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Heat And Mass Transfer on MHD flow Past an Exponentially Accelerated Vertical Plate Through Porous Medium

K. Balu [1] A. Selvaraj[2]

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

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

Email: aselvaraj_ind@yahoo.co.in

Abstract

In this paper, we analyze the magnetic hydrodynamics of the fluid flow past an exponentially accelerated inclined vertical plate with mass distribution with varying temperature and heat source through a porous medium. Applying a larger number of possible non-dimensional necessary conditions with limitations and starting conditions is a mathematical workout. The plate temperature is extended on an inclined vertical plate alongside at time t, and the focus level is close to the plate. The dimensionless administering conditions in the current examination are tackled utilizing the inverse Laplace transform technique. The velocity outlines are graphically explained for different physical parameters: heat Grashof value, mass Grashof value, Schmidt value, and duration. It has been observed that the velocity increases with an increase in the thermal grashof number Gr and also with an expansion in the time t of the plate, but the velocity increments with an increase in the permeability of the porous medium while decreasing in the presence of magnetic parameters. The impacts of boundaries M, K, t, and Sc on the velocity profiles are demonstrated graphically

Keywords: MHD, Porous medium; Exponentially, Accelerated, Vertical plate, Laplace transform.

1. Introduction

The two categories of chemical reactions are homogeneous and heterogeneous. In the first scenario, there is just one phase of the reaction, and the system is uniform. In a heterogeneous reaction, the mixture is not uniformly mixed and the reaction takes place on the catalyst's surface or the container walls. In most chemical reactions, the species concentration determines the reaction rate. Reactions are referred regarded as being of first order when their rate is directly proportional to their concentration. Many scientists have been researching heat and mass transmission for a very long time since they are so crucial to everyday life. An alternative name for this subject of study is fluid mechanics. Since magnetohydrodynamic fluxes are used in a series of technical uses, as well as geophysics, magnetohydrodynamics, electrical authority, industrial processes, etc. experimental and theoretic studies of these fluxes stay crucial since a technical standpoint. In various uses, the production of rayon, nylon, and other materials, polymers are shaped and extruded. Kushal sharma et al [15] outcomes indicate that the thermo diffusion effect results in drop in the thickness of the layer of the fluid , adjacent to a boundary consequently resulting a gradual rise in heat dissipation as it approaches an asymptotic state. [7] M. Aruna, A. Selvaraj, and T. Thangeswari conducted a study where they examined an influence of the effect of Hall on the movement in one direction on a vertically oriented parabolic accelerating plate. [18-21]. Soundalgekar et al. found that there is a diagonal magnetic field and For Gr value is negative, A rise in the plate's temperature leads to a fall in its velocity. M.A. Hossan et al. [8] study considers both forced and free convection and the analysis employs the Rosseland diffusion approximation method. Alam et al.[9] concluded that the speed drops with the rise of Thermo diffusion effect values. Choudhuri K , Nazibuddin Ahmed, And Pranab Jyoti Parashar. [3] Examined the impact of Thermo diffusion and diffusion thermo effects on the movement in one direction of three-dimensional magnetohydrodynamics (MHD) around a porous plate that extends infinitely in one direction and is moving at a constant speed. The paper authored by Basanth Kumar Jha et al. [1] thoroughly discusses the influences of natural convection and mass transfer on the flow emerging from swiftly moving vertical plate. In a separate study, Basant Kumar et al.[2] examined the effect of Soret effects on the scenario around a vertical plate with free mass transfer and convection, known as the Stoke problem. [4] Dilip Jose and Selvaraj inspected that the speed raises when Magnetic field (M) diminishes. D.Lakshmikaanth et.al [5] researched hall and heat source effect of a vertical plate with parabolic flow with rotation and chemical reaction. Muthucumaraswamy et al. [11,12] Explored the rotational effects within the magnetohydrodynamic (MHD) flow along an accelerating vertical plate. Selvaraj et al. [13,14] investigation of MHD parabolic flow with mass and heat diffusion and rotation across an accelerating isothermal vertical plate. S.Constance Angela and A. Selvaraj [16] examined the impact of Diffusion thermo efffect at an exponentially faster pace. [17] U. S. Rajput et al. explored the Diffusion thermo effect on unequal natural convection magnetohydrodynamics (MHD) flow through a plate, moving through porous material at an exponential rate. The Impact of Rotation on porousity with Constant warm and varying mass was investigated by Gowri T. and A. Selvaraj [6].

