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Rotational effect of unsteady MHD-Parabolic Flow Past a Vertical Plate through porous medium with uniform temperature mass diffusion

T. Gowri[1], A. Selvaraj[2,*]

[1] Research scholar, Department of Mathematics, Vels Institute of Science, Technology and Advanced Studies, Chennai-600117.

[2]Department of Mathematics, Vels Institute of Science, Technology and Advanced Studies, Chennai-600117.

Abstract: This research investigated the rotational impact of unsteady MHD-parabolic flow through an impermeable and electrically driven fluid via a uniform quickened unbounded isothermal perpendicular plate through porous material due to the influence of a transversely applied magnetic field. This plate temperature is increased to $\boldsymbol{T'_w}$, and focus level close to plate is increased to $\boldsymbol{C'_w}$. The Laplace Transform Technique was used to comprehend the non-dimensional administering equation. Following that, the occurrences of temperature distribution, concentration, and velocity role for Distinct Physical Frameworks such as warm Grashof integer, Schmidt integer, mass Grashof integer, time, and Prandtl integer have been examined using a graphical representation. It's worth mentioning that the Velocity rises when the mass Grashof warm or Grashof number estimates rise. It was also discovered that when the magnetic field lessens, the fluid flow velocity rises.

Keywords: Parabolic, vertical plate, mass diffusion, magnetic field, porous medium, rotation.

1. Related to work

Nowadays MHD has a vital contribution in the field of science and technology particularly MHD- the motion of electrically conducting fluids in the presence of magnetic fields, MHD generators, pumps, are numerous examples of the MHD principle. Also, MHD is used in the field of textile industries, agriculture fields, petroleum industries, a study of the geological field, recovery of an oil field, etc. MHD flow applications are very useful in the field of metrology solar physics and earth science. It has a significant impact on the environment around us. Atmospheric flow is influenced by temperature or concentration changes and may be seen in our daily lives. Thermal and solutal buoyancy forces generated by a difference in concentration or temperature or a combination of these two are responsible for natural processes such as vaporization of fog and mist, drying of porous solids, photosynthesis, sea-wind formation, transpiration, and the formation of ocean currents. These configurations can also be found in a variety of real-world systems used in the manufacturing industry. It is well known that MHD, a brand-new method of producing power that results in the great productivity and reduced pollution, is particularly remarkable for three areas: electrodynamics, physical science, as well as liquid elements.

Soundalgekar emphasized the effect of mass exchange as well as free convection on a stream passing a perpendicular plate [1]. The problem was rationalized by stating that increased chilling of the plate increases skin friction and increased plate warmness results in a reduction in skin friction. Soundalgekar also worked on the aforesaid problem when it was expanded to include mass exchange effects caused by a continually accelerated perpendicular plate [2]. Singh and Raptis [3] investigated the MHD free convection stream passing through an accelerated perpendicular plate. Singh J and Singh A.K. [4] presented the mass move implications for a stream through an accelerated perpendicular plate with steady warmth motion. Singh A.K. [5] visually presented the hydromagnetic free convection stream through an imprudently commenced perpendicular plate of rotating liquid, concluding that the basic speed profile of waterfalls with a rise in either Rotational parameter or attractive field parameter in both situations. A. Raptis and A.K. Singh investigated the rotational effects of an MHD free convection stream passing through a quickened perpendicular plate [6]. Mass exchange and free convection influences on the flow through an augmented perpendicular plate with heat sources are explained by Ravindra prasad and Basanth Kumar Jha [7]. Mass exchange effects for the flow through an exponentially accelerated perpendicular plate with constant temperature motion were visually elucidated by Jha B.K., Rai S., Prasad R. [8]. Muthucumaraswamy et al. [9] focused on the effects of rotation on the MHD stream, which is an augmented isothermal perpendicular plate with mass as well as heat dispersion. Muthucumaraswamy [10] focused on the rotational influence on MHD stream passing an accelerated perpendicular plate. Surendra Kumar and U.S. Rajput analysed the influence of rotation as well as radiation on MHD [11]. The combined consequences of MHD and thermal radiation have been analysed by Annamalai Ramachandran Vijayalakshmi et al. [12]. Muthucumaraswamy [13] focused an MHD stream through an accelerated perpendicular plate with varied mass as well as heat dispersal inside the sight of the turn. Muthucumaraswamy et al. [14] focused a radiant stream through an allegorical started isothermal perpendicular plate with identical mass motion. Muthucumaraswamy [15] investigated the radiation stream passing through an explanatory began isothermal perpendicular plate. MHD Parabolic flow across an accelerating isothermal vertical plate with mass as well as heat diffusion was studied by Selvaraj et al. [16] in the presence of rotation. The mass and heat effects of rotation on parabolic flow across a vertical plate were studied by Selvaraj et al. [17].

