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Fluid Performance of Unsteady MHD Parabolic Flow Past an Accelerated Vertical Plate in The Presence of Rotation Through Porous Medium

T. Gowri, A. Selvaraj

Research Scholar, Department of Mathematics, Vels Institute of Science, Technology and Advanced Studies, Chennai-600117.

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

Abstract: This study is recognised as the specific solution to the problem of the rotational impact of an unstable parabolic flow passing on a vertical porous plate. It is determined whether or not the impact of the porous medium and the magnetic field should be taken into account. By adding the proper dimensionless parameters to the governed dimensional equations for concentration, energy, and momentum that are connected with Primary and initial boundary conditions, the governed dimensional equations may be transformed into dimensionless expressions. The Laplace transform technique may be utilized for obtaining precise solutions to the dimensionless governing partial differential equations. This allows for more accurate results to be achieved. The velocity as well as Concentration profile, Temperature profile, have been scrutinized for Distinct Physical parameter such as permeable time and integer, Prandtl number, Schmidt number, mass Grashof integer, and warm Grashof integer. In the course of the research, both fluctuating temperatures and systematic mass dispersion have been taken into consideration. In conclusion, this is obvious to see that the velocity rises in step with more accurate estimations of either the heat or mass Grashof integer. In addition to this, it is examined that the velocity increases when there is a reduction in the magnetic field.

Keywords: Mass Diffusion, Heat transfer, Vertical plate, Rotation, porous medium, MHD

1. Introduction

MHD flow, along with mass and heat transmission, is a vital component in a variety of subfields within the scientific and technological such as aerospace technology, irrigation engineering, biomechanics, petroleum engineering, biological science, mechanical engineering, and chemical engineering. In order to accurately describe a variety of fluid models, it is necessary to combine the study of radiation with mass diffusion and heat transfer. Hossain et al. performed research on influence that radiation has on free convection when it comes from vertical porous plate [1]. Thamizhsudar and Pandurangan [2] investigated the combined radiation along with Hall current effects on MHD flow. Soundalgekar V.M. focused on mass exchange effects on the water flow that was constantly accelerated in a perpendicular direction. [3] It can be shown that increasing the Grashof number or the brightness parameter causes the skin-contact to decrease, whilst increasing the Schmidt number causes it to increase. Research by Raptis S. A. Singh A.K. analyzed the role of rotation on magnetohydrodynamic free convection flow through a fast perpendicular plate [4,] A. Neel Armstrong and R. Muthucumaraswamy focused their research on flow through an imaginary beginning unbound perpendicular plate with fluctuating temperature. Their work has been published in "On Flow" [5]. Rajput [6] the effect of rotation and radiation on the magnetohydrodynamic stream was conveyed through a discretely started perpendicular plate with a fluctuating temperature. Tina lal Ranganayakulu and R.Muthucumaraswamy examined rotation effects on unsteady flow of an incompressible viscous fluid that flows through a constant speed infinite isothermal vertical plate to find a solution. [7]. Further research was conducted by R. Muthucumaraswamy and Tina lal Ranganayakulu [8,] who explained the effect that rotation has on magnetohydrodynamic flow as it passes a sped-up perpendicular plate. Their findings included a fluctuating temperature and a uniform distribution of mass.

Selvaraj et al. studied MHD parabolic flow across an accelerated isothermal vertical surface with mass and heat diffusion [9]. Selvaraj et al. [10] observed the rotation's effects on parabolic flow over a vertical plate. Veera Krishna.M [11] investigated heat transfer in Cu and Al2O3 nanofluids flowing across a porous surface. Heikholeslami et al. [12] studied the effects of thermal diffusion on an oscillating vertical plate of radiating nanofluid. In mass as well as heat exchange, the rotational impacts of a parabolic sluice end between an electrically coordinated fluid and an impermeable thick through a footloose isothermal plate in the presence of magneto hydrodynamic are to be studied in this system. By employing the Laplace change strategy, can exfoliate light on the non-dimensional administering settings. In surrounds of reciprocal error functions and exponential issues, the Deduced arrangement brings about