2. Mathematical Formulation

The transient flow of an inclined vertical plate past viscous and electrically conductive viscous fluid with varying temperature through a porous medium is considered. It is expected that constant asset B_0 ahypnoticarea (virtual to the plate) is used inversely to the plate. The prompted attractive field is overlooked since the magnetic Reynolds value of the movement is minuscule. The stream is assumed to be in thex' - direction, taking upwards through the vertical plate.y'- axis line is set aside even to the plate. Originally the plate and the liquid are standing at the similar temperature T'_∞ at all points with concentration level C'_∞. At t'>0, the plate accelerates exponentially with a speed velocity u = $u_0 \exp(a't')$in its specific level and the plate temperature is higher linearly with time t and together to the plate. The focus near is high elevated to C'_w. The effect of viscous scattering considered negligible. By the estimate of the steady Boussinesq's, the instable movement is overseen by the following equations.

$$\frac{\partial u'}{\partial t'} = g\beta cos\phi(T' - T'_\infty) + g\beta^* cos\phi(C' - C'_\infty) + v\frac{\partial^2 u'}{\partial y'^2} - \frac{\sigma B_0^2}{\rho}u' - \frac{vu'}{K} \quad (1)$$

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

$$\frac{\partial C'}{\partial t'} = D\frac{\partial^2 C'}{\partial y'^2} \quad (3)$$

with the following suitable initial and boundary conditions:

$$t' \le 0 \quad u' = 0 \;, T' = T'_\infty C' = C'_\infty \quad \text{for all} \quad y' \le 0$$

$$t' > 0 \quad u' = u_0 cos\omega(a't') \quad , T' = T'_\infty + (T'_w - T'_\infty)At', \; C' = C'_w \text{at} \; y' = 0 \quad (4)$$

$$u' \to 0, T' \to T'_\infty, \; C' \to C'_\infty \quad \text{as} \; y' \to \infty \quad \text{where } A = \frac{u_0^2}{v}$$

Equation (1) is exits and applicable only when the magnetic lines of force are fixed relative to the plate. On presenting the resulting dimensionless magnitudes:

$$u = \frac{u'}{u_0}, \quad t = \frac{t' u'_0}{v}, \quad y = \frac{y' u_0}{v}, \quad \theta = \frac{T' - T'_\infty}{T'_w - T'_\infty}, G_r = \frac{g\beta v(T'_w - T'_\infty)}{u_0^3}, C = \frac{C' - C'_\infty}{C'_w - C'_\infty}, \quad (5)$$

$$G_c = \frac{g\beta v(C'_w - C'_\infty)}{u_0^3}, M = \frac{\sigma B_0^2 v}{\rho u_0^2}, P_r = \frac{\mu C_p}{k}, \quad S_c = \frac{v}{D}, \quad a = \frac{a' v}{u_0^2}, \quad K = \frac{u_0^2 K'}{v^2}$$

From equation (1) to (4), leads to the non dimensional equations

$$\frac{\partial q}{\partial t} = G_r \theta cos\phi + G_c C cos\phi + \frac{\partial^2 q}{\partial z^2} - mq - \frac{q}{K} \quad (6)$$

$$\frac{\partial \theta}{\partial t} = \frac{1}{P_r}\frac{\partial^2 \theta}{\partial z^2} \quad (7)$$

$$\frac{\partial C}{\partial t} = \frac{1}{S_c}\frac{\partial^2 C}{\partial z^2} \quad (8)$$

With the initial and boundary conditions

$$t \le 0: \quad q = 0, \; \theta = 0, \quad C = 0 \quad \text{for all } z$$

$$t > 0: \quad q = \cos(\omega t), \theta = e^{at}, \quad C = e^{at} \quad \text{at } z = 0 \quad (9)$$

$$q \to 0 \;, \quad \theta \to 0, \quad C \to 0 \text{as} \quad z \to \infty$$

The non-dimensional quantities are defined in the classification.

