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THE RESULTS OF A MAGNETIC FIELD ON FLOW PAST AN INCLINED ISOTHERMAL VERTICAL PLATE WITH HEAT AND VARYING MASS DIFFUSION

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ABSTRACT

This work describes the influence of a magnetic environment on the circulation of matter and thermal energy over an accelerating advanced inclined isothermal sectional surface. The temperature is elevated to E_{ω}. The proximity intensity is increased to L'_{ω}. The Laplace-transform approach is applied to solve the dimensionless analytical equation. In this research work different physical variables including thermal grashof number (Tg), mass grashof number (Tm), Schmidt number (Sc), Prandtl number(Pr), time(t), velocity profile (J'), temperature (E''), and intensity (L') are investigated. The output of the graph produced by the Matlab software commands an energy equation, momentum equation, and concentration equation. The values are shown in an aligned pattern for a variety of flow variables. Diagrammatic representations of the fluid velocity profiles are provided. The velocity rises corresponding to different Tg and the velocity rises corresponding to different Tm. As the angle is decreased, the velocity increases differently. (α_1), As the different magnetic environment values lower, the velocity rises. Elevated values of angle (α_1), Sc, Pr, and M' contribute to an enhancement in local skin friction, and an upsurge in Gr, Gc, and t leads to a reduction. A tabulated presentation of Nusselt quantities reveals a positive correlation with increasing Pr. Similarly, Sherwood quantities, as tabulated for various parameters, demonstrate a proportional increase with rising Sc.

Keywords: accelerated, isothermal, inclined plate, vertical plate, heat transfer, mass diffusion, magnetic field.

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INTRODUCTION

The practical uses of a magnetic force on circulation through an angled homogeneous perpendicular surface having thermal as well as changeable mass propagation are many. Controlling thermal and material transmission is critical in metallurgical operations. The investigation of the magnetic environment's effect on flow can provide information for optimizing processes such as solidification and casting. Heat dissipation is a significant aspect of electronic devices. Understanding how a magnetic field affects the movement of heat and mass around inclined surfaces might help designers create more efficient cooling solutions for electronic components. Chemical reactors frequently involve processes involving heat and mass transfer. Magnetized environments can be utilized to improve or regulate these processes, resulting in efficient chemical production. Understanding the influence of a magnetized environment on HMT in the atmosphere or water bodies has environmental engineering applications. This understanding can be used to simulate and optimise pollution dispersion or heat exchange in natural systems. The findings have ramifications for energy conversion systems like solar collectors. Optimising heat and mass transfer in these systems using magnetic fields can improve energy conversion efficiency. Understanding the influence of magnetic fields on HMT can be applied in areas including hyperthermia treatment, where controlled heating of tissues is used for therapeutic purposes. In aerospace engineering, heat transfer is critical in the design of spacecraft and high-speed vehicles. Investigating the influences of magnetic fields on HMT close to surfaces can build efficient thermal protection systems. Controlling HMT is critical in the manufacturing of nanostructures and Nano devices using nanotechnology. Magnetic fields provide a fresh technique to accurately manipulate these processes at a Nano scale level. Understanding magnetized environment effects on flow across exteriors could be used to optimise the effectiveness of energy harvesting equipment in terms of renewable energy, such as wind or tidal power. In the field of space exploration, where heat dissipation is difficult, the research can be used to design better thermal management systems for spacecraft and equipment.

Chamkha *et al.* [1] investigated comparable resolutions for the concurrent HMT phenomena in the presence of a magnetic field. The investigation focused on unrestricted convective flow across an inclined plate. The tilted surface under consideration was subject to interior thermal production or assimilation. This research delved into the intricate interplay between magnetic effects, thermal transmission, and material transmission in the context of natural convection. The research provided significant knowledge on the conduction of thermal and material transmission in the presence of magnetic domains and sloped substrates that include interior origins or thermal drains. Takhar *et al.* [2] examined how non-uniform surface heating or material transmission in certain parts of an angled surface impacts MHD's spontaneous convective flow. The investigation analyzed the influence of temperature changes and material transmission on spontaneous convective flow in a high-porosity environment with layered temperature. The investigation specifically examined how these factors interact with electromagnetic and physical forces. The work offers useful knowledge in slanted areas, varying barrier situations, and magnetised forces on the process of convection thermal and material transportation in elevated-perforation channels that exhibit temperature layers. Ibrahim *et al*. [3] investigated the processes of intermittent MHD micropolar liquid circulation and thermal transmission across an upward permeable surface via a separate permeable medium. The research examined the occurrence of HMT dispersion in conjunction with a consistent thermal supply. Rahman and Sattar [4] investigated the MHD convection circulation of a micropolar liquid across a vertically oscillating permeable surface, taking into consideration thermal production or absorption. Ogulu and Makinde [5] investigated the behaviour of an unrestrained and radiative fluid across a perpendicular surface under an unstable hydromagnetic unconstrained convective and uniform thermal fluctuation. Orhan Aydm and Ahmet Kaya [6] investigated the thermal energy across an angled surface by applying MHD combined convection approaches. Uddin and Kumar [7] investigated the liquid circulation across a slanted surface submerged in a permeable media, focusing on unstable free convection. Shivaiah and Anandrao [8] examined the synthetic procedures on MHD convectional circulation across an upward permeable surface. They also examined the impact of vacuum or insertion. Singh and Makinde [9] investigated the properties of MHD on an unrestricted convective circulation down an angled surface heated by Newtonian warming. They also considered the impact of volumetric thermal production.

Makinde [10] investigated the presence of MHD combined convective stationary spot circulation approaching a perpendicular surface immersed in a permeable environment. The investigation examined the consequences of emission and interior temperature. Puneet Rana and colleagues [11] investigated the combined convective barrier zone circulation of a nanofluid down a slanted surface in a permeable environment. Rashidi *et al*. [12] examined the estimated approaches for the elastomeric circulation of a hydro-magnetic barrier layer across an evolving substrate. The investigation took into account two supplementary parameters. Ali *et al*. [13] investigated the combined impact of thermal along material transmission on MHD convectional circulation over an angled surface within a permeable medium. Vijay Kumar *et al*. [14] investigated a generated magnetic environment and emission on the movement of a combined convective liquid across a permeable perpendicular surface in the presence of MHD and viscosity spread. Ismail *et al*. [15] examined the dynamics of intermittent MHD unconstrained convective circulation, considering the thermal and material transmission in a permeable environment close to an angled surface. Nandkeolyar and Das [16] investigated the MHD unconstrained convection emission circulation across a horizontal surface with thermal fluctuation over a slope. Narahari *et al*. [17] investigated the influence of increasing temperature on an unstable MHD spontaneous vortex movement across a slanted panel of unlimited extent. The analysis considered emission, thermal origin, and synthetic response. Das et al. [18] examined the combined convection MHD slippage circulation across an angled permeable surface, taking into account the implications of fluid dispersion.