2. Mathematical Formulation

Consider an unstable MHD flow with heat along with mass transfer beyond an electrically engaged fluid. The evenly accelerated rotation of an everlasting isothermal plate over a porous material also produces viscous opaque fluid flow. Unsteady flow chooses x′ parallel and y′ normal to flow plate. if the fluid is saturated by the magnetic field $\boldsymbol{B_0}$ in the x axis in xy plane Whereas time $t' \leq 0$. Due to transverse magnetic discipline $\boldsymbol{B_0}$ both plate and fluid are in an inflexible rotation state. Considered to be minimal, the viscous dissipation as well as precipitated magnetic area. At first each fluid and plate were at rest and with the identical concentration C'_∞ along with 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 raised to $\boldsymbol{T'_w}$ at same time and therefore, the concentration stage switched to $\boldsymbol{C'_w}$ and kept constant. Because the plate filling the plane, $\mathbf{Z}' = 0$ has an infinite length, evert physical portion rely on the most effective, Z′ and t′, and the unsteady flow is regulated by the provided equation using standard Boussinesq's approximation.

$$\frac{\partial u}{\partial t'} - 2\Omega' V' = g\beta(T - T_\infty) + g\beta^*(C' - C'_\infty) + v\frac{\partial^2 u}{\partial z^2} - \frac{\sigma B_0^2}{\rho}u - \frac{v}{k}u \quad (1)$$

$$\frac{\partial v}{\partial t'} + 2\Omega' u = \frac{\partial^2 v}{\partial z^2} - \frac{\sigma B_0^2}{\rho}v - \frac{v}{k}v \quad (2)$$

$$\rho C_p\frac{\partial T}{\partial t'} = k\frac{\partial^2 T}{\partial z^2} \quad (3)$$

$$\rho C_p\frac{\partial C'}{\partial t'} = D\frac{\partial^2 C'}{\partial z^2} \quad (4)$$

$$u = 0,\ T = T_\infty,\ C' = C'_\infty, \text{ for all } y,\ t' \leq 0$$
$$u = (u_0 t')^2,\ T = T'_\infty + (T'_w - T'_\infty)\,At',\ C' = C'_\infty + (C'_w - C'_\infty)\,At' > 0,\ y = 0$$
$$u = 0,\ T \to T_\infty,\ C' \to C'_\infty \text{ as } y \to \infty \quad (5)$$

Where $\boldsymbol{A} = \left(\frac{u_0^2}{v}\right)^{1/3}$

The following dimensionless quantities

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

$\theta = \frac{T - T_\infty}{T_w - T_\infty}$, $\quad Gr = \frac{g\beta(T_w - T_\infty)}{u_0}$ is thermal Grashof number,

$C = \frac{C' - C'_\infty}{C'_w - C'_\infty}$, $\quad K = \frac{k u_0^2}{v^2}$ is permeability parameter

$Gc = \frac{g\beta^*(C'_w - C'_\infty)}{u_0}$ is the solutal Grashof number (6)

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

$sc = \frac{v}{D}$ is the Schmidt number, $\Omega = \Omega'\left(\frac{u_0^2}{v}\right)^{\frac{1}{3}}$

Differential conditions (7) to (10) show rotating free convective flow across quickened perpendicular plate, with corresponding starting and limit conditions. This differential condition represents the parabolic flow past the plate (6).