In the region of mass and heat exchange, the rotational impacts of a parabolic stream passing between an electrically coordinated fluid and an impermeable viscous through an unbound isothermal plate in the presence of magneto hydrodynamic are to be studied in this method. By employing the Laplace change strategy, can shed light on the non-dimensional administering settings. In contexts of complementary error functions and exponential outcomes, the Derived arrangement brings about.

2. Mathematical Expression of the problem

Unsteady MHD flow with heat as well as mass transmission beyond an electrically engaged fluid is studied, along with the flow of a viscous impenetrable fluid generated by uniformly accelerated motion of an unending isothermal plate in the presence of rotation through a porous material. The flow is unsteady, then x'- axis is selected alongside perpendicular direction and $\boldsymbol{y}'$-axis is taken as normal to x'- and $\mathbf{Z}'$-axis is normal to it. Whereas time $t' \leq 0$. Due to transverse magnetic discipline, $\boldsymbol{B_0}$ both the fluid and the plate are in a state of inflexible rotation with uniform angular velocity $\boldsymbol{\Omega}$. Considered to be minimal, the viscous dissipation as well as precipitated magnetic area. At first each plate and fluid were at rest and with the identical concentration C'_∞ and temperature T_∞. At $\mathbf{t}'$>0 time, the plate starts moving at a pace $\boldsymbol{u} = (\boldsymbol{u_0}\mathbf{t}')^2$ in its personal plane within the perpendicular direction. The plate temperature is increased to $\boldsymbol{T'_w}$ at the same time and therefore, the concentration stage switched to $\boldsymbol{C'_w}$ and maintained constant. Because the plate filling the plane, $\mathbf{Z}' = 0$ has an infinite length, all physical portions rely on the most effective, Z′ and t′, and the unsteady flow is regulated by the provided equation using standard Boussinesq's approximation.

$$\frac{\partial U}{\partial t} - 2\Omega V = Gr\theta + GcC + \frac{\partial^2 U}{\partial Z^2} - MU - \frac{U}{K_1} \quad (1)$$

$$\frac{\partial V}{\partial t} + 2\Omega U = \frac{\partial^2 V}{\partial Z^2} - MV - \frac{V}{K_1} \quad (2)$$

$$\frac{\partial \theta}{\partial t} = \frac{1}{pr}\frac{\partial^2 \theta}{\partial Z^2} \quad (3)$$

$$\frac{\partial C}{\partial t} = \frac{1}{sc}\frac{\partial^2 C}{\partial Z^2} \quad (4)$$

The starting and limit conditions are also included:

$$\boldsymbol{u} = \mathbf{0}, \quad T' = T'_\infty, \quad C' = C'_\infty \ \ for\ all\ y, t' \leq 0$$
$$\mathbf{t}' > 0 \ \ u = (u_0 t')^2, \quad T' = T'_w, \quad C' = C'_w \ \ at\ y = 0 \quad (5)$$
$$u \to 0, \quad T' \to T'_\infty, \quad C' \to C'_\infty \ \ at\ y \to \infty$$

On proposing the following non-dimensional quantities:

$$U = \frac{u}{(Vu_0)^{\frac{1}{3}}},\ V = \frac{v}{(Vu_0)^{\frac{1}{3}}},\ t = t'\left(\frac{u_0^2}{v}\right)^{\frac{1}{3}},\ Z = z\left(\frac{u_0}{v^2}\right)^{\frac{1}{3}}$$

$\theta = \frac{T - T_\infty}{T_w - T_\infty}$, $Gr = \frac{g\beta(T_w - T_\infty)}{u_0}$ *is the thermal Grashof number*, $C = \frac{C' - C'_\infty}{C'_w - C'_\infty}$, **(6)**