Muthucumaraswamy and Jeyanthi [19] investigated hall impacts on the behaviour of MHD circulation across an unbounded perpendicular surface. Anjali Devi and Suriyakumar [20] suggested that the circulation was further influenced by the presence of a rotational liquid, which exhibited variations in HMT. Additionally, the investigation considered a 1st-level synthetic process. The present study focuses on the examination of hydromagnetic mixed convective nanofluid slippage circulation across an inclined stretching surface, including interior thermal uptake & pressure. Muthucumaraswamy and Sivakumar [21] examined the characteristics of an MHD circulation surrounding a symmetrical limitless homogeneous perpendicular plane. The analysis considered the consequences of thermal emission as well as a synthetic response. Dhal *et al*. [22] examined the influence of HMT on an MHD unrestricted convective circulation across an angled and linearly advanced surface immersed in a permeable substance subjected to thermal input. Sharma and Gupta [23] investigated heat exposure on MHD interface barrier circulation and thermal transmission over an angled surface having convection barrier circumstances. They applied a quantitative approach using non-linear research to evaluate this occurrence. Thirupathi Thumma *et al*. [24] investigated the computational prediction of MHD circulation from an undulating slanted surface. Rajput and Gaurav Kumar [25] investigated the incorporation of magnetic fluctuation, thermal origin, and changeable degree impacts. This research examined the emission influences on MHD circulation across a sloped surface with changeable exterior heating along with material dispersion. Additionally, the research included the HC existence. Shankar Goud *et al*. [26] explored the influence of HC as well as emission on the MHD spontaneous convective circulation across a tilted conical-propelled surface having changeable heating in a permeable environment. Abro *et al*. [27] investigated the quantitative assessment of liquid circulation in a circumferential conduit with a liquid, employing the Hankel Transform. Venkateswarlu *et al*. [28] examined the influence of Soret and Dufour on the convective hydromagnetic circulation of a reactive liquid across a geometrically propelled slanted permeable surface with thermal uptake and elastic dispersion. Ahmad *et al*. [29] focused on the quantitative assessment of spontaneous convective circulation of MHD liquids with thermal energy and a 1st level synthetic response.

Usharani *et al*. [30] investigated the MHD flow on a sloped perpendicular surface comprising 1st-level synthetic response, stochastic material dispersion, as well as heat exposure. Khan *et al*. [31] examined the thermal generation and exposure of MHD convective circulation in Darcy's environment, employing a partial methodology. Anique *et al*. [32] researched the unconventional circulation on a sloped barrier resulting from thermal-dependant characteristics in the context of a chemical response. Praveen Kumar Dadheech *et al*. [33] proposed a method for calculating flexibility in a radiative inclining MHD slippage inside permeable surroundings, utilising 2 distinct liquids. Anique *et al*. [34] examined unconventional circulation on an inclined barrier resulting from temporally interrelated features amidst a synthetic reaction. Praveen Kumar Dadheech *et al*. [35] conducted a flexibility analysis in a convective angled MHD slippage movement involving 2 distinct liquids. Nagarajan *et al*. [36] examined the heat expansion on the flow characteristics across a sloping accelerated rectangular surface with continuous material dispersion. Mopuri *et al*. [37] examined the influence of a chaotic MHD on the convection of a classical liquid past a sloping surface. The analysis considered a scientific response, emission intake, and the Dufour impact. NageshGulle and Raghunathkod [38] investigated the Soret emission and synthetic reaction of an MHD liquid over an inclined perpendicular surface immersed in a permeable environment. Sheri *et al*. [39] investigated the instantaneous MHD circulation across a slanted surface, concentrating on the hall current, synthetic response, and emission influences. Sundar Raj *et al*. [40] examined the chemical processes on a slanted annealed perpendicular surface. Rajaraman and Muthucumaraswamy [41] conducted a numerical investigation on the transient magnetohydrodynamic (MHD) flow over an oscillating vertical plate. The study considered the effects of thermal radiation and viscous dissipation.

The study looks at the effect of Magnetohydrodynamics (MHD) on the flow around a uniformly accelerated inclined plate with constant temperature and inconsistent mass diffusion. Using the Laplace-transform technique, the indeterminate governing equations are resolved, producing solutions given in exponential and complementary error functions. This research provides important insights into technologies such as magnetic control of warm iron flow in the fabrication of steel, metal-liquid cooling in nuclear reactors, and magnetic suppression of molten semiconducting elements.

SOLUTION COMPUTATIONAL

The investigation focused on the erratic movement of a viscid inert liquid across a slanted surface that is progressively intensified, in the midst of a magnetic environment. The surface preserves a consistent heat and undergoes varying material dispersion. The erratic circulation of a viscid inert liquid that is originally at respite and encloses a tilted surface E''_∞ and L^*_∞ is seen here. The upward orientation along the surface is designated as the x-coordinate, whereas the orientation perpendicular to the surface is designated as the y-coordinate. The surface and the liquid are both at a similar temperature E''_∞ at the same time $t'_4 \leq 0$. The surface is expedited with $u = u_0 t'_4$ at time $t'_4 > 0$, and the degree from the surface is elevated to E''_ω, as does the intensity level L^*_ω close to the surface. It is anticipated that a transverse magnetic environment of homogeneous strength would be supplied orthogonal to the surface. The controlling of the uneven circulation is governed by the formulae specified within Boussinesq's approach.

$$\frac{\partial u}{\partial t'_4} = g\beta \cos\alpha_1 (E'' - E''_\infty) + g\,\beta^* \cos\alpha_1 (L^* - L^*_\infty) + \nu \frac{\partial^2 u}{\partial y^2} - \frac{\sigma B_0^2}{\rho} u \tag{1}$$

$$\rho L'_p \frac{\partial E''}{\partial t'} = k \frac{\partial^2 E''}{\partial y^2} \tag{2}$$

$$\frac{\partial L^*}{\partial t'} = D \frac{\partial^2 L^*}{\partial y^2} \tag{3}$$