3. Method of Solution

The non-dimensional governing Equations from (6) to (8) apply and get to consistent starting limit constrains [9], also handled utilizing Laplace transforms method also result determined in this way of structure

$$q = \frac{e^{at}}{2}\left[\begin{array}{l}\exp\left(-2\eta\sqrt{\left(a+m+\frac{1}{k}\right)t}\right)\operatorname{erf}c\left(\eta-\sqrt{\left(a+m+\frac{1}{k}\right)t}\right)+\\ \exp\left(2\eta\sqrt{\left(a+m+\frac{1}{k}\right)t}\right)\operatorname{erf}c\left(\eta+\sqrt{\left(a+m+\frac{1}{k}\right)t}\right)\end{array}\right]$$

$$-\frac{G_r\cos\phi}{(a-(b+d))(1-P_r)}\frac{e^{at}}{2}\left[\begin{array}{l}\exp\left(-2\eta\sqrt{\left(a+m+\frac{1}{k}\right)t}\right)\operatorname{erf}c\left(\eta-\sqrt{\left(a+m+\frac{1}{k}\right)t}\right)+\\ \exp\left(2\eta\sqrt{\left(a+m+\frac{1}{k}\right)t}\right)\operatorname{erf}c\left(\eta+\sqrt{\left(a+m+\frac{1}{k}\right)t}\right)\end{array}\right]$$

$$-\frac{G_r\cos\phi}{((b+d)-a)(1-P_r)}\frac{e^{(b+d)t}}{2}\left[\begin{array}{l}\exp\left(-2\eta\sqrt{\left(b+d+m+\frac{1}{k}\right)t}\right)\operatorname{erf}c\left(\eta-\sqrt{\left(b+d+m+\frac{1}{k}\right)t}\right)+\\ \exp\left(2\eta\sqrt{\left(b+d+m+\frac{1}{k}\right)t}\right)\operatorname{erf}c\left(\eta+\sqrt{\left(b+d+m+\frac{1}{k}\right)t}\right)\end{array}\right]$$

$$-\frac{G_c\cos\phi}{(a-(c+f))(1-Sc)}\frac{e^{at}}{2}\left[\begin{array}{l}\exp\left(-2\eta\sqrt{\left(a+m+\frac{1}{k}\right)t}\right)\operatorname{erf}c\left(\eta-\sqrt{\left(a+m+\frac{1}{k}\right)t}\right)+\\ \exp\left(2\eta\sqrt{\left(a+m+\frac{1}{k}\right)t}\right)\operatorname{erf}c\left(\eta+\sqrt{\left(a+m+\frac{1}{k}\right)t}\right)\end{array}\right]$$

$$-\frac{G_c\cos\phi}{((c+f)-a)(1-Sc)}\frac{e^{(c+f)t}}{2}\left[\begin{array}{l}\exp\left(-2\eta\sqrt{\left(c+f+m+\frac{1}{k}\right)t}\right)\operatorname{erf}c\left(\eta-\sqrt{\left(c+f+m+\frac{1}{k}\right)t}\right)+\\ \exp\left(2\eta\sqrt{\left(c+f+m+\frac{1}{k}\right)t}\right)\operatorname{erf}c\left(\eta+\sqrt{\left(c+f+m+\frac{1}{k}\right)t}\right)\end{array}\right]$$

$$+\frac{G_r\cos\phi}{\big(a-(b+d)\big)(1-P_r)}\frac{e^{at}}{2}\left[\begin{array}{l}\exp\left(-2\eta\sqrt{Prat}\right)erfc\left(\eta\sqrt{Pr}-\sqrt{at}\right)\\ +\\ \exp\left(2\eta\sqrt{Prat}\right)erfc\left(\eta\sqrt{Pr}+\sqrt{at}\right)\end{array}\right]$$

$$+\frac{G_r\cos\phi}{((b+d)-a)(1-Pr)}\frac{e^{(b+d)t}}{2}\left[\begin{array}{l}\exp\left(-2\eta\sqrt{\Pr(b+d)t}\right)\operatorname{erf}c\left(\eta\sqrt{Pr}-\sqrt{(b+d)t}\right)+\\ \exp\left(2\eta\sqrt{\Pr(b+d)t}\right)\operatorname{erf}c\left(\eta\sqrt{Pr}+\sqrt{(b+d)t}\right)\end{array}\right]$$

$$+\frac{G_c\cos\phi}{(a-(c+f))(1-Sc)}\frac{e^{at}}{2}\left[\begin{array}{l}\exp\left(-2\eta\sqrt{Scat}\right)\operatorname{erf}c\left(\eta\sqrt{Sc}-\sqrt{at}\right)+\\ \exp\left(2\eta\sqrt{Scat}\right)\operatorname{erf}c\left(\eta\sqrt{Sc}+\sqrt{at}\right)\end{array}\right]$$

$$+\frac{G_c\cos\phi}{((c+f)-a)(1-Sc)}\frac{e^{(c+f)t}}{2}\left[\begin{array}{l}\exp\left(-2\eta\sqrt{Sc(c+f)t}\right)\operatorname{erf}c\left(\eta\sqrt{Sc}-\sqrt{(c+f)t}\right)+\\ \exp\left(2\eta\sqrt{Sc(c+f)t}\right)\operatorname{erf}c\left(\eta\sqrt{Sc}+\sqrt{(c+f)t}\right)\end{array}\right] \quad (10)$$

