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SIMULATION OF THERMAL TRANSFER ATTRIBUTES UNDER VARYING MAGNETIC FIELDS STRAIN INFLUENCES AND VISCOUS ENERGY DISSIPATION

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This study investigates the mathematical modeling of impermeable fluid motion that conducts electricity, focusing on the effects of magnetism and chemical interactions on thermal energy, mass transfer, viscosity dissipation, and Soret-Dufour phenomena. These interactions are vital for advancements in technology, geophysical sciences, and biology, particularly in magnetohydrodynamics (MHD). The research describes the governing equations for momentum and energy conservation under varying magnetic fields and performs a numerical analysis of flow behavior influenced by viscous dissipation on a semi-infinite surface. The study employs a set of nonlinear coupled partial differential equations (PDEs) under specific boundary conditions, using a similarity transformation to convert these PDEs into simpler ordinary differential equations (ODEs). The resulting first-order simultaneous equations are solved using the boundary value solution (BVP-4c) technique in MATLAB. Results are illustrated through visual representations showing the impact of various parameters on velocity, temperature, and concentration contours, as well as variations in shear stress, Nusselt number, and Sherwood number coefficients. The primary aim is to explore the magnetic parameter (D) and stretching degree (n) concerning heat and mass transfer and chemical reaction characteristics such as Soret amount (Sr) and Dufour number. The findings reveal that changes in the magnetic field significantly affect heat and mass transport properties and enhance the efficiency of these processes in industrial and natural contexts. This study innovatively incorporates viscosity dissipation and chemical interactions into the MHD framework, thereby improving the predictive capability of fluid dynamics models in complex scenarios.

Key words: thermal energy and mass, chemical interaction, dissipation of viscosity, degree of stretch, varying magnetic field.

1. Introduction

The consensus among scientists is that biodiversity is at risk due to widespread environmental deterioration and pollution, mostly driven by excessive carbon dioxide emissions. It is essential to prioritize the increased utilization of energy in fabrication, particularly in manufacturing, due to the industry's high-power consumption. The use of heat transfer systems for the purpose of reducing emission levels and preserving energy is a recent advancement. In recent years, many techniques have been used to improve heat transfer [1-6]. Industries that deal with the movement and transfer of heat via fluids may reduce energy consumption by optimizing fluid circulation patterns, minimizing frictional losses, and using advanced equipment and ducting systems [7]. To reduce the utilization of energy and pollutants, it is possible to boost techniques for mass transfer such as amplifying, transpiration, and precipitation. This may be achieved by raising variables like pressurization, temperature, and circulation rates [8]. In their study, Dharmaiah *et al.* [9] investigated the flow within the boundary layer of a thick insoluble heat-absorbing and conductive fluid through a semi-infinite upright porous movable surface. They discovered that heat absorption has a significant impact on the flow, particularly in relation to diffusion-thermo and absorbed radiation consequences. In their

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analysis of the constant bounds of circulation and heat transmission past an extensible sheet, Ene *et al.* [10] used a nonlinear simultaneous equation. They discovered a decrease in the fluid environment. A thermal rise for higher radiation parameters is seen in the study of heat and mass transmission in micropolar streams next to a substance's detachment zones, conducted by Salahuddin *et al.* [11].

According to Majeed *et al.* [12], who studied the thermal properties and mass propagates of a Casson fluid moving through an oval in an undulating conduit, the drag and lifting coefficients seem to be decreasing at the same time.

Less energy consumption due to reduced heat loss via viscous dissipation may lead to more efficient material usage, which may have an unforeseen effect on emissions. Velocity dissipation of heat describes the process by which the frictional strains inherent to a fluid convert its momentum into radiation. This phenomenon is critical for fast access fluid flow because it may significantly affect the distribution of energy levels and temperature variations inside the mechanism. For a comprehensive understanding of Brownian movement and heat transfer, Loh *et al.* [13] conducted a study on the impact of viscous dissipation on fluid flow in a miniature channel with opposite elevation. They explained how the presence of viscosity affects the distribution of heat transfer and causes the point of highest concentration, which has low thermal conductivity, to move further away from the isothermal surface. In their empirical work, Ajibade *et al.* [14] examined the effects of electrically transmitted insoluble fluids passing via an upward heterogeneous conduit, taking into account the dissipation of viscosity and the porosity of permeable substances. Masthanaiah *et al.* [15] conducted an analytical study on the consequences of entropy creation and viscosity dissipation on a frozen liquid passing through a transparent conduit. A more considerable ambient temperature gradient was found to be associated with lower viscous absorption, according to research by Alharbi *et al.* [16] on the effects of viscous dissipation and Coriolis motion on the transfer of mass and energy in three-dimensional unconventional flows. Through a thorough analysis of the effects of thermal dissipation and separation layer thickness on the uniform transpiration stream caused by an impermeable viscous solution with changing characteristics, Ajibadea and Umar [17] reached the finding that the heat exchange decreases with an increase in the outer surface diameter. Several interesting perspectives on the effects of viscous dissipation in different shapes are presented in the studies cited in Refs. [18-21].