The specified initial along with other criteria are as follows:

$$\begin{aligned} & u = 0, E'' = E''_\infty L^* = L^*_\infty \ \ for\,all\ \ y, t'_4 \leq 0 \\ & when,\ t > 0, \\ & u = u_0 t'_4, E'' = E''_\omega, L^* = L^*_\infty + (L^*_\omega - L^*_\infty) A t'_4 \qquad (4) \\ & \qquad\qquad at\ \ y = 0 \\ & u \to 0,\ E'' \to E''_\infty, L^* \to L^*_\infty,\ as\ \ y \to \infty \end{aligned}$$

While the following dimensionless parameters are originated:

$$J' = \frac{u}{(\nu u_0)^{\frac{1}{3}}}, t = t'_4 \left(\frac{u_0^2}{\nu}\right)^{\frac{1}{3}}, Y = y\left(\frac{u_0}{\nu^2}\right)^{\frac{1}{3}},$$

$$M' = \frac{\sigma B_0^2}{\rho}\left(\frac{\nu}{u_0^2}\right)^{\frac{1}{3}}, Pr = \frac{\mu L'_p}{k}, Sc = \frac{\nu}{D}$$

$$\Omega' = \frac{E'' - E''_\infty}{E''_\omega - E''_\infty}, Gr = \frac{g\nu\beta(E''_\omega - E''_\infty)}{u_0}, L' = \frac{L^* - L^*_\infty}{L^*_\omega - L^*_\infty},$$
$$Gc = \frac{g\nu\beta^*(L^*_\omega - L^*_\infty)}{u_0} \tag{5}$$

leads to solutions (1) to (4)

$$\frac{\partial J'}{\partial t} = Gr\cos\alpha_1\,\Omega' + Gc\cos\alpha_1\,L' + \frac{\partial^2 J'}{\partial Y^2} - M'J' \tag{6}$$

$$\frac{\partial \Omega'}{\partial t} = \frac{1}{Pr}\frac{\partial^2 \Omega'}{\partial Y^2} \tag{7}$$

$$\frac{\partial L'}{\partial t} = \frac{1}{Sc}\frac{\partial^2 L'}{\partial Y^2} \tag{8}$$

In dimensionless parameters, the initial as well as limiting constraints are:

$$\begin{array}{llllll} & J' = 0, & \Omega' = 0, & L' = 0 & for\ all & Y, t \le 0 \\ t > 0: & J' = t, & \Omega' = 1, & L' = t & at & Y = 0 \\ & J' \to 0, & \Omega' \to 0, & L' \to 0 & as & Y \to \infty \end{array} \tag{9}$$

The undefined regulating formulae (6) to (8) are resolved via the conventional Laplace-transform approach, yielding the following outcomes:

$$\Omega' = erfc(\lambda'\sqrt{Pr}) \tag{10}$$

$$L' = t\left[(1 + 2\lambda'^2 Sc)\,erfc(\lambda'\sqrt{Sc}) - \frac{2\lambda'\sqrt{Sc}}{\sqrt{\pi}}e^{-\lambda'^2 Sc}\right] \tag{11}$$

$$\begin{aligned} J' = {} & \left(\frac{t}{2} + c + d\right)\left[e^{2\lambda'\sqrt{M't}}\,erfc(\lambda' + \sqrt{M't}) + e^{-2\lambda'\sqrt{M't}}\,erfc(\lambda' - \sqrt{M't})\right] \\ & - \frac{\lambda'\sqrt{t}}{2\sqrt{M'}}\left[e^{-2\lambda'\sqrt{M't}}\,erfc(\lambda' - \sqrt{M't}) - e^{2\lambda'\sqrt{M't}}\,erfc(\lambda' + \sqrt{M't})\right] \\ & - c\,e^{at}\left[e^{2\lambda'\sqrt{A_1}}\,erfc(\lambda' + \sqrt{A_1}) + e^{-2\lambda'\sqrt{A_1}}\,erfc(\lambda' - \sqrt{A_1})\right] \\ & + 2bd\left\{\begin{array}{l} \frac{t}{2}\left[e^{2\lambda'\sqrt{M't}}\,erfc(\lambda' + \sqrt{M't}) + e^{-2\lambda'\sqrt{M't}}\,erfc(\lambda' - \sqrt{M't})\right] \\ - \frac{\lambda'\sqrt{t}}{2\sqrt{M'}}\left[e^{-2\lambda'\sqrt{M't}}\,erfc(\lambda' - \sqrt{M't}) - e^{2\lambda'\sqrt{M't}}\,erfc(\lambda' + \sqrt{M't})\right] \end{array}\right\} \\ & - d\,e^{bt}\left[e^{2\lambda'\sqrt{A_2}}\,erfc(\lambda' + \sqrt{A_2}) + e^{-2\lambda'\sqrt{A_2}}\,erfc(\lambda' - \sqrt{A_2})\right] \\ & - 2c\,erfc(\lambda'\sqrt{\Pr}) \\ & + c\,e^{at}\left[e^{-2\lambda'\sqrt{\Pr at}}\,erfc(\lambda'\sqrt{\Pr} - \sqrt{at}) + e^{2\lambda'\sqrt{\Pr at}}\,erfc(\lambda'\sqrt{\Pr} + \sqrt{at})\right] \\ & - 2d\,erfc(\lambda'\sqrt{Sc}) \\ & - 2bd\,t\left[(1 + 2\lambda'^2 Sc)\,erfc(\lambda'\sqrt{Sc}) - \frac{2\lambda'\sqrt{Sc}}{\sqrt{\pi}}e^{-\lambda'^2 Sc}\right] \\ & + d\,e^{bt}\left[e^{-2\lambda'\sqrt{Sc\,bt}}\,erfc(\lambda'\sqrt{Sc} - \sqrt{bt}) + e^{2\lambda'\sqrt{Sc\,bt}}\,erfc(\lambda'\sqrt{Sc} + \sqrt{bt})\right] \end{aligned} \tag{12}$$

where,

$$a = \frac{M'}{Pr - 1}, b = \frac{M'}{Sc - 1}, c = \frac{Gr\cos\alpha_1}{2a(1 - Pr)}, d = \frac{Gc\cos\alpha_1}{2b^2(1 - Sc)}$$

$A_1 = (M' + a)t, A_2 = (M' + b)t$ and $\eta = Y/2\sqrt{t} = \lambda'$.