$$\frac{\partial u'}{\partial t} - 2\Omega v' = Gr\theta + GcC + \frac{\partial^2 u'}{\partial Z^2} - Mu' - \frac{u'}{K} \quad (7)$$

$$\frac{\partial v'}{\partial t} + 2\Omega u' = \frac{\partial^2 v'}{\partial Z^2} - MV - \frac{v'}{K} \quad (8)$$

$$\frac{\partial \theta}{\partial t} = \frac{1}{pr}\frac{\partial^2 \theta}{\partial Z^2} \quad (9)$$

$$\frac{\partial C}{\partial t} = \frac{1}{sc}\frac{\partial^2 C}{\partial Z^2} \quad (10)$$

$$u' = 0,\ v' = 0,\ \theta = 0,\quad C = 0\quad for\ all\ Z, t \leq 0$$
$$q = t^2,\quad \theta = t,\quad C = 1\quad at\ t > 0,\quad Z = 0 \quad (11)$$
$$q \to 0,\quad \theta \to 0,\quad C \to 0\quad Z \to \infty$$

Due to the fact that the required equation is very difficult for solving, we offer a complicated velocity equation in the form q = u + iv. After this, the conditions first as well as second are comprehended and combined into a single condition. It is now possible to combine the two sets of equations, (7) and (8), together with the boundary condition (11). This results in a single equation.

$$\frac{\partial q}{\partial t} = \mathrm{Gr}\theta + \mathrm{Gc}C + \frac{\partial^2 q}{\partial \mathrm{Z}^2} - mq - \frac{q}{K} \tag{12}$$

Following are the beginning and stopping conditions in dimensionless amounts.

$$\begin{aligned} &q = 0, \quad \theta = 0, \quad C = 0 \quad for\ all\ Z, t \le 0 \\ &q = t^2, \quad \theta = t, \quad C = 1 \quad at\ \mathrm{t} > 0, \quad Z = 0 \\ &q \to 0, \quad \theta \to 0, \quad C \to 0 \quad Z \to \infty \end{aligned} \tag{13}$$

Here, m = M+2iΩ

3. Solution Procedure

Laplace transform method may be used to solve the dimensionless administering situation that is tended to in the 2nd, 3rd, and 7th equations, together with additional beginning as well as limit condition that is provided in equation (8). In the end, the inverse transform is carried out, and the answer may be determined as follows:

$$\begin{aligned} \boldsymbol{q} = &\left[\frac{(\eta^2 + \left(\frac{1}{K} + m\right) t)t}{4\left(\frac{1}{K} + m\right)}\left[e^{2\eta}\sqrt{\left(\frac{1}{K} + m\right) t}\, erfc\left(\eta + \sqrt{\left(\frac{1}{K} + m\right) t}\right) + e^{-2\eta}\sqrt{\left(\frac{1}{K} + m\right) t}\, erfc\left(\eta - \sqrt{\left(\frac{1}{K} + m\right) t}\right)\right]\right. \\ &+ \frac{\eta\sqrt{t}\left(1 - 4\left(\frac{1}{K} + m\right) t\right)}{8\left(\frac{1}{K} + m\right)^{\frac{3}{2}}}\left[e^{-2\eta}\sqrt{\left(\frac{1}{K} + m\right) t}\, erfc\left(\eta - \sqrt{\left(\frac{1}{K} + m\right) t}\right)\right. \\ &\left.\left. - e^{2\eta}\sqrt{\left(\frac{1}{K} + m\right) t}\, erfc\left(\eta + \sqrt{\left(\frac{1}{K} + m\right) t}\right)\right] - \frac{\eta t}{2\left(\frac{1}{K} + m\right)\sqrt{\pi}} e^{-(\eta^2 + \left(\frac{1}{K} + m\right) t}\right] \\ &+ \left[\frac{Gr}{a(1 - pr)} + \frac{Gc}{b(1 - sc)}\right]\frac{1}{2}\left[\begin{array}{l} e^{2\eta}\sqrt{\left(\frac{1}{K} + m\right) t}\, erfc\left(\eta + \sqrt{\left(\frac{1}{K} + m\right) t}\right) \\ + e^{-2\eta}\sqrt{\left(\frac{1}{K} + m\right) t}\, erfc\left(\eta - \sqrt{\left(\frac{1}{K} + m\right) t}\right) \end{array}\right] \\ &+ \frac{Gr}{a(1 - pr)}\left[\begin{array}{l} \left(\frac{t}{2} - \frac{\eta\sqrt{t}}{2\sqrt{\left(\frac{1}{K} + m\right)}}\right)\left(e^{-2\eta\sqrt{\left(\frac{1}{K} + m\right)t}}\, \mathrm{erfc}\left(\eta - \sqrt{\left(\frac{1}{K} + m\right) t}\right)\right) \\ + \left(\frac{t}{2} + \frac{\eta\sqrt{t}}{2\sqrt{\left(\frac{1}{K} + m\right)}}\right)\left(e^{2\eta\sqrt{\left(\frac{1}{K} + m\right)t}}\, \mathrm{erfc}\left(\eta + \sqrt{\left(\frac{1}{K} + m\right) t}\right)\right) \end{array}\right] \\ &- [\left[\frac{Gr}{(1 - pr)}\right]\left[\begin{array}{l} \frac{e^{at}}{2}\left[e^{2\eta}\sqrt{\left(\left(\frac{1}{K} + m\right) + a\right) t}\, erfc\left(\eta + \sqrt{\left(\left(\frac{1}{K} + m\right) + a\right) t}\right)\right] \\ + \left[e^{-2\eta}\sqrt{\left(\left(\frac{1}{K} + m\right) + a\right) t}\, erfc\left(\eta - \sqrt{\left(\left(\frac{1}{K} + m\right) a\right) t}\right)\right] \end{array}\right] \\ &- \left[\frac{Gc}{a(1 - sc)}\right]\left[\frac{e^{bt}}{2}\left[e^{2\eta}\sqrt{\left(\left(\frac{1}{K} + m\right) + b\right) t}\, erfc\left(\eta + \sqrt{\left(\left(\frac{1}{K} + m\right) + b\right) t}\right)\right]\right. \\ &\left. + \left[e^{-2\eta}\sqrt{\left(\left(\frac{1}{K} + m\right) + b\right) t}\, erfc\left(\eta - \sqrt{\left(m + \frac{1}{k} - b\right) t}\right)\right]\right] \end{aligned}$$

$$-\frac{G_r}{a^2(1-pr)}erfc(\eta\sqrt{pr})-\frac{G_r}{a(1-pr)}t\left[(1+2\eta^2Pr)erfc(\eta\sqrt{Pr})-\frac{2\eta\sqrt{Pr}}{\sqrt{\pi}}e^{-\eta^2Pr}\right]$$
$$+\frac{G_r}{a^2(1-pr)}\left[\frac{e^{at}}{2}\left(e^{2\eta\sqrt{Prat}}erfc(\eta\sqrt{Pr}+\sqrt{at})+e^{-2\eta\sqrt{Prat}}erfc(\eta\sqrt{Pr}-\sqrt{at})\right)\right]$$
$$-\frac{G_c}{a(1-Sc)}erfc\,(\eta\sqrt{Sc})$$
$$+\frac{G_c}{b^2(1-Sc)}\left[\frac{e^{bt}}{2}\left(e^{2\eta\sqrt{Scbt}}erfc(\eta\sqrt{Sc}+\sqrt{bt})+e^{-2\eta\sqrt{Scbt}}erfc(\eta\sqrt{Sc}-\sqrt{bt})\right)\right] \quad (14)$$

$$\theta = t\left\{(1+2\eta^2Pr)erfc(\eta\sqrt{Pr})-\frac{2\eta\sqrt{Pr}}{\sqrt{\pi}}e^{-(\eta^2Pr)}\right\} \quad (15)$$

$$C = erfc(\eta\sqrt{sc}) \quad (16)$$

where $a=\frac{m+\frac{1}{k}}{pr-1}$, $b=\frac{m+\frac{1}{k}}{sc-1}$, $\eta=\frac{z}{2\sqrt{t}}$