$Gc = \frac{g\beta^*(C'_w - C'_\infty)}{u_0}$ *is the solutal Grashof number*, $K_1 = \frac{k_1 U_0^2}{v^2}$ *is the permeability parameter*

$M = \frac{\sigma B_0^2}{\rho}\left(\frac{v}{u_0^2}\right)^{\frac{1}{3}}$ *is the magnetic parameter*, $pr = \frac{\mu C_p}{k}$ *is the prandtl number*

$sc = \frac{v}{D}$ **is the Schmidt number**

The hydromagnetic is Coupling differential conditions (1) and (3), a rotating free convective stream through a quickened perpendicular plate is shown (4). To understand the condition, we first provide a complex velocity F=u+iv and then solve and combine 1st and 2nd equations.

$$\frac{\partial F}{\partial t} = \mathrm{Gr}\theta + \mathrm{Gc}C + \frac{\partial^2 q}{\partial Z^2} - mq - \frac{q}{K_1} \quad (7)$$

The following are the starting and limit conditions in dimensionless quantities:

$$q = 0, \quad \theta = 0, \quad C = 0 \quad for\ all\ Z, t \leq 0 \mathrm{t} > 0$$
$$q = t^2, \quad \theta = 1, \quad C = 1 \quad Z = 0 \quad (8)$$
$$q \to 0, \quad \theta \to 0, \quad C \to 0 \quad Z \to 0$$

where **m=M+2iΩ**

3 Analysis

The Dimensionless administering equation (1) to (4) and (7) with the prescribed limit condition (8) are solved by the Laplace change method and the Solution for velocity profile as "follows.

$$q = \left[\frac{(\eta^2 + \left(m + \frac{1}{k_1}t\right)t}{4\left(m + \frac{1}{k_1}\right)}\left[e^{2\eta}\sqrt{\left(m + \frac{1}{k_1}\right)t}\, erfc\left(\eta + \sqrt{\left(m + \frac{1}{k_1}\right)t}\right) + e^{-2\eta}\sqrt{\left(m + \frac{1}{k_1}\right)t}\, erfc\left(\eta - \sqrt{\left(m + \frac{1}{k_1}\right)t}\right)\right] + \frac{\eta\sqrt{t}\left(1 - 4\left(m + \frac{1}{k_1}\right)t\right)}{8\left(m + \frac{1}{k_1}\right)^{\frac{3}{2}}}\left[e^{-2\eta}\sqrt{\left(m + \frac{1}{k_1}\right)t}\, erfc\left(\eta - \right.\right.\right.$$

$$\sqrt{\left(m+\frac{1}{k_1}\right)t}\Big) - e^{2\eta}\sqrt{\left(m+\frac{1}{k_1}\right)t}\, erfc\Big(\eta + \sqrt{\left(m+\frac{1}{k_1}\right)t}\Big)\Big] - \frac{\eta t}{2(m+\frac{1}{k_1})\sqrt{\pi}} e^{-(\eta^2+(m+\frac{1}{k_1})t)}\Bigg] + \Big[\frac{Gr}{a(1-pr)} +$$

$$\frac{Gc}{b(1-sc)}\Big]\frac{1}{2}\left[\begin{array}{l} e^{2\eta}\sqrt{\left(m+\frac{1}{k_1}\right)t}\, erfc\Big(\eta+\sqrt{\left(m+\frac{1}{k_1}\right)t}\Big) \\ +e^{-2\eta}\sqrt{\left(m+\frac{1}{k_1}\right)t}\, erfc\Big(\eta-\sqrt{\left(m+\frac{1}{k_1}\right)t}\Big)\end{array}\right] -$$

$$-\frac{Gr}{a(1-pr)}\left[\frac{e^{at}}{2}\left[e^{2\eta}\sqrt{\left((m+\frac{1}{k_1}+a\right)t}\, erfc\Big(\eta+\sqrt{\left((m+\frac{1}{k_1}+a\right)t}\Big)\right] + \left[e^{2\eta}\sqrt{\left((m+\frac{1}{k_1}-a\right)t}\, erfc\Big(\eta+\sqrt{\left((m+\frac{1}{k_1}-a\right)t}\Big)\right]\right] -$$