SKIN FRICTION (τ)

The friction factor for non-dimensional plates appears to be

$$\tau = -\left[\frac{\partial J'}{\partial y}\right]_{y=0} = -\frac{1}{2\sqrt{t}}\left[\frac{dJ'}{d\lambda'}\right]_{\lambda'=0}$$

$$\tau = \frac{-\sqrt{t}}{4}\left[2\sqrt{M't}(erfc(\sqrt{M't}) - erfc(-\sqrt{M't})) - \frac{4}{\pi}e^{-M't}\right]$$
$$-\frac{1}{4\sqrt{M'}}\left[erfc(-\sqrt{M't}) - erfc(\sqrt{M't})\right]$$
$$-\frac{c}{2\sqrt{t}}\left[(2\sqrt{M't}\, erfc(\sqrt{M't}) - \frac{2}{\sqrt{\pi}}e^{-M't} + \frac{4\sqrt{M't}}{\sqrt{\pi}}e^{-M't})\right]$$
$$+\frac{c\,e^{at}}{2\sqrt{t}}\left[2\sqrt{A_1}(erfc(\sqrt{A_1}) - erfc(-\sqrt{A_1})) - \frac{2}{\sqrt{\pi}}e^{-A_1}\right]$$
$$-\frac{d}{2\sqrt{t}}\left[(2\sqrt{M't}\, erfc(\sqrt{M't}) - \frac{2}{\sqrt{\pi}}e^{-M't} + \frac{4\sqrt{M't}}{\sqrt{\pi}}e^{-M't})\right]$$
$$-2bd\frac{\sqrt{t}}{4}\left\{\begin{array}{c}\left[2\sqrt{M't}(erfc(\sqrt{M't}) - erfc(-\sqrt{M't})) - \frac{4}{\pi}e^{-M't}\right] \\ -\frac{1}{4\sqrt{M'}}\left[erfc(-\sqrt{M't}) - erfc(\sqrt{M't})\right]\end{array}\right\}$$
$$+\frac{d\,e^{bt}}{2\sqrt{t}}\left[2\sqrt{A_2}(erfc(\sqrt{A_2}) - erfc(-\sqrt{A_2})) - \frac{2}{\sqrt{\pi}}e^{-A_2}\right]$$
$$-\frac{2c}{\sqrt{t\pi}} - \frac{c\,e^{at}}{2\sqrt{t}}\left[2\sqrt{\Pr a t}(erfc(\sqrt{at}) - erfc(-\sqrt{at})) - \frac{4}{\sqrt{\pi}}e^{-at}\right]$$
$$-\frac{2d}{\sqrt{t}\sqrt{\pi}} + \frac{bd\sqrt{t}}{2}\left[\frac{\sqrt{Sc}}{\sqrt{t}\sqrt{\pi}} - \frac{2\sqrt{Sc}}{\sqrt{\pi}}\right]$$
$$-\frac{d\,e^{bt}}{2\sqrt{t}}\left[2\sqrt{Sc\,bt}(erfc(\sqrt{bt}) - erfc(-\sqrt{bt})) - \frac{4}{\sqrt{\pi}}e^{-bt}\right]$$

Where, $A_1 = (M'+a)t, A_2 = (M'+b)t$

SHERWOOD NUMBER (S_h)

S_h is given by $S_h = -\left[\frac{dL'}{dy}\right]_{\lambda'=0} = \frac{2\sqrt{t}\sqrt{Sc}}{\sqrt{\pi}}$

NUSSELT NUMBER (N_u)

N_u is given by $N_u = -\left[\frac{d\Omega'}{dy}\right]_{\lambda'=0} = \frac{\sqrt{P_r}}{\sqrt{\pi}\sqrt{t}}$

PERFORMANCE AND ARGUMENT

In order to get a more comprehensive understanding of the issue, quantitative computations are performed, taking into account a range of fundamental factors and their impact on circulation and transit properties. The S_c 2.01 is set to a value representative of water vapor, and the P_r 7 is specified for water. The computations involve determining the velocity and concentration for different physical parameters such as Pr, Gr, Gc, magnetic field strength, duration, and the angle of inclination.

Figure-1 depicts the impact of the magnetized environment variable on velocity for a given set of conditions involving specific values of $(M' = 2,5,10,15)$, $Gr = 2$, $Gc = 5, t = 0.4$ and angle $\alpha_1 = \pi/3$. Similarly in Figure2 $(M' = 2,5,10,15)$, $Gr = 2$, $Gc = 5, t = 0.8$ and angle $\alpha_1 = \pi/6$ and Figure-3 $(M' = 2,5,10,15)$, $Gr = 2$, $Gc = 5, t = 0.2$ and angle $\alpha_1 = \pi/4$ illustrate the influences of the magnetized environment variable on speed under different conditions. When the three numbers are observed, a consistent observation emerges: the velocity demonstrates an upward trend as the magnetic field parameter decreases. The observed trend suggests that a decrease in the magnetic field variable is associated with a surge in pace. This observation is consistent with existing expertise since it is well-documented that the existence of a magnetic environment imposes a resistive influence on the movement of unconstrained convective circulation, resulting in a reduction in its speed.

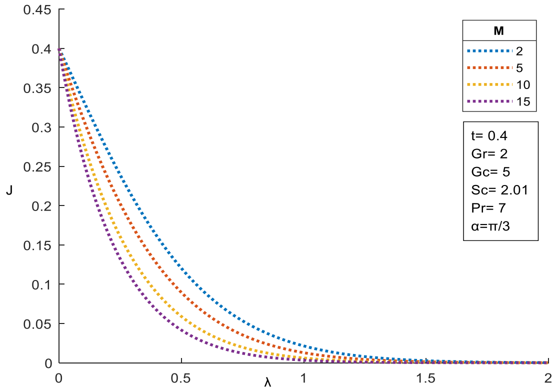

Figure-1. 'v' vs. 'M'.