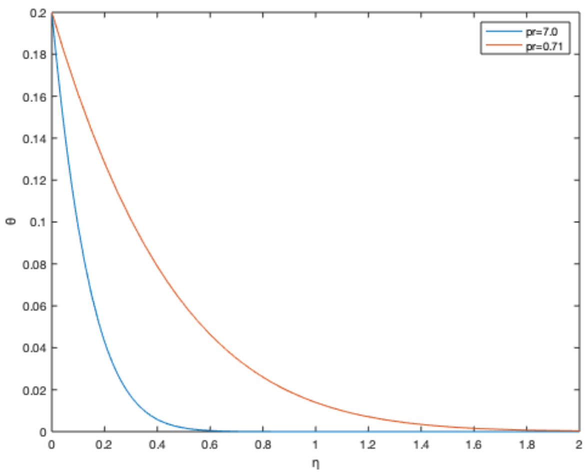
Condition nine illustrates the issue's speed profile, concentration profile, and temperature profile, respectively. in order to get concrete information on the matter. The process involves carrying out numerical estimation. The Dominant Velocity Profile (Primary) and the Auxiliary Velocity Profile may both be determined using this Equation.

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

During the process of evaluating the statement that begins with "q," this is established that argument about the error function is puzzling; therefore, articulation is broken up into complex and real components by making use of equation technique described earlier.

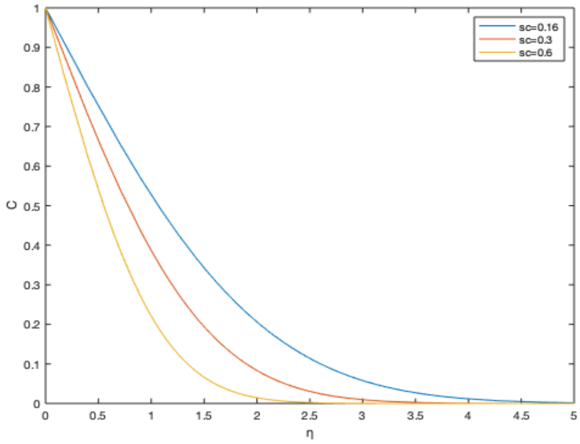
4.Results and Interpretation

Derived condition, which consists of 3 fundamental things: velocity profile, concentration profile, along with temperature profile, has been managed and altered using the MATLAB 2019 programming, and the resultant photos have been exchanged and documented down below.



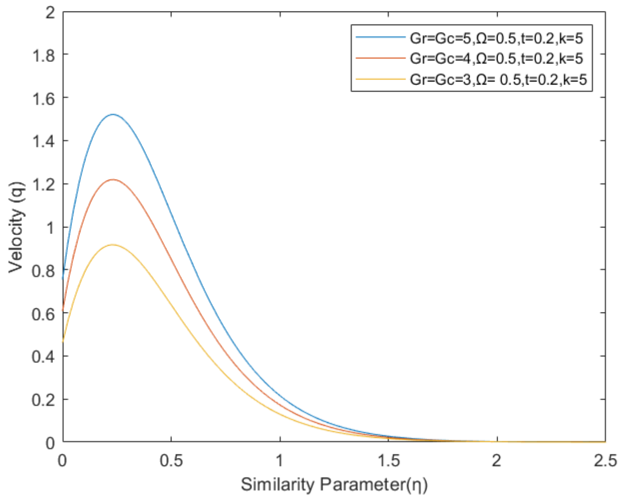
" **Fig 1.** Temperature Profile for Various Value of **Pr**"

For understanding better physical problem, certain numerical calculations have been performed. These calculations have been done for the distinct criteria of heat Grashof, Prandtl number, Schmidt number, magnetic field, and mass Grashof. The temperature profile was determined based on the circumstances (15), and the contribution of the Prandtl broad variety was chosen to be 0.71 for air and 7.0 for water, with 0.2 time being shown in figure 1. Temperature is inversely proportional to Prandtl number. In order to facilitate computation, the estimate of Schmidt has been given the value of two 01.



