gas fiber production, condensation process of metallic plate in a cooling bath, glass and also polymer industries (Ezzatet al., 2009).

The effect of heat generation or absorption on hydro magnetic three dimensional free convection flows over a vertical stretching sheet was discussed by Chamkha (2009). Youn (2000) has studied the unsteady MHD convective heat transfer past a semi-infinite vertical porous moving plate with variable suction. Singh and Rakesh Kumar (2010) analyzed the effects of chemical reaction and heat generation absorption on unsteady MHD free convection heat and mass transfer flow of an electrically conducting, viscous, incompressible fluid past an infinite hot vertical porous plate through porous medium when the plate temperature is span wise fluctuating with time.

Krisha Murthy (2012) analyzed the combined heat and mass transfer process by natural convection from a corrugated vertical surface immersed in a non-Darcy porous medium. Hall current was ignored while applying Ohm's law because it has no significant effect for small and average values of the magnetic field. The effects of Hall current are very important in the presence of a strong magnetic field. Chamkhaet al. (2006) studied magnetic field effects on Jeffery on electrically conducting free convection heat and mass transfer from an inclined place with heat generation/absorption. Reddy et al. (2013) examined the effect of variable viscosity and thermal diffusivity on MHD free convection flow along a moving vertical plate embedded in a porous medium with heat generation. Kumar et al. (2006) studied heat and mass transfer characteristics in the unsteady free convection flow of an incompressible viscoelastic fluid over a moving vertical cone and a flat plate in the presence of magnetic field and higher order chemical reaction. Seth et al. (2010) studied the effects of Hall current and rotation on a hydro magnetic natural convection flow with heat and mass transfer of an electrically conducting, viscous, incompressible, chemically reacting and optically radiating fluid past an impulsively moving infinite vertical plate embedded in a porous medium in the presence of thermal and mass diffusion. Mamtaet al. (2017) investigated the effects of radiation absorption, heat absorption/ generation and chemical reaction on unsteady heat and mass MHD oscillatory flow of a viscoelastic fluid between two inclined plates.

Dulal Pal et al. (2012) presented an analytical study for the problem of unsteady hydro magnetic heat and mass transfer for a micro polar fluid bounded by semi-infinite vertical permeable plate in the presence of first-order chemical reaction, thermal radiation and heat absorption. A uniform magnetic field acts perpendicularly to the porous surface which absorbs the micro polar fluid with a time-dependent suction velocity.

The basic partial differential equations are reduced to a system of nonlinear ordinary differential equations which are solved analytically using perturbation technique.

Eshetu Haile et al. (2014) explore the effects of heat and mass transfer through a porous media of MHD flow of Nano fluids with thermal radiation, viscous dissipation and chemical reaction. Mamtaet al. (2015) investigated the effects of radiation absorption, heat absorption/ generation and chemical reaction on unsteady heat and mass MHD oscillatory flow of a viscoelastic fluid between two inclined plates. The equations of continuity, linear momentum, energy and diffusion, which govern the flow field, are solved by using a regular perturbation method. Free convective flow of a Jeffrey fluid in a vertical deformable porous stratum is investigated by Sreenadhet al. (2015) and noticed that the effect of increasing Jeffrey parameter is to increase the skin friction in the deformable porous stratum. Aiyesimiet al. (2016) examined the magneto hydrodynamic (MHD) flow of unsteady convective third grade fluid in a cylindrical system and it is observed that velocity decreases and increases with increasing magnetic field and porosity, temperature increases as magnetic field increases.