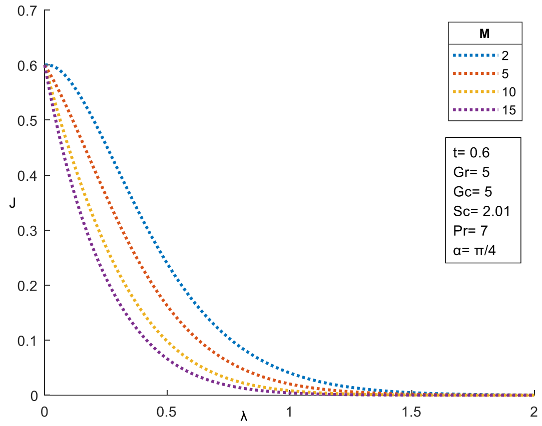

Figure-2. 'v' vs. 'M'.

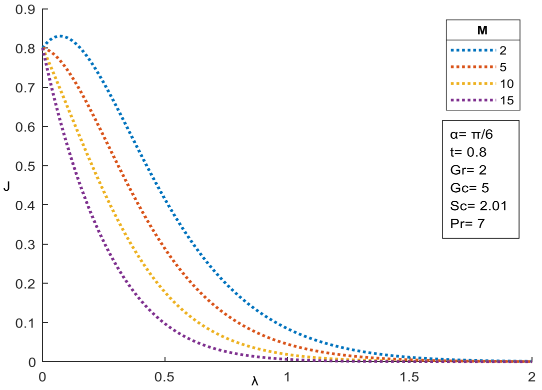

Figure-3. ‘v’ vs. ‘M’.

In Figure-4, the variations in Gr, $(Gr = 2,5,10,15)$ $t = 0.2, Gc = 2, M' = 10, \alpha_1 = \pi/4$, revealing a noticeable trend of increasing velocity as Gr values rise. Similarly, Figure-5 Gc, $(Gc = 2,5,10,15)$ $t = 0.2, Gr = 2, M' = 2, \alpha_1 = \pi/6$, portrays the diverse Gc scenarios, and it is evident that higher Gc values correspond to increased velocities.

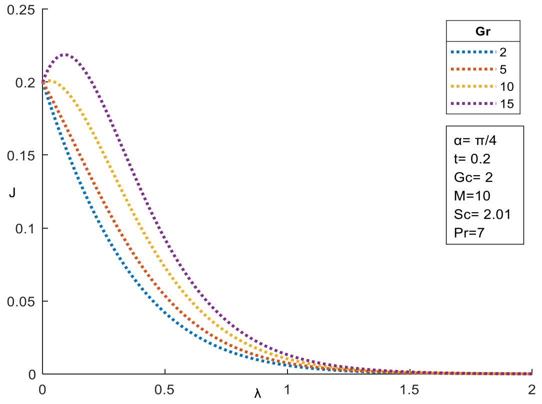

Figure-4. ‘v’ vs. Gr.

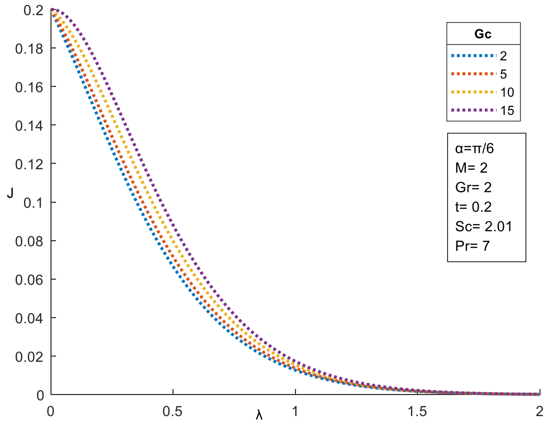

Figure-5. ‘v’ vs. Gc.

Figure-6 displays the examination of velocity contours for various $(t = 0.2,0.4,0.6), M' = 5,$ $Gr = 2, Gc = 5, \alpha_1 = \pi/3$. Similarly, in Figure-7, the velocity contours for various $t = 0.2,0.4,0.6$ $M' = 2, Gr = Gc = 2, \alpha_1 = \pi/4$ are investigated and depicted. It is noteworthy that in both Figure-6 and Figure-7, a consistent observation emerges: the velocity demonstrates an upward trend with higher numbers of t.

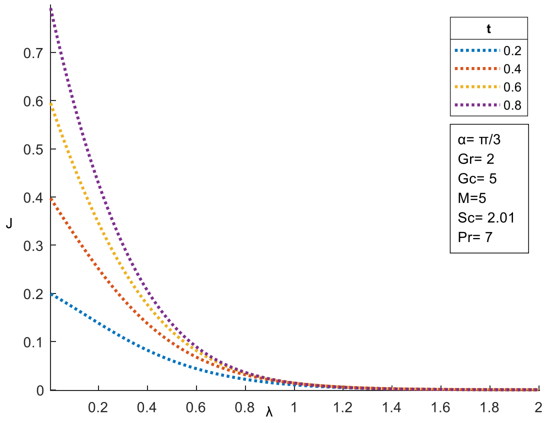

Figure-6. ‘v’ vs. t.

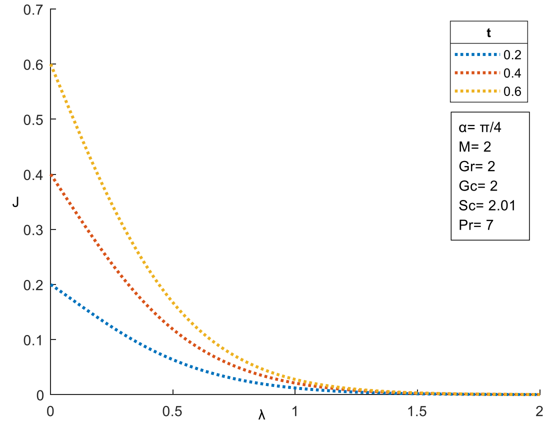

Figure-7. ‘v’ vs. ‘t’.

Figure-8 illustrates the examination of velocity contours for various $(\alpha_1 = \pi/3, \pi/4, \pi/6), M' = 5, Gr = Gc = 10$. Notably, the observation from the figure indicates that as the angles decrease, there is a corresponding increase in velocity.