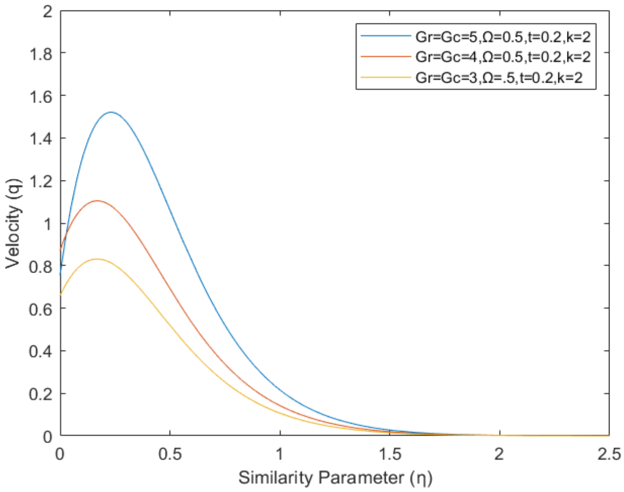
"Fig 2. Temperature Profile for Various Value **Sc"**

Using the Distinct Schmidt range of 0.16,0.3,0.6, Figure.2 shows the Concentration profile impacts at 0.2 sec. Divider concentration is inversely proportional to Schmidt number. The main portion of profile demonstrates that the focal point decreases in consistent path from the zero-regard many distances route with in the loosened stream.



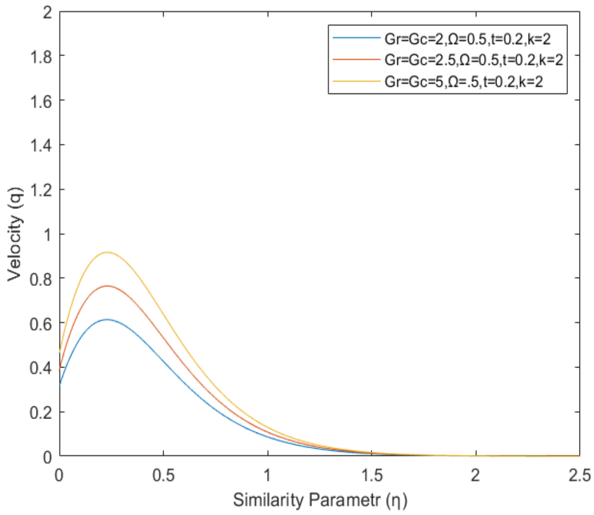
"Fig 3. Velocity Profile for Various **Gr** and **Gc"**

Figure 3 demonstrates the Dominant quickness profile impacts for Different heat Grashof amount, 5,4,3 and mass Grashof range, 5,3,3 and electricity field, unique for occasion 2, 0.5 is rotational parameter, similarly 7 is Prandtl along with 0.2sec time. This is generally accepted that rate of change improves in tandem with rising estimates of heat along with mass Grashof number.



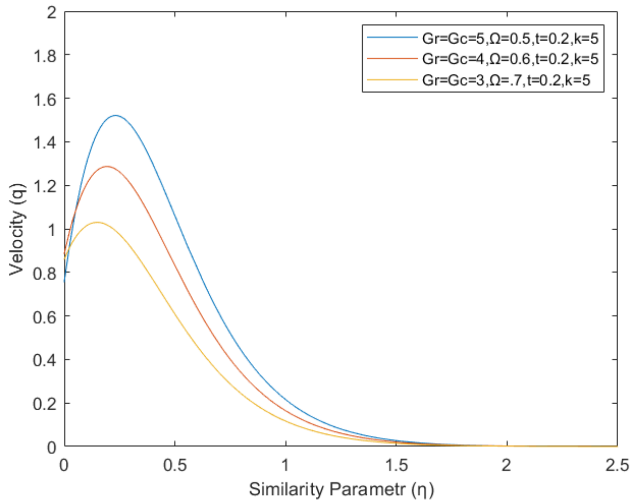
"Fig 4. Dominant Velocity Profile for Various **M"**

Figure.4 is a representation of the impact that the energy discipline parameter has on the speed when the pressure discipline is specified as 1,5,10, the heat Grashof is 5, 4,3, and the mass Grashof is given the value 5, 0.5 is the rotational parameter, 7 is Prandtl, along with 0.2 sec time. This is believed that rise in velocity with decrease in velocity represent estimates of the force discipline variable. This causes an increase in the parameter for the attracting field, which in turn causes a reduction in speed.