$$\theta = \frac{e^{at}}{2}\left[\exp\left(-\sqrt{Pra}\right)z\operatorname{erf}c\left(\eta\sqrt{Pr}-\sqrt{at}\right)+ exp\sqrt{Pra}\,z\operatorname{erf}c\left(\eta\sqrt{Pr}+\sqrt{at}\right)\right] \quad (11)$$

$$C = \frac{e^{at}}{2}\left[\exp\left(-\sqrt{Sca}\right)z\operatorname{erf}c\left(\eta\sqrt{Sc}-\sqrt{at}\right)+ exp\sqrt{Sca}\,z\operatorname{erf}c\left(\eta\sqrt{Sc}+\sqrt{at}\right)\right] \quad (12)$$

4. Result and discussions

To study the effects of the heat sources the plate accelerates in its own plane with velocity $u = u_0 \exp\,(a't')$ numerical calculations are made for different values of G_r(Thermal grashof number), G_c(Mass grashof number), S_C(Schmidt number), M (Magnetic field parameter), K (Permeability parameter), a (Accelerating parameter), when the prandtl number P_r is equal to 0.71 corresponding to the air. This is in order to reveal the different outcomes parameters in the dimensionless velocity field, temperature field, concentration field.

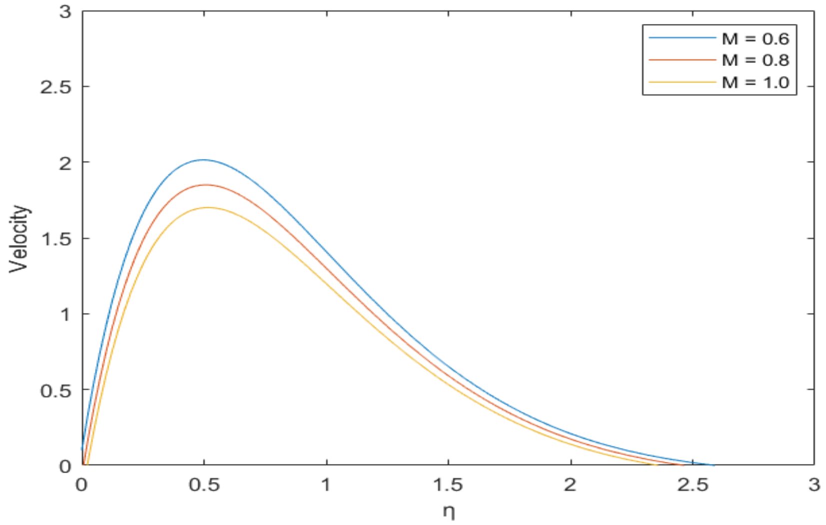

Figure 1. Velocity profiles when $G_r = 10, G_c = 5$, $P_r = 0.71$, $S_c = 0.22$, K = 2, a = 1, t = 1.

Figure (1) represents the velocity profiles for different values of magnetic parameter (M = 0.6, 0.8, 1.0), $G_r = 10, G_c = 5$, $P_r = 0.71$, $S_c = 0.22$, K = 2, a = 1 of the plate at t=1. As of the diagram it is establish that the velocity growths through the decrease in M.

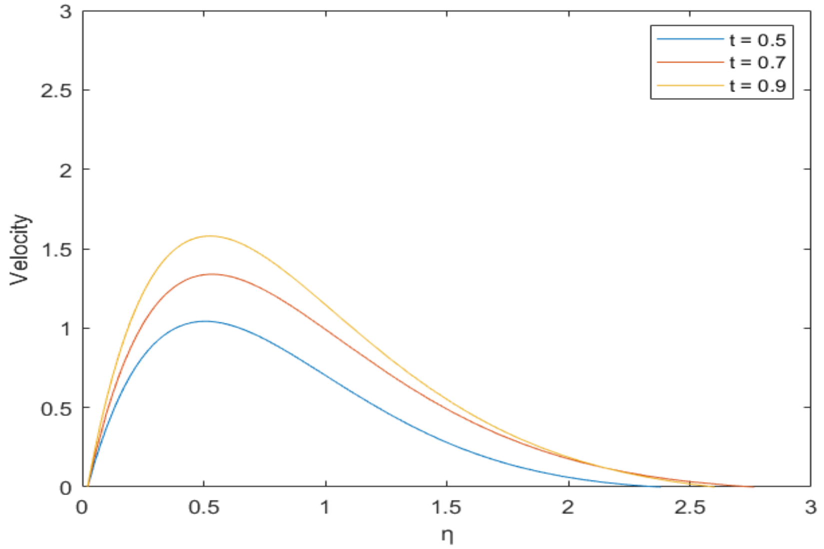

Figure 2. Velocity profiles when $G_r = 10, G_c = 5$, $P_r = 0.71$, $S_c = 0.22$, K = 2, a = 1, M = 1.

