Journal of Engineering Science 14(2), 2023, 137-144
DOI: https://doi.org/10.3329/jes.v14i2.71237

JES
an international Journal

EFFECTS OF HEAT GENERATION AND CHEMICAL REACTION ON TIME-DEPENDENT MHD NATURAL CONVECTIVE TRANSPORT PAST IN A VERTICAL PERFORATED SHEET

Md. Abu Bkar Pk[1]

[1]*Department of Applied Mathematics, Rajshahi University, Rajshahi-6205, Bangladesh*

Received: 10 December 2023 Accepted: 28 December 2023

ABSTRACT

This investigation focused on the impacts of heat production and chemical reaction on time-dependent MHD-free convective transport via a vertical permeable sheet. The ODEs are obtained by transforming the governing PDEs using similarity transformations. With the assistance of MATLAB software, the shooting technique is utilized to numerically resolve the non-dimensional governing equations with boundary conditions. The role of emerging non-dimensional parameters or numbers like the Schmidt number (Sc)*, heat generation parameter (Q), Prandtl number* (Pr)*, and chemical reaction parameter (Kr) on fluid temperature, velocity, and concentration were discussed within the boundary layer. The results show that temperature and fluid motion are improved by raising the heat generating parameters. On the contrary, as the chemical reaction value goes up, the fluid velocity and concentration do as well.*

Keywords: *MHD; Chemical reaction; Heat generation; Heat and mass transfer; Permeability.*

1. INTRODUCTION

Heat and mass transmission by free convection in a fluid-saturated perforated medium was an active region of research owing to the abundance of applications like geothermal reservoirs, oil recovery, cooling of nuclear reactors, and drying of porous solids. The flow around a stagnant line has attracted several researchers over the past century. Convective mass and heat transfer including chemical reactions perform a noteworthy role in the burning of haystacks, meteorological phenomena, fluidized bed catalysis, cooling towers, and spray drying of milk. Bhuvaneswari et al. (2009) deliberated the consequence of the first-order homogeneous chemical reaction on the convective heat and mass transmission movement of an incompressible viscous fluid over a semi-infinite inclined surface. In their simulation, they applied the Lie group analysis. The important impact of the chemical reaction and the convective surface boundary condition on the MHD magnetic heat and mass transmission upon a vertical sheet are explored by Gangadhar (2013) with the Soret and Dufour influences. Bhuvaneswari and Sivasankaran (2014) analyzed the effect of the variable thermal conductivity on the free convective heat and mass transmission movement upon an inclined semi-infinite sheet. The impacts of the chemical reaction and the radiative on a visco-elastic MHD free convective movement on a vertical permeable sheet over a perforated media are presented by Choudhury and Kumar Das (2014). A sliding vertical sheet in a porous medium was used to observe the effects of rotation and Hall current on time-dependent MHD natural convective transport of an electrically conducting, incompressible viscous fluid by Seth et al. (2014).

In problems involving the impact of chemical reactions and fluid dissociation, the research regarding heat production or absorption in transportable fluids is essential. The influence of heat production or absorption can improve or decrease the temperature distribution and This can therefore have an impact on how quickly particles accumulate in nuclear reactors, semiconductor wafers, and electrical chips. Its general behavior under most physical situations can be expressed in a number of simpler mathematical models. One can classify heat generation or absorption as constant, space-dependent, or temperature-dependent. In a comparable solution for a fluid with an exponential erosion heat absorption or generation term in a vertical plate, Crepeau and Clarksean (1997) examined the impact of a fixed temperature. There are many attractive computational kinds of research on heat generation or absorption consequence on responsive MHD border layer movement with heat and mass transmission are explored by Patil and Kulkarni (2008), Salem and El-Aziz (2008), Samad and Mohebujjaman (2009), Mohamed (2009), and Mahdy (2010). Numerous scientific and engineering uses for the magnetic field influences heat generation or absorption in the fluid of electrically conducting flows. Recently Hasanuzzaman et al. (2022) examined the impacts of radiative and chemical reactions on Hasanuzzaman et al (2021). Moreover, Hasanuzzaman et al. (2022) studied the impact of the internal heat production effect on a time-dependent MHD convective heat and mass transmission flow moving in a vertical porous sheet. This work now expands on

*Corresponding Author: *pkbakar@gmail.com*

Hasanuzzaman et al. (2021) by regarding the chemical reaction and heat generation. Their simulation is almost the same as our simulation.