The usage of a catalyst in conjunction with the interaction of two substances produces a chemical reaction. Many industrial processes rely on chemical reactions as key components, such as steam rolling, chemical treatment of flat surfaces, and polymeric ejection. Utilizing chemical processes that take place throughout mass and energy transfer operations may greatly enhance catalytic reactor design. In order to convert hazardous pollutants into less dangerous ones before discharging them into the environment, reactors like this use catalysts to accelerate operations. Using this model, Sedki [22] investigates the effects of heat exposure and chemical reactions on the asymmetrical mass and heat transport across an interface surface, which results from a stretched, see-through interface that generates heat and is then transferred to an opaque medium. The impact of chemical reactions on harmonic dissipative fluid flow in permeable medium via an elastic sheet using radiant heat was investigated by Samuel and Fayemi [23]. Through an increasingly stretched layer that incorporates heat and chemical modification effects and a thermal source, Khalili *et al.* [24] investigated MHD boundary-layer fluids. They found that the intensity characteristics were significantly related to the reactant measure variable, and that the intensity gauge for the outer layer decreased as the retaliatory velocity coefficient increased. In their study on the effects of chemical reactions and radiant heat on fluid motion in a rotating conduit, Lv *et al.* [25] found that a combination of chemical interaction and stimulation energy improves mass propagation. More recent research that takes the effects of chemical reactions into account may be accessible by perusing the writings of several writers [26-28].

The Soret impact is associated with mass flux factors created by thermal dispersion, whereas the Dufour phenomena is related to the energy flux generated by the chemical disparity. The transfer of heat and mass using the Soret and Dufour entities is crucial to many industrial and scientific processes, including the following: groundwater pollution remediation, multicomponent corrosion in the earth sciences, dual metal alloy clumping, chemical plants, spacecraft cooling, crude oil storage facilities, etc. Kumara *et al.* [29] investigated the effect of Soret and Dufour on the flow of an unstable multi-layer hydrodynamic convection event via an infinitely rising surface embedded in a porous medium. They found that a positive relationship exists between the Soret amount and the resultant concentration contour, but a negative relationship emerges as the Dufour amount increases. Using Dufour and Soret phenomena, Siddique *et al.* [30] examine the energy distribution and intermittent mass of a second-grade fluid in magnetohydrodynamics inside an accelerating membrane. Quader and Alam [31] investigated the chaotic spontaneous adiabatic transport of energy and mass flow through a semi-infinite ascending perforated material in a rotating structure using the combined Soret and Dufour results. And it was discovered that the ambient temperature of the fluid is higher for the atmosphere than for a liquid, and lower for less dense particles than for larger ones. In their discussion of the effects of Soret and Dufour on fluid-filled aperture transpiration, Balla *et al.* [32] showed that the usual Sherwood count of microbes and nanoparticles increases as a function of the Soret and Dufour concentrations. The importance of Dufour and Soret characteristics on the shape of three-dimensional aquatic composite nanofluid flow was highlighted by Bilal *et al.* [33]. It was discovered that increasing the Dufour quantity promotes material dispersion while minimizing the thermal gradient. A increasing component of temperature fluctuation is predicted by the Dufour impact, according to Rasool *et al.* [34], and a similar trend is seen for concentration change in place of the Soret effect. For further in-depth research on the Soret and Dufour effects, see references [35-38].