III. METHODOLOGY

Formulation of the Problem

An unsteady MHD flow of laminar, Jeffery, incompressible, electrically conducting and generating fluid past a vertical porous plate with variable suction and subject to a uniform transverse magnetic field β_o in the presence of thermal radiation and the first order homogeneous chemical reaction, it is assumed that there is no applied voltage which implies the absence of an electrical field. The transversely applied magnetic field, Prandtl number, and Schmidtl number are assumed to be very small so that the induced magnetic field and Hall Effect are negligible. x^*-axis is taken in the upward direction along with the flow and y^*-axis is taken perpendicular to it. At y^*=0, the plate is initially assumed to be moving with a uniform velocity u'in the direction of the fluid flow and the free stream velocity follows the exponentially increasing small perturbation law.

It is assumed that the temperature, concentration at the wall as well as suction velocity is exponentially varying with time. By considering the above assumptions, the governing equations are given as follows:

Continuity Equation

$$\frac{\partial v^*}{\partial y^*} = 0 \tag{3.1}$$

Momentum Equation

$$\frac{\partial u^*}{\partial t^*} + v^*\frac{\partial u^*}{\partial y^*} = \frac{1}{1+\lambda_1}\frac{\partial^2 u^*}{\partial y^{*2}} + g\beta_T(T^* - T^*_\infty) + g\beta_C(C^* - C^*_\infty) - \frac{\sigma B_0^2 u^*}{\rho} - \frac{\vartheta u^*}{K^*} \tag{3.2}$$

Energy Equation

$$\frac{\partial T^*}{\partial t^*} + v^*\frac{\partial T^*}{\partial y^*} = k\frac{\partial^2 T^*}{\partial y^{*2}} - \frac{Q_o}{\rho C_p}(T^* - T^*_\infty) \tag{3.3}$$

Concentration Equation

$$\frac{\partial c^*}{\partial t^*} + v^*\frac{\partial c^*}{\partial y^*} = D_m\frac{\partial^2 c^*}{\partial y^{*2}} - R_m(C^* - c'_\infty) \tag{3.4}$$

Non-dimensional Variables and Parameters

$$u = \frac{u^*}{u_*},\ \eta = \frac{V_o y^*}{\nu},\ t = \frac{t^* V_o^2}{\nu},\ \theta = \frac{T^* - T^*_\infty}{T^*_w - T^*_\infty},\ c = \frac{C^* - C^*_\infty}{C^*_w - C^*_\infty},\ V^* = -V_o(1 + \varepsilon A e^{nt}) \tag{3.5}$$

Using the non-dimensional variable and parameters in (3.5) on equations (3.2)-(3.4) and since $v^* = -V_o(1 + \varepsilon A e^{nt})$. Where A is a real positive constant, ε is small and V_o is a non-zero positive constant, the negative sign indicate the suction towards the plate is respectively written as:

$$\frac{\partial u}{\partial t} - (1 + \varepsilon A e^{nt})\frac{\partial u}{\partial \eta} = \frac{1}{\gamma}\frac{\partial^2 u}{\partial \eta^2} + G_r\theta + G_c C - Mu - \frac{1}{k}u \tag{3.6}$$

$$\frac{\partial \theta}{\partial t} - (1 + \varepsilon A e^{nt})\frac{\partial \theta}{\partial \eta} = \frac{1}{P_r}\frac{\partial^2 \theta}{\partial \eta^2} - Q\theta \tag{3.7}$$

$$\frac{\partial C}{\partial t} - (1 + \varepsilon A e^{nt})\frac{\partial C}{\partial \eta} = \frac{1}{S_c}\frac{\partial^2 C}{\partial \eta^2} - \delta C \tag{3.8}$$

Skin-Friction

Knowing the velocity field, the skin-friction at the plate can be obtained, and is given by:

$C_f = -\left(\frac{\partial u}{\partial \eta}\right)_{\eta=0} = (A_{12}m_{12} + A_{13}m_7 + A_{14}m_2) + \varepsilon(A_{16}m_{16} + A_{17}m_9 + A_{18}m_7 + A_{19}m_4 + A_{20}m_2 + A_{21}m_{12} + A_{22}m_7 + A_{23}m_2)exp(nt)$ (3.28)