Figure (2) represents the velocity profiles for different values of time (t = 0.5, 0.7, 0.9), $G_r = 10, G_c = 5$, $P_r = 0.71$, $S_c = 0.0.22$, K = 2, M = 1 and a = 1.From this figure the velocity is found to increase with an increase in time t of the plate

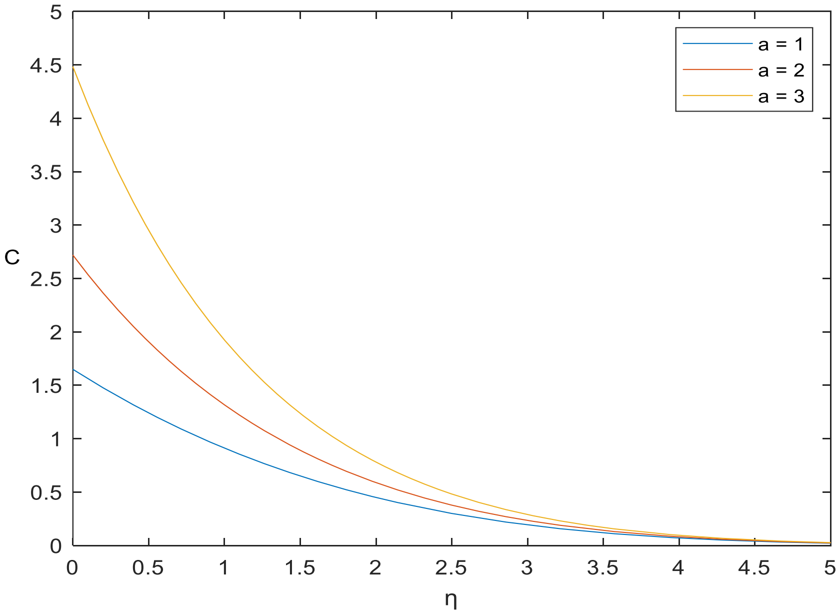

Figure 3. Concentration profiles when G_r= 5, G_c =5, S_c = 0.22, P_r = 0.71, t = 0.5, M = 5

Figure (4) represent the concentration profiles for different values of accelerating parameter (a = 1, a = 2, a = 3), $G_r = 5$, G_c = 5, P_r = 0.71, S_c = 0.22 , M = 5 of the plate at t= 0.5. The concentration from the figures increases with an increase in a (accelerating parameter) of the plate.

5. Conclusions

In this paper we have considered an investigation study of the effects of MHD and heat and mass absorption fluid flow past an exponentially accelerated vertical with porous medium. The solutions for the model have been comprehended by Laplace transformation method. The conclusions of this examination are

- The Velocity profiles increase with an decrease in magnetic parameter M.
- The velocity growth through an expansion in time t of the plate.
- The velocity growths through an increase in Schmidt numberS_c .
- The velocity is found to increase with an increment in a (accelerating parameter) of the plate.
- Velocity increments with an increase in permeability of the porous medium while decrease in the presence of magnetic parameter.

References

[1] Basanth Kumar Jha and Ravindra Prasad,“Free convection and mass transfer effects on the flow past an accelerated vertical plate with heat sources”, Mechanics Research Communications, vol.17, pp.143-148. (1990).

[2] Basant Kumar, J. H. A., and A. K. Singh. "Soret effects on free-convection and mass transfer flow in the stokes problem for a infinite vertical plate." *Astrophysics and Space Science* ,173, pp.251-255, (1990)

[3] Choudhuri, K., Nazibuddin Ahmed, And Pranab Jyoti Parashar. "Soret And Dufour Effects in A Three-Dimensional MHD Flow Past A Semi-Infinite Uniformly Moving Vertical Plate With Constant Heat Flux: Soret And Dufour Effects In A Three-Dimensional MHD Flow." Latin American Applied Research-An International Journal 53.3 (2023): 263-270.