The impacts of chemical reactions and heat generation on an unstable MHD-free convective heat and mass transference past an infinite vertical porous sheet are examined based on the literature study mentioned above. The main novelty of this research is further improved by regarding the chemical reaction and heat generation through the shooting technique which has not yet been clarified. Computations have been completed for a wide range of non-dimensional parameters or numbers such as heat generation parameter, Prandtl number, Darcy number, magnetic number, Schmidt number, Dufour number, suction parameter, chemical reaction parameter, and Soret number on velocity, temperature, and concentration distributions are observed graphically. Additionally, the characteristics of the mass and heat transmission, as well as the coefficient of local skin friction, were studied in tabular arrangements

2. GOVERNING EQUATIONS

In this paper, the fluid flow is taken to be two-dimensional. This fluid flow is time-dependent MHD free convective heat and mass transmission movement of an incompressible viscous electrical conducting fluid through a vertical permeable plate. A uniform magnetic with strength ***B*** is applied on the porous sheet. The fluid particle is moving in the direction of the x-axis. With respect to the fluid particle, the y-axis is normal. The length of the x-axis is unlimited since the plate is infinite. For this reason, $\frac{\partial u}{\partial x} \to 0$ when $x \to \infty$. The fluid particle is therefore just a function of y and t.

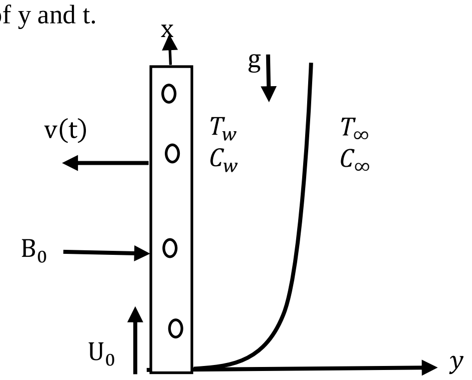

Figure 1: Physical model

The governing equations are provided by the Boussinesq approximation and the aforementioned assumptions as follows:

Continuity Equation:

$$\frac{\partial v}{\partial y} = 0 \tag{1}$$

Momentum Equation:

$$\frac{\partial u}{\partial t} + v\frac{\partial u}{\partial y} = \upsilon\frac{\partial^2 u}{\partial y^2} + g\beta(T - T_\infty) + g\beta^*(C - C_\infty) - \frac{\sigma' B_0^2 u}{\rho} - \frac{\nu}{K}u \tag{2}$$

Energy Equation:

$$\frac{\partial T}{\partial t} + v\frac{\partial T}{\partial y} = \frac{k}{\rho C_p}\frac{\partial^2 T}{\partial y^2} + \frac{D_m k_T}{C_s C_p}\frac{\partial^2 C}{\partial y^2} + \frac{Q_0}{\rho C_p}(T - T_\infty) \tag{3}$$

Concentration Equation:

$$\frac{\partial C}{\partial t} + v\frac{\partial C}{\partial y} = D_m\frac{\partial^2 C}{\partial y^2} + \frac{D_m k_T}{T_m}\frac{\partial^2 T}{\partial y^2} + K'(C - C_\infty) \tag{4}$$

The associated boundary conditions:

$$u = U_0(t), v = v(t), T = T_w, C = C_w, t > 0, \text{at } y = 0 \tag{5}$$

$$u = 0, v = 0, T \to T_\infty, C \to C_\infty, t > 0, \text{at } y \to \infty \tag{6}$$

where ρ is the fluid density, K is the permeability of the porous plate, T is the fluid temperature, u is the velocity component in the x-axis, υ is kinematic viscosity, C_p is the specific heat at constant pressure, T_∞ is the fluid temperature in the free stream, v is the velocity component in the y-axis, T_w is the wall temperature, C_s is the susceptibility of the concentration, g is the gravitational acceleration, β^* is the coefficient of concentration expansion, σ' is the electric conductivity,C_w is the wall concentration, K' is the chemical reaction rate of spices concentration, C is the fluid concentration, C_∞ is the free stream concentration, k is the thermal conductivity of the sheet, D_m is the mass diffusivity coefficient, k_T is the thermal diffusion ratio, T_m is the fluid mean temperature, and β is the coefficient of thermal expansion.

The similarity parameter is denoted by σ which represents the unsteady length, where

$$\sigma = \sigma(t) \tag{7}$$

The solution to equation (1) by using this length scale is taken into consideration as:

$$v = -v_0 \frac{\upsilon}{\sigma} \tag{8}$$

The dimensionless normal velocity at the plate is represented here by v_0. When $v_0 < 0$, then the blowing or injection happens in the system. On the other hand, when $v_0 > 0$ then the suction happens in the system.