$$\frac{Gc}{b(1-sc)}\left[\frac{e^{bt}}{2}\left[e^{2\eta}\sqrt{\left((m+\frac{1}{k_1}+b\right)t}\, erfc\Big(\eta+\sqrt{\left((m+\frac{1}{k_1}+b\right)t}\Big)\right] + \left[e^{2\eta}\sqrt{\left((m+\frac{1}{k_1}-b\right)t}\, erfc\Big(\eta+\sqrt{\left((m+\frac{1}{k_1}-b\right)t}\Big)\right]\right] - \frac{Gr}{a(1-pr)} erfc(\eta\sqrt{pr}) -$$

$$\frac{Gc}{b(1-sc)} erfc(\eta\sqrt{sc}) + \frac{Gr}{a(1-pr)}\left[\frac{e^{at}}{2}\left[e^{2\eta}\sqrt{prat}\, erfc(\eta\sqrt{pr}+\sqrt{at})\right] + \left[e^{-2\eta}\sqrt{prat}\, erfc(\eta\sqrt{pr}-\sqrt{at})\right]\right] +$$

$$\frac{Gc}{b(1-sc)}\left[\frac{e^{bt}}{2}\left[e^{2\eta}\sqrt{scbt}\, erfc(\eta\sqrt{sc}+\sqrt{bt})\right] + \left[e^{-2\eta}\sqrt{scbt}\, erfc(\eta\sqrt{sc}-\sqrt{bt})\right]\right]$$

(9)

$$\theta = erfc(\eta\sqrt{pr})$$

(10)

$$C = erfc(\eta\sqrt{sc})$$

(11)

Where” $a = \frac{(m+\frac{1}{k_1})}{pr-1}$ $and\ b = \frac{(m+\frac{1}{k_1})}{sc-1}$ $\eta = \frac{z}{2\sqrt{t}}$

The velocity profile for the issue is shown in equation nine. To gain a physical understanding of the problem. Conducting a Numerical Estimation. Dominant velocity (primary) and auxiliary velocity profiles may be obtained using this equation (Secondary).

$$erfc(a+ib) = \mathrm{erf}(a) + \frac{\exp(-a^2)}{2a\pi}[1-\cos(2ab) + i\sin(2ab)] + \frac{2\exp(-a^2)}{\pi}\sum_{n=1}^{\infty}\frac{\exp(-\eta^2/4)}{\eta^2+4a^2}[f_n(a,b) + ig_n(a,b)] + \in(a,b)$$

the equation approach is used to interpret q, which shows that the contention of the mistake task is complicated, and therefore it disintegrates into complex and real portions.

4. Results & Interpretation

MATLAB software-R2020 has been used to process and program the three major temperature, concentration, and velocity profiles that constitute the derived equation. Numerical figure is handed on for Distinct Criterion enlisted to mass Grashof number, thermal Grashof, Pr (“Prandtl number”), Sc (“Schmidt number”), time, and Magnetic field for physical comprehension of the problem. The Prandtl number is estimated to be 0.71 for air and 7.0

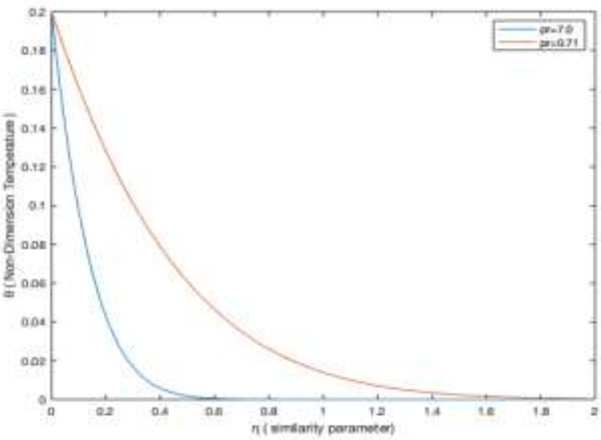

Figure 1. Temperature Profile for **Pr** different values

For water and air temperature profiles are shown in Figure 1 for conditions (10) at 0.2 seconds. The effect of the Pr number undertakes a remarkable task in the temperature field. The temperature rises with a reduction in the Pr integer, which is considered to be 2.01.