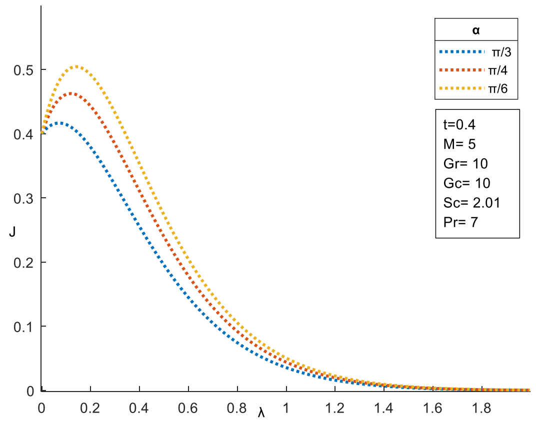

Figure-8. ‘v’ vs. ‘α’.

In Figure-9, velocity contours are presented for different numbers of $Gr = 5,10$, $Gc = 5,10$, $t = 0.4, M' = 2, \alpha_1 = \pi/4$. It is evident from the figure that an increase in either the Gr or Gc corresponds to an increment in ‘v’.

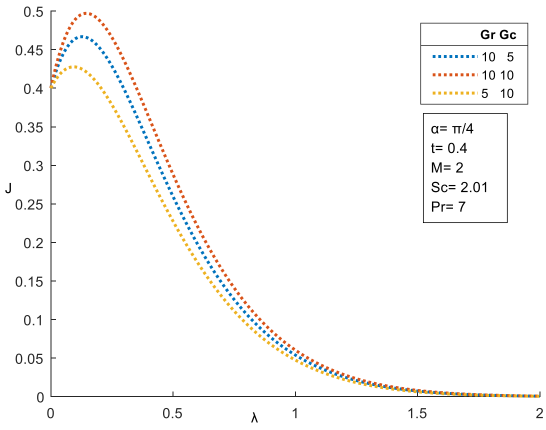

Figure-9. ‘v’ vs. ‘Gr’ and ‘Gc’.

Figure-10 reveals the impact of concentration profiles for various numbers of time (t) $(t = 0.2, 0.4, 0.6, 0.8), Sc = 0.3$. A notable observation from the figure is that as time increases, there is a corresponding elevation in the intensity.

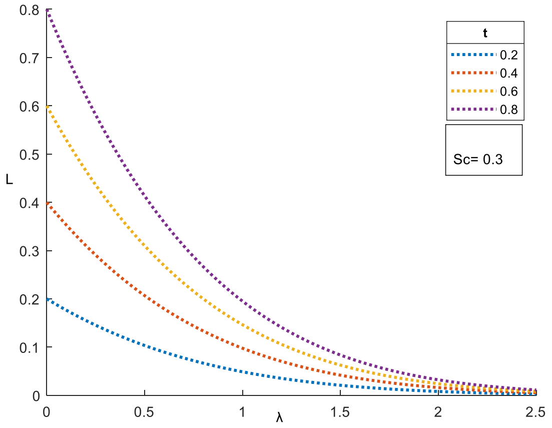

Figure-10. Concentration vs.‘t’.

Table-1 illustrates the impact of τ different parameters. It is evident that raising the incline, P_r and S_c, and results in an augmentation of skin friction (τ). Conversely, it has the opposite effect of escalating the time, thermal, and mass Grashof numbers.

Table-1. The Sherwood number for various elements.

t	S_c	S_h
0.2	2.01	0.7154
0.2	0.16	0.2018
0.2	0.6	0.3908
0.4	2.01	1.0117
0.4	0.3	0.3908
0.6	0.16	0.3496
0.6	0.3	0.4787

Table-2 illustrates the impact of S_c and t on S_h as follows. The increase in direct and proportional influences. As S_c rises, the mass transfer also experiences a corresponding increase.

Table-2. Nusselt amount for different variables.

t	P_r	N_u
0.2	7.0	3.3377
0.2	0.71	1.0630
0.4	7.0	2.3601
0.4	0.71	0.7516
0.6	7.0	1.9270
0.6	0.71	0.6137

Table-3 presents the results for different physical parameters P_r and times. It highlights that an elevation in P_r leads to a concurrent increase in (Nu), suggesting a direct correlation between the rise in heat transmission and the increase in Pr.

Table-3. Skin -Friction due to several reasons.

(Pr=7, Sc=2.01)

Angle (α_1)	t	Gr	Gc	M'	τ
$\pi/3$	0.8	5	2	5	-2.5556
$\pi/6$	0.2	2	5	10	-3.3972
$\pi/4$	0.6	2	2	2	-2.3980
$\pi/6$	0.8	5	5	2	-5.4681
$\pi/4$	0.6	2	5	5	-5.2281
$\pi/3$	0.4	2	2	2	-1.9792
$\pi/6$	0.2	5	5	5	-3.7468
$\pi/3$	0.8	5	2	2	-1.9094
$\pi/4$	0.4	2	2	10	-3.3226

CONCLUSIONS

The analysis focused on examining the magnetohydrodynamics of the circulation features when a consistent temperature is applied to an angled surface, whilst incorporating the presence of fluctuating material dispersion. The undefined regulating formulas are solved with Laplace Transform techniques. The investigation involves a visual examination of velocity patterns and intensity across different variables, including Gr, Gc, magnetized environment, Pr, Sc, and t. It was noticed that the velocity exhibited a positive correlation with the rising values of Gr, Gc, and t. The velocity exhibits an increase when the values of the magnetic field decrease. The rise in α, Pr, and Sc leads to an elevation in τ.

NOMENCLATURE

A	constant
B_0	external magnetic field
L^*	species concentration in the fluid
L^*_ω	concentration of the plate
L^*_∞	concentration of the fluid far away from the plate
L'	dimensionless concentration
L'_p	specific heat at constant pressure
D	mass diffusion coefficient
Gc	mass Grashof number
Gr	thermal Grashof number
g	accelerated due to gravity
k	thermal conductivity
M'	magnetic field parameter
Nu	Nusselt number
$\Pr$	Prandtl number
Sc	Schmidt number
Sh	Sherwood number
E''_∞	temperature of the fluid far away from the plate
E''_ω	temperature of the plate
$(E''_\omega)'$	temperature on the wall
$E'',(E'')'$	temperature of the fluid near the plate
t'_4	time
t	dimensionless time
u	velocity of the fluid in the x-direction
u_0	velocity of the plate
J',J	dimensionless velocity
x	spatial coordinate along the plate
y	coordinate axis normal to the plate
Y	dimensionless coordinate axis normal to the plate

GREEK SYMBOLS

α,α_1	thermal diffusivity
β	volumetric coefficient of thermal expansion
$\beta\,*$	volumetric coefficient of expansion with concentration
μ	coefficient of viscosity
σ	electric conductivity
υ	kinematic viscosity
ρ	density of the fluid
τ	dimensionless skin-friction
Ω'	dimensionless temperature
λ,λ'	similarity parameter
$erfc$	complementary error function

Subscripts

ω	conditions at the wall
∞	conditions in the free stream

REFERENCES

[1] Ali J. Chamkha and Abdul-Rahim A. Khaled. 2001. Similarity solutions for hydromagnetic simultaneous heat and mass transfer by natural convection from an inclined plate with internal heat generation or absorption. Heat and Mass Transfer. 37: 117-123.