The similarity variables are:

$$\eta = \frac{y}{\sigma}\ ,\ f(\eta) = \frac{u}{U_0}\ ,\ \theta(\eta) = \frac{T - T_\infty}{T_w - T_\infty}\ ,\ \phi(\eta) = \frac{C - C_\infty}{C_w - C_\infty} \tag{9}$$

The equations (1) – (4) are transformed into the dimensionless coupled ODEs through the use of the aforementioned equations (7)–(9) as follows:

$$f''(\eta) + 2\xi f'(\eta) + Gr\theta(\eta) + Gm\phi(\eta) - Mf(\eta) - \frac{1}{Da} f(\eta) = 0 \tag{10}$$

$$\theta''(\eta) + Pr\{2\xi\theta'(\eta) + Df\phi''(\eta) + Q\,\theta(\eta)\} = 0 \tag{11}$$

$$\phi''(\eta) + 2Sc\xi\phi'(\eta) + ScSr\theta''(\eta) + Kr\phi(\eta) = 0 \tag{12}$$

The transformed boundary conditions are:

$$f(\eta) = 1\ ,\ \theta(\eta) = 1,\ \phi(\eta) = 1 \qquad \text{at } \eta = 0 \tag{13}$$

$$f(\eta) = 0,\ \theta(\eta) = 0, \qquad \phi(\eta) = 0 \qquad \text{as } \eta \to \infty \tag{14}$$

where $Da = \frac{K}{\sigma^2}$ is the Darcy number, $Gm = \frac{g\beta^*(C_w - C_\infty)\sigma^2}{U_0\upsilon}$ is the modified local Grashof number, Prandtl number is $Pr = \frac{\rho\upsilon C_p}{k}$, Schmidt number is $Sc = \frac{\upsilon}{D_m}$, chemical reaction parameter is $Kr = \frac{K'\sigma^2}{\upsilon}$, $Q = \frac{Q_0}{\rho C_p}$ is the internal heat generation or absorption parameter,Dufour number is $Df = \frac{D_m k_T (C_w - C_\infty)}{C_s C_p \upsilon (T_w - T_\infty)}$, local Grashof number is $Gr = \frac{g\beta(T_w - T_\infty)\sigma^2}{U_0\upsilon}$, Soret number is $Sr = \frac{D_m k_T (T_w - T_\infty)}{\upsilon T_m (C_w - C_\infty)}$, $\xi = \eta + \frac{v_0}{2}$ is the unsteady parameter, and Magnetic parameter is $M = \frac{\sigma' B_0^2 \sigma^2}{\rho\upsilon}$.

The local skin friction ($\mathbf{f'(0)}$), mass transmission rate ($\mathbf{-\phi'(0)}$), and heat transmission rate are proportional to the shear stress ($\boldsymbol{\tau}$), Sherwood number (Sh), and Nusselt number ($\mathbf{Nu}$) which are stated as:

$$\boldsymbol{\tau} \propto \mathbf{f'},\ \mathbf{Nu} \propto -\boldsymbol{\theta'}\ ,\ \mathbf{Sh} \propto -\boldsymbol{\phi'} \tag{15}$$

3. RESULTS AND DISCUSSION

The impacts of heat production and chemical reactions on time-dependent MHD convective transference past in a vertical porous sheet are studied numerically in this work. The set of coupled ODEs (10) - (12) with the boundary conditions (13) - (14) is resolved by by means of the finite difference method throughout the shooting technique in MATLAB. The impacts of the Dufour number (Df), magnetic parameter (M), chemical reaction parameter (Kr), Schmidt number (Sc), heat generation parameter (Q), Prandtl number (Pr), suction parameter (v_0), and Darcy number (Da) on concentration, temperature, and velocity distributions are exhibited in the Figures 2-12.