"Fig 5. Auxiliary Velocity Profile for Various **Gr**&**Gc"**

Figure.5 provides an estimate of the speed for various estimations of mass and heat Grashof. 0.5 is the Rotational value, Prandtl figuring is unique 7, and time is 0.2, M = 2. With the rise in Grashof mass, pace of proliferation also rise.



"Fig 6. Auxiliary Velocity Profile for Various **Ω"**

The secondary velocity profile for a number of different rotational parameters is represented by the values 0.5, 0.6, and 0.7 warm. The Grashof number has been determined to be 5,4,3, and the mass Grashof total variety has also been determined to be 5, 4,3. Figure 6 depicts a situation in which Pr equals 7, the force field quals 2, and time equals 0.2. Auxiliary velocity is inversely proportional to rotation value

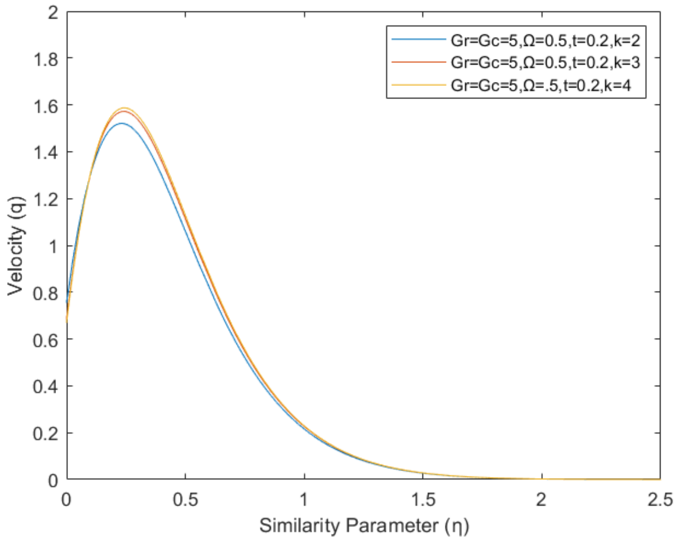


Fig 7. Auxiliary Velocity Profile for Various k

Figure.7 depicts an estimated velocity profile for a number of different permeability parameters. These parameters are given the values 2, 3, and 4, the warm Grashof quantity is given the value 5, and the mass Grashof entire range is also given the value 5. Additionally, Pr = 7, Force field = 2, and time = 0.2 are taken into consideration. It has been hypothesised that auxiliary velocity is directly proportional to permeability.

5.Conclusion

With varying temperatures and systematic mass scattering, the possible movement direction of a parabolic rotation around a beautiful isothermal vertical plate was envisioned. The Laplace exchange technique is utilized for solving the problem of dimensionless administration. The sum of several terrible physical criteria, such as time t, force field, rotational parameter, mass Grashof integer, and heat Grashof integer are assessed visually. The following list summarises the findings reached from the investigation.

- It has been observed that temperature is inversely proportional to Prandtl number.
- It has been observed that when the estimates of the Schmidt range are reduced, there is an increase in the separator's concentration.
- It has come to light that the speed increases in tandem with the rising estimates of the mass or heat Grashof variation of the broad variety.
- It is abundantly clear that the expansion rate is correlated with a reduction in the estimates of the force field parameter.
- Things are quite changed now that we know more about rotational parameters and force fields.
- It has been hypothesized that the auxiliary velocity is directly proportional to permeability.

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