[2] Takhar H. S., Chamkha A. J. and Nathc G. 2003. Effects of non-uniform wall temperature or mass transfer in finite sections of an inclined plate on the MHD natural convection flow in a temperature stratified high-porosity medium. International Journal of Thermal Sciences. 42: 829-836.

[3] Ibrahim F. S., Hassanien I. A. and Bakr A. A. 2004. Unsteady magnetohydrodynamic micropolar fluid flow and heat transfer over a vertical porous plate through a porous medium in the presence of thermal and mass diffusion with a constant heat source. Canadian Journal of Physics. 10: 775-790.

[4] Rahman M. M and Sattar M. A. 2006. MHD convective flow of a micropolar fluid past a continuously moving vertical porous plate in the presence of heat generation/absorption. AMSE J Heat Trans. 128(2): 142-52.

[5] Ogulu A. and Makinde O. D. 2009. Unsteady hydromagnetic free convection flow of a dissipative and radiating fluid past a vertical plate with constant heat flux. Chem Eng Commun. 196(4): 454-462.

[6] Orhan Aydm and Ahmet Kaya. 2009. MHD mixed convective heat transfer flow about an inclined plate, Heat Transfer. 46: 129-136. DOI: 10.1007/s00231-009-0551-4.

[7] Uddin Z. and Kumar M. 2010. Unsteady free convection in a fluid past an inclined plate immersed in a porous medium. Comput Model NewTech. 14(3): 41-7.

[8] Shivaiah S. and Anandrao J. 2011. Chemical reaction effect on an unsteady MHD free convection flow past a vertical porous plate in the presence of suction or injection, Theoretical and Applied Mechanics. 39: 185-208. DOI: 10.2298/TAM1202185S.

[9] Singh G. and Makinde O. D. 2012. Computational dynamics of MHD free convection flow along an inclined plate with Newtonian heating in the presence of volumetric heat generation. Chem Eng Commun. 199(9): 1144-54.

[10] Makinde O. D. 2012. Heat and mass transfer by MHD mixed convection stagnation point flow toward a vertical plate embedded in a highly porous medium with radiation and internal heat generation. Meccanica. 47: 1173-84.

[11] Puneet Rana, Bhargava R. and Bég O. A. 2012. Numerical solution for mixed convection boundary layer flow of a nanofluid along an inclined plate embedded in a porous medium. Computers and Mathematics with Applications. 64: 2816-2832.

[12] Rashidi M. M., Momoniat E. and Rostami. B. 2012. Approximate solutions for hydro magnetic boundary layer viscoelastic flow over moving stretching surface with two auxiliary parameters. - Journal Applied Math. Article ID 780415, https://doi.org/10.1155/2012/780415.

[13] Ali F., Khan I., Samiulhaq and Shafie S. 2013. Conjugate effects of heat and mass transfer on MHD free convection flow over an inclined plate embedded in a porous medium. PLOS ONE. 8(6): e65223. DOI:10.1371/journal.pone.0065223.39.

[14] Vijay Kumar A. G., Kumar B. R. and.Varma S. V. K. 2014. The effect of induced magnetic field and radiation on MHD mixed convection fluid flow over a porous vertical plate in the presence of viscous and magnatic dissipation. International Journaof Applied Engineering, Research. 9(22): 13847-13866.

[15] Ismail Z., Khan I., Nasir N. M., Jusoh R., Salleh M. Z. and Shafie S. 2014. Rotation effects on coupled heat and mass transfer by unsteady MHD free convection flow in a porous medium past an infinite inclined plate. In: Proceedings of AIP conference. 1605: 410 doi: http://dx.doi.org/10.1063/1.4887624.

[16] Nandkeolyar R. and Das M. 2015. MHD free convective radiative flow past a flat plate with ramped temperature in the presence of an inclined magnetic field. Computational and Applied Mathematics. 34(1): 109-123.

[17] Narahari M., Tippa S., Pendyala R. and Nayan M. Y. 2015. Ramped temperature effect on unsteady MHD natural convection flow past an infinite inclined plate in the presence of radiation, heat source and chemical reaction, Recent Advances in Applied and Theoretical Mechanics: 126-137. ISBN 978-1-61804-304-7.

[18] Das S., Jana R. N. and Makinde O. D. 2015. Magnetohydrodynamic mixed convective slip flow over an inclined porous plate with viscous dissipation and Joule heating, Alexandria Engineering Journal. 54: 251-161. htts://doi.org/10.1016/j.aej.2015.03.003.

[19] Muthucumaraswamy R. and Jeyanthi L. 2015. Hall effects on MHD flow past an infinite vertical plate in the presence of rotating fluid of variable temperature and mass diffusion with first order chemical reaction. ARPN Journal of Engineering and Applied Sciences. 10(20): 9596-9603.

[20] Anjali Devi S. P. and Suriyakumar P. 2016. Hydromagnetic Mixed Convective Nanofluid Slip Flow past an Inclined Stretching Plate in the Presence of Internal Heat Absorption and Suction. Journal of Applied Fluid Mechanics. 9(3): 1409-1419.

[21] Muthucumaraswamy R. and Sivakumar P. 2016. MHD flow past a parabolic flow past an infinite isothermal vertical plate in the presence of thermal radiation and chemical reaction. International journal of Applied Mechanics and Engineering. 21(1): 95-105, doi: 10.1515/ijame-2016-0006.

[22] Dhal R. K., Banamali Jena and Sreekumar P. M. 2017. Heat and mass transfer effects on MHD free convection flow over an inclined and exponentially accelerated plate embedded in a porous medium with heat source. International Research Journal of Advanced Engineering and Science. 2(2): 299-303.