The effect of magnetir parameter (M) on the velocity outline is plotted in Figure 2. From Figure 2 reveals that the fluid motion diminishes for improving amounts of M. These results indicate the magnetic force tends to obstruct the fluid speed. The fact is that the magnetic force dominates the flow characteristics. The influence of Darcy number (Da) on the velocity field is displayed in Figure 3. The equation (10) discloses that Da is directly proportional to the permeability of the plate. For greater amounts of Da, the permeability of the plate is enhanced. For this reason, the fluid motion accelerates quickly as indicated in Figure 3. For growing amounts of the modified local Grashof number (Gm), thermal buoyancy forces rise, which results in accelerating the flow rate as shown in Figure 4. In this case, a positive amount for Gm denotes the surface cooling and the surface is heating for a negative value of Gm. It is observed from equation (11) that the Prandtl number (Pr) is directly proportionate to the kinematic viscosity. Then the kinematic viscosity improves when the Prandtl number grows. The fluid particles are unable to move easily in the computational domain to improve the kinematic viscosity. Therefore, the fluid velocity declines as Pr improves, which is shown in Figure 5. This is because the higher Pr leads to faster cooling of the sheet. It is also shown from equation (11) that the thermal conductivity and Pr have an inverse relationship. The lower thermal conductivity is obtained for advanced amounts of Pr. The heat transmission rate reduces for the lower quantities of the thermal conductivity. For greater amounts of Pr, as seen in Figure 6, the fluid temperature drops as a result.