Nusselt Number

From the temperature field, we obtain Nusselt number (rate of change of heat transfer) which is given as:

$Nu = -\left(\frac{\partial \theta}{\partial \eta}\right)_{\eta=0} = m_7 + \varepsilon(A_9m_9 + A_{10}m_7)exp(nt)$ (3.29)

Sherwood Number

From the concentration field, now we get the Sherwood number (rate of change of mass transfer) which is:

$Sh = -\left(\frac{\partial C}{\partial \eta}\right)_{\eta=0} = m_2 + \varepsilon(A_4m_4 + A_5m_2)exp(nt)$ (3.30)

IV. RESULTS AND DISCUSSION

In this paper research, the unsteady flow of an incompressible Jeffery fluid flow past a vertical porous plate with variable suction is investigated. Regular Perturbation technique is employed in solving non-linearly coupled partial differential equations. The results show the effects of various pertaining parameter such as Grashof number for heat transfer (Gr), Grashof number for mass transfer (Gc), Magnetic field parameter (M), Permeability parameter (K), Prandtl number (Pr), Schmidt number (Sc), Heat absorption parameter (Q), and Jeffrey fluid parameter (λ) on velocity, temperature and concentration profiles have been analyzed. In the present study following default parameter values are adopted for computations: Pr = 0.71, M = 1, Gr = 1, Gc = 1, λ =1, K = 1, Sc = 0.22, Q = 1, n = 0.1, t = 1.0, A = 0.5,δ = 1, ζ= 1 and ε = 0.001. All graphs therefore correspond to these values unless specifically indicated on the appropriate graph.