[23] Kalpna Sharma and Sumit Gupta. 2017. Homotopy Analysis Solution to Thermal Radiation Effects on MHD Boundary Layer Flow and Heat Transfer Towards an Inclined Plate with Convective Boundary Conditions. International Journal of Applied and Computational Mathematics. 3: 2533-2552, https://doi.org/10.1007/s40819-016-0249-5.

[24] Thirupathi Thumma, Anwar Beg O. and Siva Reddy Sheri. 2017. Finite element computation of magnetohydrodynamic nanofluid convection from an oscillating inclined plate with radiative flux, heat source and variable temperature effects. Proc imeche-part n- journal of Nanomaterials, Nanoengineering and Nanosystems. dx.doi.10.1177/2397791417731452.

[25] Rajput U. S. and Gaurav Kumar. 2018. Rotation and radiation effects on MHD flow past an inclined plate with variable wall temperature and mass diffusion in the presence of Hall current. Applications and Applied Mathematics: An International Journal. 13(1): 484-495.

[26] Shankar Goud B., Pudhari Srilatha and Raja Shekar M. N. 2018. Study of Hall Current and Radiation Effects on MHD Free Convective Flow Past an Inclined Parabolic Accelerated Plate with Variable Temperature in a Porous Medium. International Journal of Mechanical Engineering and Technology. 9(7): 1268-1276.

[27] Abro K. A., Khan I. and Gomez-Aguilar J. F. 2018. A mathematical analysis of a circular pipe in rate type fluid via Hankel transform. The European Physical Journal Plus. 10: 133(397). DOI:10.1140/epjp/i2018-12186-7.

[28] Venkateswarlu M., Bhaskar P. and Venkata Lakshmi D. 2019. Soret and Dufour effects on radiative hydromagnetic flow of a chemically reacting fluid over an exponentially accelerated inclined porous plate in presence of heat absorption and viscous dissipation. J. Korean Soc. Ind. Appl. Math. 23(3): 157-178.

[29] Ahmad M., Imran M. A., Aleem M. and Khan I. 2019. A comparative study and analysis of natural convection flow of MHD non-Newtonian fluid in the presence of heat source and first-order chemical reaction. Journal of Thermal Analysis and Calorimetry. 137: 1783-1796. https://doi.org/10.1007/s10973-019-08065-3.

[30] Usharani V., Selvaraj A., Constance Angela R. and Neel Armstrong A. 2020. Impact of MHD Stream past an Exponentially Inclined Vertical Plate of First-Order Chemical Response with Variable Mass Diffusion and Thermal Radiation. Mathematical Modeling and Computational Science, Advances in Intelligent Systems and Computing. 1292: 485-497. https://doi.org/10.1007/978-981-33-4389-4_45.

[31] Khan I., Saeed, S. T., Riaz M. B., Abro, K. A., Husnine S. M. and Nissar K. S. 2020. Influence in a Darcy's Medium with Heat Production and Radiation on MHD Convection Flow via Modern Fractional Approach. Journal of Materials Research and Technology. 5(9): 10016-10030.

[32] Riaz M. B., Saeed S. T. and Baleanu D. 2020. Role of Magnetic field on the Dynamical Analysis of Second Grade Fluid: An Optimal Solution subject to Non-integer Differentiable Operators. Journal of Applied and Computational Mechanics. 6(SI): 1475-1489.

[33] Nazish Iftikhar, Dumitru Baleanu, Muhammad Bilal Riaz and Syed Muhammad Husnine. 2021. Heat and Mass Transfer of Natural Convective Flow with Slanted Magnetic Field via Fractional Operators. Journal of Applied and Computational Mechanics. 7(1): 189-212.

[34] Shahzad A., Anique A., Kashif A., Hina B. and Muhammad Farooq I. 2021. Effect of non-Newtonian flow due to thermally-dependent properties over an inclined surface in the presence of chemical reaction, Brownian motion and thermophoresis. Alexandria

Engineering Journal. 60: 4931-4945. https://doi.org/10.1016/j.aej.2021.03.014.

[35] Praveen kumar Dadheech, Priyanga Agrawal, AnilSharma, Amit Dadheech, Qasem Al-Mdallal and Sunil Dutt Purohit. 2021. Entropy analysis for radiative inclined MHD slip flow heat source in porous medium for two different fluids. Case Studies in Thermal Engineering. 28: 101491.

[36] Nagarajan G., Sundar Raj M. and Muthucumaraswamy R. 2022. The Influence of Thermal Expansion on Flow past an Inclined Accelerated Sectional Plate with Persistent Mass Diffusion. International Journal of Applied Mechanics and Engineering. 27(4): 105-116. https://doi.org/10.2478/ijame-2022-0053.

[37] Mopuri O., Madhu R. K., Peram M. R. and Ganteda C. 2022. Unsteady MHD on Convective Flow of a Newtonian Fluid Past an Inclined Plate in Presence of Chemical Reaction with Radiation Absorption and Dufour Effects, CFD Letters. 14(7): 62-76. https://doi.org/10.37934/cfdl.14.7.6276.

[38] Nagesh Gulle and Raghunathkodi. 2022. Soret radiation and chemical reaction effect on MHD Jeffrey fluid flow past an inclined vertical plate embedded in porous medium. Materials today proceedings. 50(5): 2218-2226. https://doi.org/10.1016/j.matpr.2021.09.480.

[39] Sheri S. R., Peesu M. and Mamidi Narsimha R. 2022. Hall current, chemical reaction and radiation results on transient magnetohydrodynamic flow past an inclined plate. FEM. 51(2): 1876-1899. https://doi.org/10.1002/htj.22379.

[40] Sundar Raj M., Nagarajan G., Murugan V. P. and Muthucumaraswamy R. 2023. Impacts of Chemical Reactions on Inclined Isothermal Vertical Plate, International Journal of Applied Mechanics and Engineering. 28(2): 64-76. DOI: 10.59441/ijame/168439.

[41] Rajaraman R. and Muthucumaraswamy R. 2023. Numerical study of a transient MHD flow across an oscillating vertical plate with thermal radiation and viscous dissipation, International Journal of Applied Mechanics and Engineering. 28(2): 77-89. doi.org/10.59441/ijame/168931.