An oscillating electromagnetic field is generated when a magnetic field undergoes a gradual shift, resulting in the emergence of eddy currents. When heat exchange processes occur, the changing magnetic field has the capacity to generate stresses and alter the conductivity of compounds or streams. The literature on heat transfer in the presence of variable magnetic fields is sparse, as shown, for example, in the studies [39-42]. Researchers have paid more attention to the role of changing magnetic fields in heat transmission than in mass transfer, despite the fact that the latter has far-reaching consequences. Utilizing fluctuating magnetic fields in the transfer of energy and mass flows to lessen combustion might be beneficial for many sectors, especially those that deal with fuel combustion or have a high concentration of stream-based pollutants. This is a discrepancy in future studies that has to be addressed and studied. In order to make the model even more special, the fluid flow considers the real-world effects of chemical changes, dissipation of viscosity, Soret and Dufour influences, and more. The proposed framework is made faster by using boundary layer prediction and non-dimensional transitions. Later on, the Numerical scaling of bvp4c in MATLAB is used to solve the underlying coupled non-linear system of equations. The bvp4c quantified analyzer in MATLAB provides a great setting for dealing with coupled typical concurrent equations. Dey *et al.* [43-44] recently performed study utilizing the previously mentioned numerical approach.

The research's findings have a wide range of practical uses, especially in improved fluid transportation, cooling technological advances, and energy utilisation. Understanding how magnetohydrodynamic (MHD) fluids behave in fluctuating magnetism is useful for improving nuclear plants, thermal exchangers, and cooling mechanisms in aviation. The study also helps with chemically based industrial operations like material encasing and crude oil extraction. Soret-Dufour effect analyses facilitates biological applications such as microfluidics and targeted drug distribution.

The primary aim of this research is to address a set of enquiries:

- Investigate the influence of magnetic properties and mass index on fluid flow.
- The transmission of heat and mass is influenced by the Soret and Dufour phenomena, as well as the chemical reaction parameter. How do these factors impact the transfer of heat and mass?
- Examine how skin friction, Sherwood number, and Nusselt number are affected by flow characteristics.
- Investigate ways to accelerate the rate of emission reduction in light of the findings.

Assertions of the work's originality:

- The analysis takes into account the impacts of chemical variations, viscosity dissipation, Soret and Dufour consequences, and other factors in the real-world setting.
- The suggested model is accelerated by the use of non-dimensional transitions and boundary layer estimation.

- The analysis examines how the motion of both heat and mass confined across a semi-infinite upright axial surface in an opaque liquid is negatively impacted by viscous dispersion, chemical reactions, Soret-Dufour effects, and a changing magnetic field.

2. Mathematical formulation

Using Cartesian coordinates, Fig.1 provides a schematic representation of the issue. The x-axis is perpendicular to the plate's surface, and the y-axis is perpendicular to the fluid's circulation, assuming the x-path. Considerations for the mobility of fluids include the impact of Soret-Dufour, the detrimental consequences of chemical reactions, viscous dispersion, and variable magnetic fields

The mathematical formulation of this problem is based on the following assumptions:

- Two-dimensional flow.
- Incompressible fluid.
- Laminar flow.
- Newtonian fluid.
- Constant fluid properties.
- Low magnetic Reynolds number.
- Boussinesq approximation.
- Boundary layer approximations.
- Negligible radiation effects.
- No-slip condition.
- Constant surface temperature/concentration.
- Chemical reaction is homogeneous.

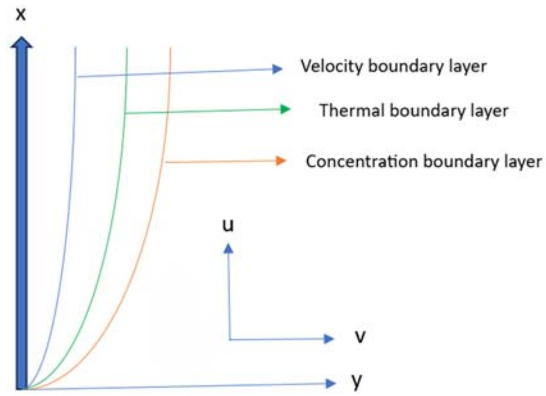

Fig.1. Flow geometry.

The dimensional form encapsulating the formulae for flow, temperature, and concentration may be derived based on the presumptions made on the boundary layer (Jabeen *et al*. [45]).