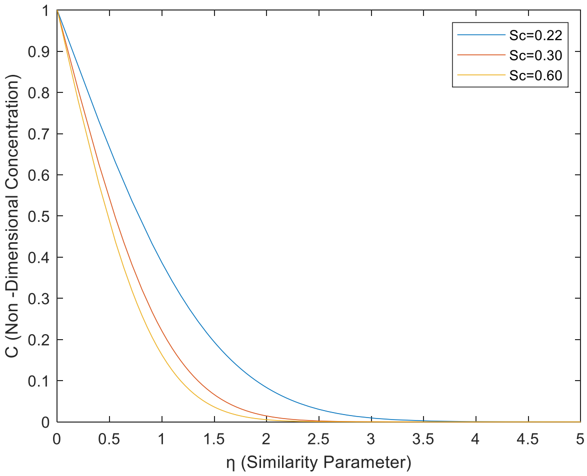

Figure 2. Concentration Profile for different **Sc** values

For the Distinct Schmidt number, the influence of the Concentration profile at time 0.2 shown in Figure 2 is 0.22,0.30,0.60, respectively. It can be shown that when the Schmidt number is reduced, the wall concentration increases. The profile has the fundamental component that the concentration decreases in a uniformity way from zero-esteem some distances way within the unfastened stream

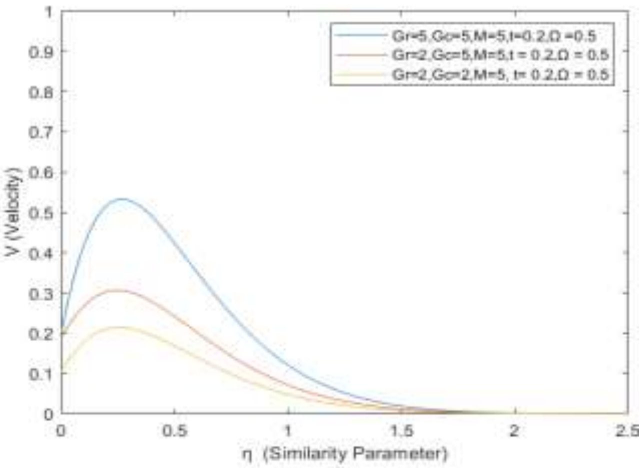

Fig 3. Auxiliary Velocity Profile for different **Gc** & **Gr**

The influence of a dominant velocity profile for a distinct warm Grashof integer of 5,2,2 and a mass Grashof integer of 5,5,5 is demonstrated in Figure 3 and a power field that is one of a type for instance 1, Prandtl integer of 7, a rotational parameter of 0.5, and time of 0.2. The Velocity increases when mass Grashof or warm Grashof number is estimated more accurately.

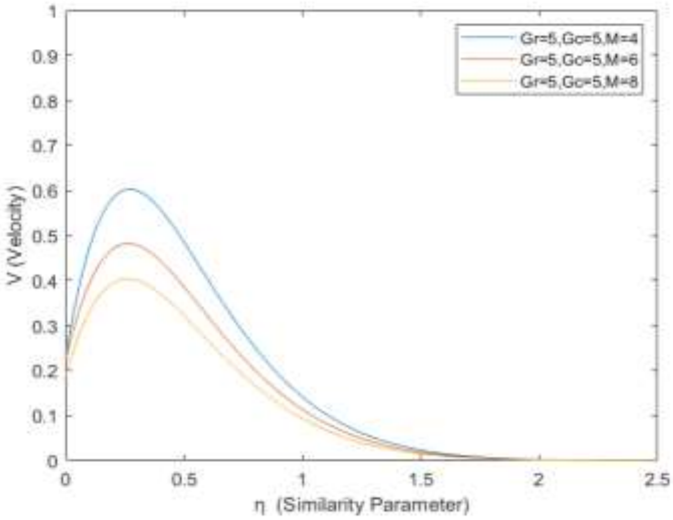

Fig 5. Auxiliary Velocity Profile for different **of M**

Figure 4 shows the influence of force field parameter on velocity when power field is set to 4,6,8, warm Grashof is set to 5, mass Grashof is set to 5, a rotational parameter is set to 0.5, Pr equals to 7 whereas time is set to 0.2. It can be observed that the velocity increases as the attractive field parameter's estimates decrease. As a consequence, the attractive field parameter rises, causing velocity to decrease.