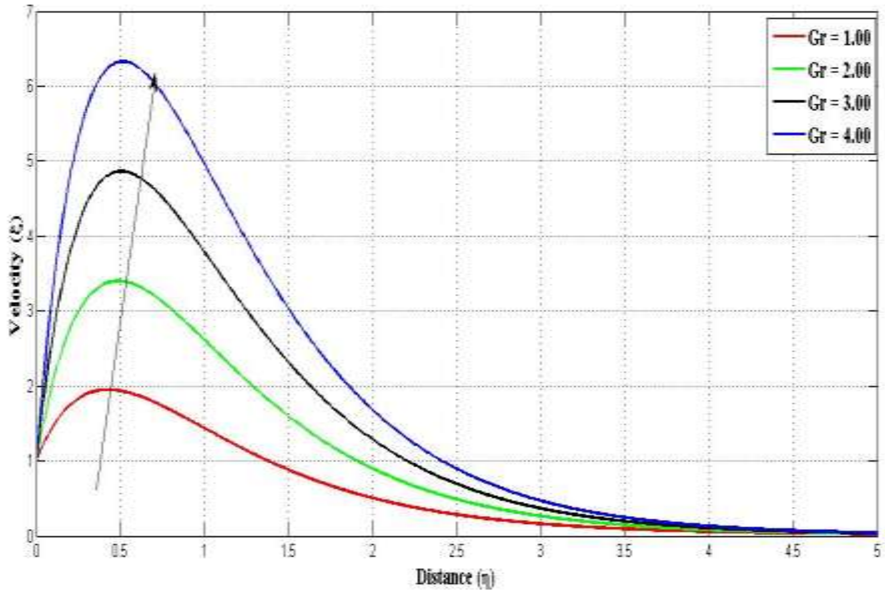

Figure 4.1 Effects of heat transfer on velocity profiles

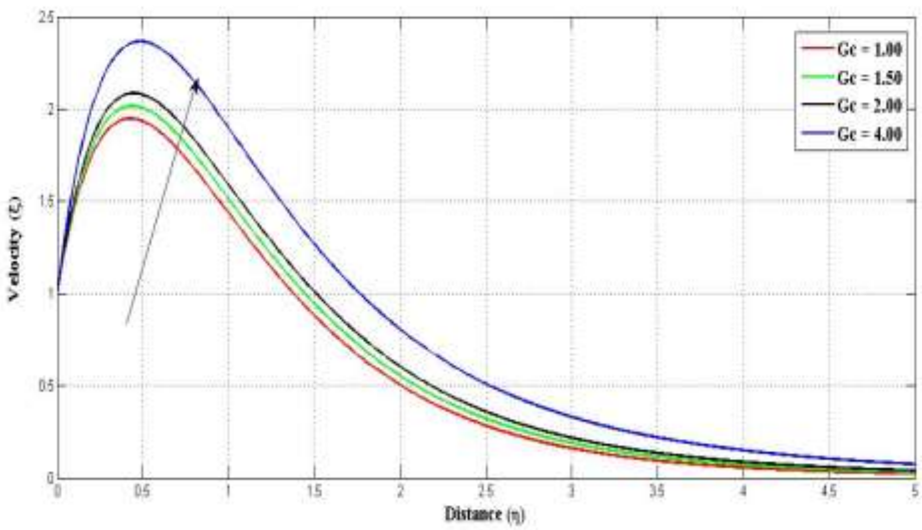

Figure 4.2 Effects of mass transfer on velocity profiles

Summary

The research project consists of five paper researchs: paper research one which is the general introduction, back ground of the study, statement of the problem, objective of the study, scope and delimitation of the study. Paper research two reviewed related literature to the work while paper research three explained the formulation of the problem and the method of the solution, paper research four which present and analyzed the result and discussion, and the last paper research which is five contained the summary, conclusion, and contribution to knowledge.

V.CONCLUSION

Heat absorption and magnetohydrodynamic (MHD) effects on Jeffery fluid flow past a vertical porous plate with variable suction has been analyzed. The fundamental coupled partial differential equations are solved by perturbation technique. Results were obtained and compared with previously reported cases available in the literature and they were found to be in good agreement. Graphical results for various parametric conditions were presented and discussed for different values. From the present study, the following conclusions were drawn:

1. The magnetic field parameter retards the velocity of the flow field at all points, due to the magnetic pull of the Lorentz force acting on the flow field.
2. An increase in Prandtl number leads to a decrease of both velocity and temperature profiles.
3. An increase in heat and mass transfer leads to an increase in the velocity profiles.
4. Velocity profiles as well as the concentration profiles decreases with an increase in the Schmidt number.

VI. RECOMMENDATION

The researcher is here by recommending the study variable suction and temperature effects on Jeffery fluid flow which has application in chemical engineering, nuclear reactors, geophysical and petroleum industries. Also students should be allowed to expand on the scope by covering other areas not touch in the cause of this research work, not only Jeffery fluid but also other kind of fluids such as Darcy Fluid, Casson Fluid etc.

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Appendix: Program Code

```
vel
y=0:0.01:7;
epsilon=0.2;
m=((3*F+4)/(3*F));
n=1+(1/e);
d1 = sqrt(((Sc).^2+4.*r*Sc)./4);
d2 = sqrt(((Sc).^2+4.*Sc*(r+i*w))./4);
d3 = sqrt(((1/m).^2+((4.*S)/m))./4);
d4 = sqrt(((1/m).^2+4.*((S+i*w)/m))./4);
d5 = sqrt(((1/n).^2+4.*(M+1/K)/n)./4);
d6 = sqrt(((1/n).^2+4.*(M+1/K+i*w)/n)./4);
r2=(Sc)./2+d1;
r10=(1/2*n)+d5;
r12=(1/2*n)+d6;
r6=1/(2*m)+d3;
r8=1/(2*m)+d4;
T0=exp(-r6*y);
C0=exp(-r2*y);
r4=(Sc)./2+d2;
D3=Sc*A*r2/(r2^2-Sc*r2-(r+i*w)*Sc);
D2=1-D3;
D6=A*r6/(r6^2-(1/m)*r6-(r+i*w));
D5=1-D6;
```