Equation of continuity

$$u_x + v_y = 0. \tag{2.1}$$

In relation to the x-coordinate, u_x is the rate at which the x-component of velocity (u) changes. The fluid's velocity fluctuation along the x-axis is indicated. The rate at which the y-component of velocity (v) changes in relation to the y-coordinate is denoted by v_y. It shows the change in the flow rate along the y-axis (Panton [46]).

$$uu_x + vu_y = \nu u_{yy} - \frac{\sigma D^2(x)u}{\rho}. \tag{2.2}$$

The Lorentz force's term, denoted by $\frac{\sigma D^2(x)u}{\rho}$, results from interactions of a flowing electrically conductive fluid with a field of magnetization. This equation delineates the equilibrium of forces exerted on the fluid element, encompassing diffusion, viscosity, and the Lorentz force (Panton [46]).

$$uT_x + vT_y = \alpha T_{yy} + \frac{DK_T}{C_p C_s}\frac{\partial^2 C}{\partial y^2} + \frac{\mu}{\rho C_p}\left(\frac{\partial u}{\partial y}\right)^2. \tag{2.3}$$

The preceding equation delineates the energy equilibrium within fluid dynamics, encompassing diffusion, thermal dispersion, transmission induced by concentration variations (Dufour effect), and viscous dissipation (Bejan [47]).

$$uC_x + vC_y = D\frac{\partial^2 C}{\partial y^2} + \frac{DK_T}{T_m}\frac{\partial^2 T}{\partial y^2} - K(C - C_\infty). \tag{2.4}$$

The equilibrium of chemical compounds in the fluid's flow is described by this equation. It encompasses chemical reactions, condensation, diffusion, and thermal transfer brought on by variations in temperature (Soret effect) (Sherwood *et al.* [48]).

The boundary conditions are (Jabeen *et al.* [45]):

$$\left.\begin{aligned} &y = 0: \quad u = U = cx^n, \quad v = 0, \quad T = T_w, \quad C = C_w, \\ &y \to \infty: \quad u \to 0, \quad T \to T_\infty, \quad C \to C_\infty. \end{aligned}\right\} \tag{2.5}$$

$D(x) = D_0 x^{\frac{n-1}{2}}$, variable magnetic field.

Introducing the stream function $\Psi(x, y)$ such that $u = \frac{\partial \Psi}{\partial y}$ and $v = -\frac{\partial \Psi}{\partial x}$ so that Eq.(2.1) satisfies.

Similarity transformation (Jabeen *et al.* [45]).

$$\eta = x^{\frac{n-1}{2}} y \sqrt{\frac{C(n+1)}{2\nu}}, \qquad \Psi = x^{\frac{n+1}{2}} \sqrt{\frac{2C\nu}{n+1}} f(\eta) \tag{2.6}$$

Expression (2.2) implies

$$f''' + ff'' - \frac{2n}{n+1} f'^2 - \frac{2}{n+1} Mf' = 0 \tag{2.7}$$

where $$M = \frac{\sigma D^2(x)}{\rho c x^{n-1}} = \frac{\sigma D_0^2}{\rho c}$$

Expression (2.3) implies

$$\frac{1}{P_r}\theta'' + D_u\varphi'' + E_c f''^{2} + f\theta' = 0 \tag{2.8}$$

where $P_r = \dfrac{\nu}{\alpha}$, $E_c = \dfrac{U^2}{C_p\left(T_w - T_\infty\right)}$, $D_u = \dfrac{C_w - C_\infty}{T_w - T_\infty}\dfrac{DK_T}{C_p C_s \nu}$,

$$\theta(\eta) = \frac{T - T_\infty}{T_w - T_\infty}, \quad \varphi(\eta) = \frac{C - C_\infty}{C_w - C_\infty},$$

Expression (2.4) implies

$$\frac{1}{S_c}\varphi'' + S_r\theta'' - \frac{2kx}{U(n+1)}\varphi + f\varphi' = 0, \qquad \frac{1}{S_c}\varphi'' + S_r\theta'' - K\varphi + f\varphi' = 0 \tag{2.9}$$

where $S_c = \dfrac{\nu}{D}$, $S_r = \dfrac{T_w - T_\infty}{C_w - C_\infty}\dfrac{DK_T}{T_w \nu}$, $K = \dfrac{2kx}{U(n+1)}$.