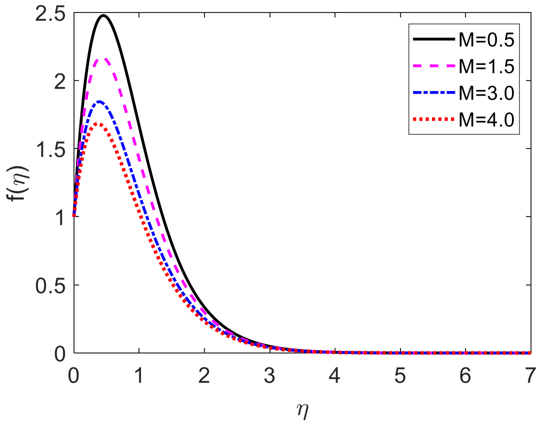

Figure 2: Velocity Profile for M

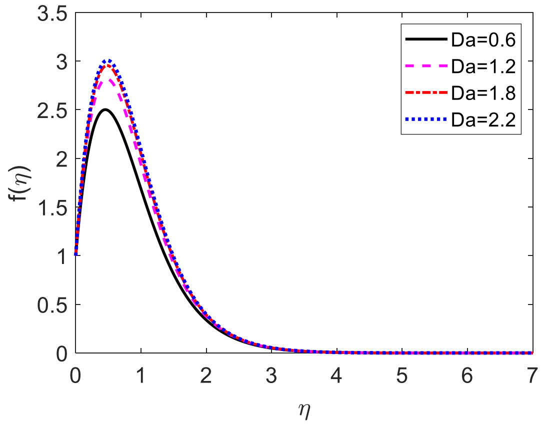

Figure 3: Velocity Profile for Da

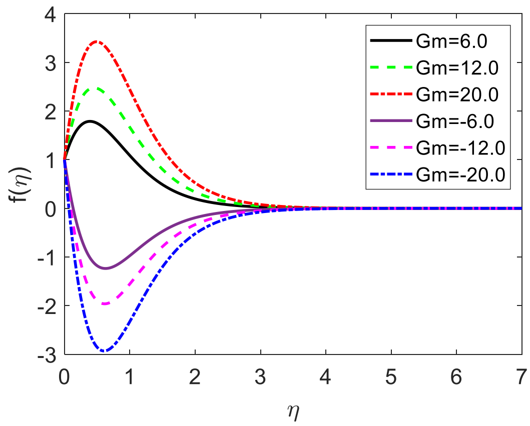

Figure 4: Velocity Profile for Gm

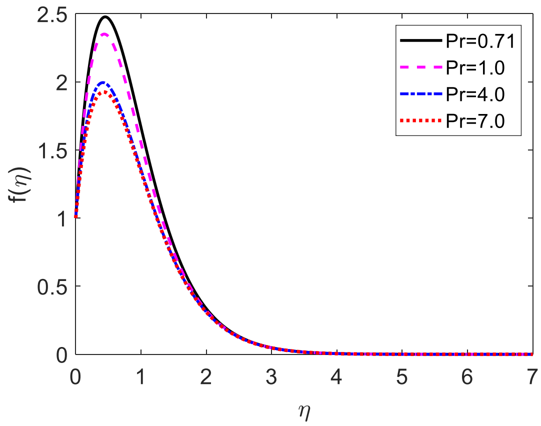

Figure 5: Velocity Profile for Pr

The important role of internal heat generation on the velocity and temperature outlines is revealed in Figures (7-8). The heat generation happens in the computational domain when $Q > 0$. In contrast, heat absorption occurs for $Q < 0$. The fluid velocity improves for higher quantities of $Q > 0$ but decreases for $Q < 0$ as shown in Figure 7. Physically, the existence of thermal source (heat generation) impacts has enhanced the fluid speed. Conversely, for the heat absorption ($Q < 0$), the opposite pattern is noted. Figure 8 showed that at larger amounts of internal heat generation ($Q > 0$), the border layer generates energy, which makes the temperature to be developed significantly. This is because the buoyancy force raises the fluid temperature when heat is generated. Regarding the heat absorption ($Q < 0$), an opposite pattern is noticed.

With the improvement in Schmidt number (Sc), the fluid velocity goes down as demonstrated in Figure 9. Since Sc varies with the viscosity, so the fluid viscosity enhances for the rising amounts of Sc. The quantity $f'(0)$ goes down as Sc increases. Also, Sc inversely varies as the molecular (species) diffusivity. Figure 10 describes that the concentration field goes down for growing amounts of Sc. The allied declining in mass diffusivity provides a minor strong mass transmission that diminishes the density gradient. Consequently, the density boundary layer thickness reduces for Sc.