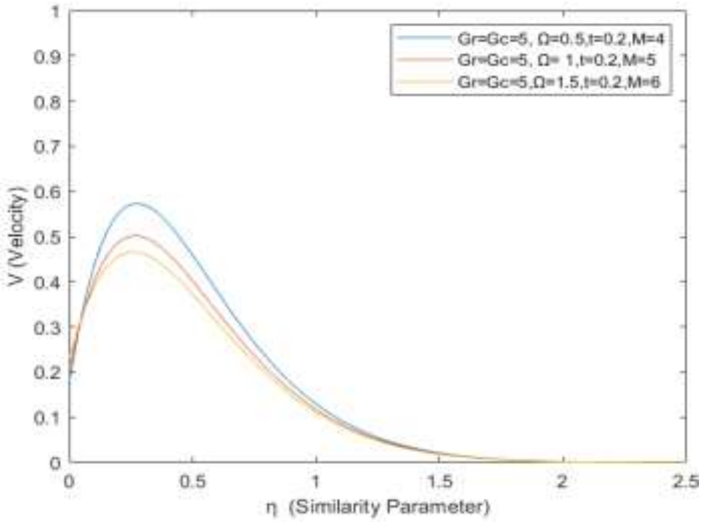

Fig 5. Auxiliary Velocity Profile for different **M**

Figure 5 shows the assistant optional velocity for several estimations of the warm Grashof integer of 5,5,5 and the mass Grashof integer of 5,5,5. 0.5,1.0,1.5 rotational value seized Figure 5 shows the Prandtl integer set apart 7 and M=4,6,8, time 0.2. The Pattern demonstrates that when Grashof or mass Grashof integers are expanded, the speed increases.

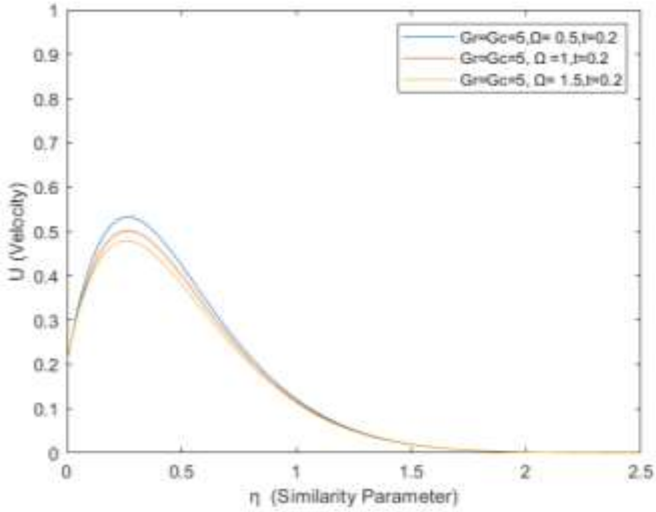

Fig 6. Auxiliary Velocity Profile for different **Ω**

Fig. 6 shows the Secondary velocity profile for different rotational parameters as 0.5, 1, 1.5, with the thermal Grashof integer set to 5 and the mass Grashof set to 5. Figure 6 also shows Force field=5, Pr=7, and time=0.2. The speed of warm Grashof or mass Grashof number increases when Rotation parameter of the mass Grashof or warm Grashof number is reduced.

5. Conclusion

The impact action of a parabolic stream moving through a continually hastened huge isothermal Perpendicular plate in presence of magnetic fields is examined, and the non-dimensional administering conditions have been resolved using the Laplace transforms approach. The conclusion is provided below based on a combination of distinct physical criteria such as mass Grashof number, warm Grashof value, permeability parameter, as well as a rotational parameter.

- The temperature rises as the Prandtl number decreases, which is clear.
- With decreasing Schmidt range opinions, it is obvious that the Concentration profile will rise.
- With the rapidly increasing studies of the heat Grashof and mass Grashof broad Range, it is obvious that Dominant proportion is increasing.
- It's apparent that the charge increases when the power subject limit is reduced.

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* Corresponding author: (A. Selvaraj)
Email: aselvaraj_ind@yaoo.co.in

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