[4] Dilip Jose S, Selvaraj A, “Convective Heat and Mass Transfer Effects of Rotation on Parabolic Flow Past an Accelerated Isothermal Vertical Plate in The Presence of Chemical Reaction of First order” Jp Journal of Heat and Mass Transfer, Vol. 24(1), pp. 191-206, (2021)

[5] D.Lakshmikaanth, A.Selvaraj, P.Selvarasu, S.Dilip Jose “Hall and Heat Source effects of flow past a parabolic accelerated isothermal vertical plate in the presence of Chemical reaction and Radiation”, JP Journal Heat and Mass Transfer,vol.32,pp105-126,(2023).

[6] Gowri T, A. Selvaraj, “Rotational effect of unsteady Parabolic Flow Past a Vertical Plate through porous medium with uniform temperature and mass diffusion”,Neuroquantology, vol.22(10), pp.10869-10877. (2022)

[7] M. Aruna, A. Selvaraj, T. Thangeeswari, “Magnetic Field and Hall Effects on Flow Past a Parabolic Accelerated Vertical Plate with Differing Temperature and Mass Diffusion in the Existence of Thermal Radiation” European chemical Bulletin, vol.12(5), pp.764-778, (2023)

[8] M. A. Hossain and H. S. Takhar, Radiation effect on mixed convection along a vertical plate with uniform surface temperature, Heat Mass Trans. 31(1996), pp.243-248

[9] M.S.Alam, M.M. Rahman and M.A. Maleque, Local similarity solutions for unsteady MHD free convection and mass transfer flow past an impulsively started vertical porous plate with Dufour and Soret effects, Thammasatint.j.sci.tech. 10(3) (2005), 1-8.

[10] M.M. Alam and M. A. Sattar, Transient MHD heat and mass transfer flow with thermal diffusion in a rotating system, J.Energy Heat Mass trans. 21 (1999)m 9-21.

[11] R. Muthucumaraswamy. Tina lal Ranganayakulu. Rotation effect on MHD flow past an accelerated vertical plate with variable temperature and uniform mass diffusion. Int.journal of Engineering.

[12] R. Muthucumaraswamy. Tina lal Ranganayakulu. Effect of rotation on MHD flow past an accelerated isothermal vertical plate with heat and mass diffusion. Theory and applied mechanics, 27:289-202 (2010).

[13] Selvaraj A, Jose SD, Muthucumaraswamy R, Karthikeyan S. MHD-parabolic flow past an accelerated isothermal vertical plate with heat and mass diffusion in the presence of rotation. Materials Today: Proceedings. 2021.3546-3549.

[14] Selvaraj A, Gowri T, “Rotational effect of unsteady MHD-Parabolic Flow Past a Vertical Plate through porous medium with uniform temperature mass diffusion”, International journal of mechanical engineering, vol.6(3), PP.10869-10877.

[15] Sharma, Kushal, et al. "Dynamics of MHD Casson fluid in non-Darcy porous medium: The impact of thermal radiation, Dufour–Soret, and chemical reaction." Modern Physics Letters B (2023): 2341007.

[16] S. Constance Angela, A. Selvaraj, “Dufour and Hall Effects on MHD Flow past an Exponentially Accelerated Vertical Plate with Variable Temperature and Mass Diffusion”, Turkish Journal of Computer and Mathematics Education, Vol.12, No.6, PP. 3542-3556.

[17] U. S. Rajput and N. K. Gupta, “Dufour effect on unsteady free convection MHD flow past an exponentially accelerated plate through porous media with variable temperature and constant mass diffusion in an inclined magnetic field”, International Research Journal of Engineering and Technology, vol.3(8), pp.2135-2140.

[18] U . N. Das, R.K. Deka and V.M. Soundalgekar , Radiation effects on flow past an impulsively started vertical infinite plate, J.theo. Mech. 1(1996), 111-115.

[19] V.M. Soundalgekar, S.K. Gupta and N.S. Birajdar, Effects of mass transfer and free convection currents on MHD Stokes problem for a vertical plate, Nuclear Eng. Des. 53(1979), 339-346.

[20] V. M. Soundalgekar, M. R. Patil and M.D. Jahagirdar, MHD Stokes problem for a vertical plate with variable temperature, Nuclear Eng. Des. 64(1981), 39-42.

[21] V.M. Soundalgekar and H.S. Takhar, Radiation effects on free convection flow past a semi-infinite vertical plate, Model. Measure. Comrol (1993), 31-40.