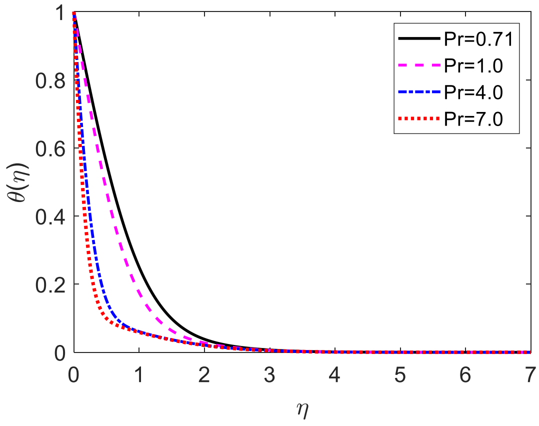

Figure 6: Temperature Profile for Pr

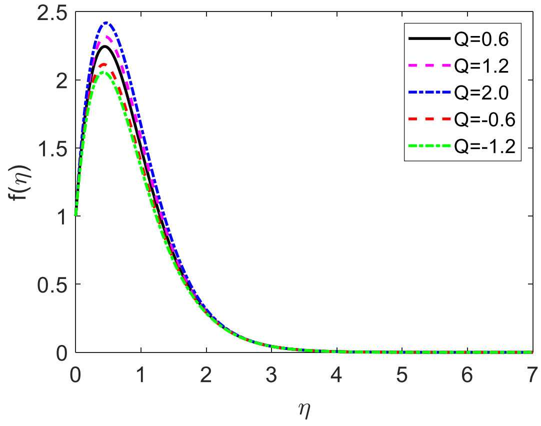

Figure 7: Velocity Profile for Q

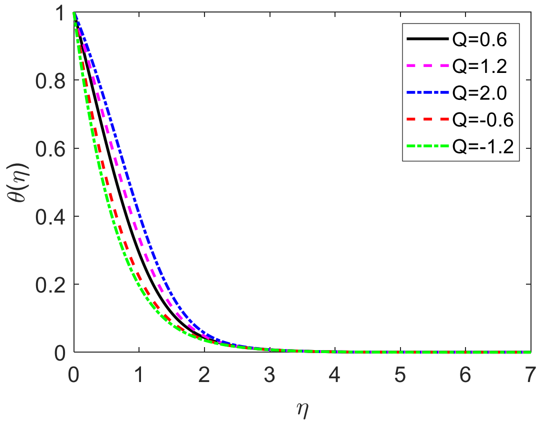

Figure 8: Temperature Profile for Q

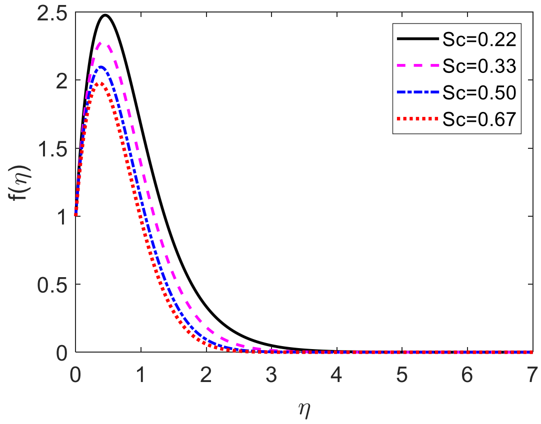

Figure 9: September Profile for Sc

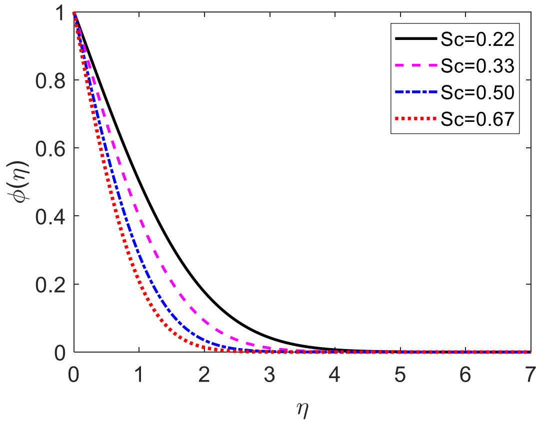

Figure 10: Concentration Profile for Sc

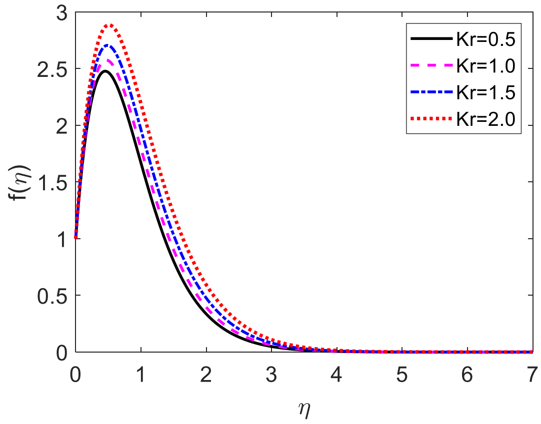

Figure 11: Velocity Profile for Kr

This is the reason the mass transmission uses the interplay with the concentration distribution, and the velocity profile of the material can be dominated via the Sc. The concentration and velocity fields are significantly impacted by the chemical reaction parameter (Kr), as seen in Figures 11 and 12. Figure 11 demonstrates that the fluid motion is upgraded substantially for higher amounts of Kr. Figure 12 shows that the fluid concentration improves for growing amounts of Kr. Physically, Greater amounts of Kr result in a reduction in both the the local skin friction and mass transport rate.

This research also explores the properties of several parameters and numbers upon the mass transmission rate, local skin friction, and heat transmission rate in tabular representations.

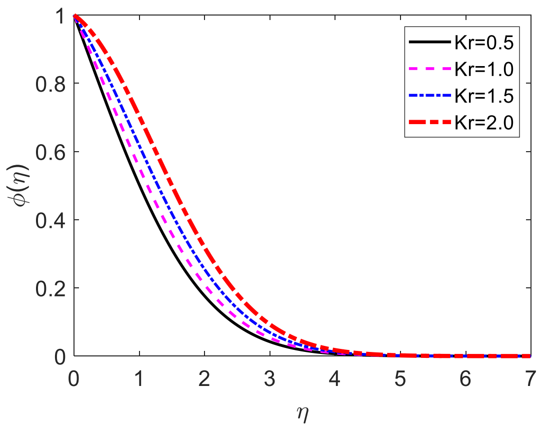

Figure 12: Concentration Profile for Kr

Table 1: Effect of the chemical reaction (Kr) on the thermo-physical quantities.

Kr	$f'(0)$	$-\theta'(0)$	$-\varphi'(0)$
0.5	7.66178990872177	0.950453165930887	0.522830028716789
1.0	7.93576145567695	0.950453165930887	0.415935872836597
1.5	8.28478007967778	0.950453165930887	0.289317277544702
2.0	8.75332500403808	0.950453165930887	0.132025272387480

Table 2: Effect of the magnetic parameter (M) on the thermo-physical quantities.

M	$f'(0)$	$-\theta'(0)$	$-\varphi'(0)$
0.5	7.66178990872177	0.950453165930887	0.522830028716789
1.5	6.51356010297499	0.950453165930887	0.522830028716789
3.0	5.19296919186248	0.950453165930887	0.522830028716789
4.0	4.48976321288106	0.950453165930887	0.522830028716789

Table 3: Effect of the heat generation parameter (Q) on the thermo-physical quantities.

Q	$f'(0)$	$-\theta'(0)$	$-\varphi'(0)$
0.6	7.66178990872177	0.950453165930887	0.522830028716789
1.2	7.97795064769763	0.693800725789022	0.522830028716789
2.0	8.59644940687339	0.240399101180280	0.522830028716789
-0.6	7.22390176164337	1.35036214879922	0.522830028716789

Table 4: Effect of the Prandtl number (Pr) on the thermo-physical quantities.

Pr	$f'(0)$	$-\theta'(0)$	$-\varphi'(0)$
0.71	7.66178990872177	0.950453165930887	0.522830028716789
1.0	7.27048466167117	1.18690505591210	0.522830028716789
4.0	5.90710209743859	3.18534459823594	0.522830028716789
7.0	5.49228559780563	4.95834381379279	0.522830028716789

Table 5: Effect of the Schmidth number (Sc) on the thermo-physical quantities.

Sc	$f'(0)$	$-\theta'(0)$	$-\varphi'(0)$
0.22	7.66178990872177	0.950453165930887	0.522830028716789
0.33	7.10998348687709	0.950453165930887	0.666445200923756
0.50	6.54949525646770	0.950453165930887	0.861324446082485
0.67	6.16393609329308	0.950453165930887	1.037427841127340

Tables (1-5) reveal the effects of the numerous amounts of dimensionless parameters or numbers on the heat transmission rate ($-\theta'(0)$), local skin friction ($f'(0)$), and mass transmission rate ($-\varphi'(0)$). From the above Tables, we detected that ($f'(0)$) reduces for higher amounts of Schmidt number (Sc), the Prandtl number (Pr), absorption parameter ($Q < 0$), and tmagnetic parameter (M). However, the reverse trend is found for chemical reaction and the heat generation. The values of $f'(0)$ decrease by about 20, 5, 2, and 41% due to improving values of Sc (0.22-0.67), Pr (0.71-1.0), Q(0.6-1.2), and M (0.5-4.0), respectively. This results in an overall reduction in fluid speed. But the quantities of $f'(0)$ enhance by around 12, and 14% owing to rising amounts of

Q (0.6-2.0), and Kr (0.5-2.0), respectively. So, the fluid speed is improved in this situation. The mass transfer rate enhances for Sc but reduces for Kr. The mass transmission rate goes up by around 98% and declines by around 75% due to growing amounts of Sc (0.22-0.67), and Kr (0.5-2.0), respectively. This is because the fluid concentration lessens for Sc and enhances the concentration for higher values of Kr. The rate of heat transmission gets higher with a raise in the Prandtl number and the absorption parameter. Contrary, the heat transmission rate decays for advanced amounts of heat generation parameter. The heat transmission rate falls by around 75% and is enhanced by about 25% for rising amounts of (0.6 - 2.0) and Pr (0.71 to 1.0).

4. CONCLUSIONS

The impacts of chemical reactions and heat production on time-dependent MHD convective transference past in a vertical porous sheet are investigated numerically in this study. The following conclusions can be made from the discussion mentioned above:

- The fluid speed enhances for higher quantities of the heat generation, modified local Grashof number, and chemical reaction.
- The fluid motion declines for growing levels of the heat absorption, Schmidt number, Prandtl number, and magnetic parameter.
- More heat generation results in an upsurge in fluid temperature; higher heat absorption and Prandtl number cause a reduction in fluid temperature.
- The fluid concentration goes up with higher levels of the chemical reaction.
- The amounts of $f'(0)$ decrease by about 20, 5, 2, and 41% due to improving values of Q (0.6 -1.2), M (0.5 - 4.0), Sc (0.22 - 0.67), and Pr (0.71-1.0), respectively.
- The heat transmission rate falls by about 75% and is enhanced by about 25% because of increasing amounts of Q (0.6 - 2.0) and Pr (0.71 - 1.0).

REFERENCES

Bhuvaneswari, M., & Sivasankaran, S., 2014. Free convection flow in an inclined plate with variable thermal conductivity by scaling group transformations. In *AIP Conference Proceedings,* American Institute of Physics, 1605(1), 440-445.

Bhuvaneswari, M., Sivasankaran, S., & Ferdows, M., 2009. Lie group analysis of natural convection heat and mass transfer in an inclined surface with chemical reaction. *Nonlinear Analysis: Hybrid Systems*, *3*(4), 536-542.

Choudhury, R., & Kumar Das, S. (2014). Visco-elastic MHD free convective flow through porous media in presence of radiation and chemical reaction with heat and mass transfer. *Journal of Applied Fluid Mechanics*, *7*(4), 603-609.

Crepeau, J. C., & Clarksean, R., 1997. Similarity solutions of natural convection with internal heat generation. *Transactions-American Society of Mechanical Engineers Journal of Heat Transfer*, *119*, 183-184.

Gangadhar, K., 2013. Soret and Dufour effects on hydro magnetic heat and mass transfer over a vertical plate with a convective surface boundary condition and chemical reaction. *Journal of Applied Fluid Mechanics*, *6*(1), 95-105.

Hasanuzzaman, M., Sharin, S., Hassan, T., Kabir, M. A., Afroj, R., & Miyara, A., 2022. Unsteady magneto-convective heat-mass transport passing in a vertical permeable sheet with internal heat generation effect. *Transportation Engineering*, *9*, 100126.

Hasanuzzaman, M., Ahamed, T., & Miyara, A., 2022. Thermal Radiation Effect on Unsteady Magneto-Convective Heat-Mass Transport Passing in a Vertical Permeable Sheet with Chemical Reaction. *Computational and Mathematical Methods in Medicine*.

Hasanuzzaman, M., Azad, M., Kalam, A., & Hossain, M., 2021. Effects of Dufour and thermal diffusion on unsteady MHD free convection and mass transfer flow through an infinite vertical permeable sheet. *SN Applied Sciences*, *3*(12), 1-11.

Mahdy, A., 2010. Effect of chemical reaction and heat generation or absorption on double-diffusive convection from a vertical truncated cone in a porous media with variable viscosity. International Communications in Heat and Mass Transfer, 37, 548-554.

Mohamed, R. A., 2009. Double-Diffusive Convection-radiation Interaction on Unsteady MHD Flow over a Vertical Moving Porous Plate with Heat Generation and Soret Effects, Applied Mathematical Sciences, 3, (13), 629-651.

Patil, P. M., and Kulkarni P. S., 2008. Effects of chemical reaction on free convective flow of a polar fluid through a porous medium in the presence of internal heat generation, *International journal of Thermal sciences* 47, 8, 1043-1054.

Samad, M. A., and Mohebujjaman, M., 2009. MHD heat and mass transfer free convection flow along a vertical stretching sheet in presence of magnetic field with heat generation. *Research Journal of Applied Sciences, Engineering and Technology*, *1*(3), 98-106.

Salem, A. M., and Abd El-Aziz, M., 2008. Effect of Hall currents and chemical reaction on hydromagnetic flow of a stretching vertical surface with internal heat generation/absorption. *Applied Mathematical Modelling*, *32*(7), 1236-1254.

Seth, G. S., Sarkar, S., Hussain, S. M., & Mahato, G. K., 2014. Effects of hall current and rotation on hydromagnetic natural convection flow with heat and mass transfer of a heat absorbing fluid past an impulsively moving vertical plate with ramped temperature. *Journal of Applied Fluid Mechanics*, *8*(1), 159-171.

Nomenclature

MHD	Hydromagnetic	FDM	Finite difference method
C	fluid concentration	T	the temperature of the fluid
T_w	wall temperature	**B**	uniform magnetic field
g	acceleration due to gravity	ρ	fluid density
C_w	wall concentration	T_∞	free stream temperature
C_∞	free stream concentration	υ	kinematic viscosity
k	thermal conductivity	C_p	specific heat at constant pressure
$v(t)$	suction velocity	$U_0(t)$	uniform surface velocity
D_m	mass diffusivity coefficient	T_m	fluid mean temperature
k_T	thermal diffusion ratio	C_s	concentration susceptibility
σ	similarity parameter	v_0	suction and blowing
G_r	local Grashof number	G_m	modified local Grashof number
M	Magnetic force parameter	Pr	Prandtl number
Df	Dafour number	Sr	Soret number
Sc	Schmidt number	t	Time
τ	Shear stress	N_u	Nusselt number
S_h	Sherwood number	$f(\eta)$	non-dimensional velocity
$\theta(\eta)$	non-dimensional temperature	$\phi(\eta)$	non-dimensional concentration
K	perbeabilty	Q_0	dimensional heat production /absorption coefficient
Q	internal heat production/absorption parameter	$\theta'(0)$	heat transfer rate
$f'(0)$	local skin friction coefficient	$\phi'(0)$	mass transfer rate
u	velocity component in the x-axis	v	velocity component in the y-axis,