Modified boundary conditions:

$$\begin{aligned} &\eta = 0: \quad f(0) = 0, \quad f'(0) = 1, \quad \theta(0) = 1, \; \varphi(0) = 1, \\ &\eta \to \infty: \quad f'(\infty) \to 0, \quad \theta(\infty) \to 0, \; \varphi(\infty) \to 0. \end{aligned} \tag{2.10}$$

3. Methodology

The first step is to transform the non-dimensional higher-order linear Eqs (2.7)-(2.9) into a transitional initial boundary value problem that includes the relevant threshold constraints (2.5). The aforementioned dimensionless ordinary differential equations are solved using an implementation method and the widely used bvp4c technique in MATLAB. The bvp4c decoding module ensures accurate outcomes by effectively addressing complex and unexpected issues linked to restriction values [19, 43, 44]. Furthermore, it is necessary to have an initial calculation that meets the dimensions constraints of the bvp4c decoder in order to effectively employ it. The Bvp4c technique, with a convergence threshold of 10^{-6}, is the most precise approach for measuring the simulated outcomes of non-dimensional complex ordinary differential equations. The present inquiry employs MATLAB's integrated solver bvp4c to numerically solve Eqs (2.7) to (2.9) and the boundary condition (2.10).

To use this method, we considered the following variables:

$$f = y_1, \quad y_1' = f' = y_2, \quad y_2' = f'' = y_3, \quad y_3' = f''' = -y_1 y_3 + \frac{2n}{n+1}(y_2)^2 + \frac{2}{n+1}My_2,$$

$$\theta = y_4, \quad y_4' = \theta' = y_5,$$

$$y_5' = \theta'' = -\frac{\Pr Du\, Sc}{1 - Sc \Pr Sr\, Du}\left[Sr \Pr E\, y_3^2 + Sr \Pr y_1 y_5 + K\, y_6 - y_1 y_7 - \Pr E\, y_3^2 - \Pr y_1 y_5 \right],$$

$$\phi = y_6, \quad y_6' = \phi' = y_7, \quad y_7' = \phi'' = \frac{Sc}{1 - Sc \Pr Sr\, Du}\left[Sr \Pr E\, y_3^2 + Sr \Pr y_1 y_5 + K\, y_6 - y_1 y_7 \right].$$

4. Results and discussion

The present investigation explored the influence of mass and heat transmission effects on fluid flow, along with chemical reaction, the Soret-Dufour effect, viscous dissipation, and variable magnetic field. Written content assessment procedures include extensive tables and vivid visual representations. Unless explicitly stated, solutions for parameters $M = 2$, $n = 1$, $Sr = 0.10$, $Du = 0.1$, and $K = 0.2$ are accessed. The shifting behavior of velocities $f'(\eta)$, temperature $\theta(\eta)$ and concentration $\varphi(\eta)$ in the non-linear mathematical dilemma with parameterized variables is shown graphically. Fluid property-specific velocity curves are shown in Figs 5.1-5.2. Fluid velocity decreases as the magnetic parameter *M* increases, as seen in Fig.5.1. The Lorentz force, which results from the interaction of the flowing electrically conducting fluid with the magnetic field, is responsible for this phenomenon. As a drag force, the Lorentz force opposes the fluid's motion and lowers its velocity. A bigger magnetic field physically produces a larger retarding force, which causes the velocity inside the boundary layer to drop more sharply. In applications requiring magnetohydrodynamics (MHD), where magnetic field control of fluid flow is essential, this effect is especially pertinent. The effect of the power-law index *n* on the velocity distribution is seen in Fig.5.2. The rheological behavior of the fluid has relevance to the power-law index. While $n \neq 1$ denotes non-Newtonian behavior ($n > 1$ for dilatant fluids and $n < 1$ for pseudoplastic fluids), $n = 1$ denotes a Newtonian fluid. Consideration must be given to the precise impact of 'n' on the velocity pattern in light of the fundamental equations that underlie this investigation. The non-linear interaction of shear stress and shear velocity that defines non-Newtonian fluids is generally shown by departures from $n = 1$. Figures 5.3 to 5.6 depict the contour shapes that show the heat distribution caused by variations in tandem flow. Figures 5.3 illustrates how the Prandtl number *Pr* affects the distribution of temperature. The ratio of momentum diffusivity to heat diffusivity is known as the Prandtl number. Momentum diffuses more quickly than heat, according to higher *Pr* values. As a result, the temperature gradient close to the surface steepens and the thermal boundary layer gets smaller as *Pr* grows. In terms of physics, this means that heat is concentrated in a smaller area close to the surface, which causes the temperature to drop away from the surface more quickly. Fluids with higher *Pr* values can result in more effective heat transfer, hence this behaviour is important for heat exchanger design. The impacts of the Soret *Sr* and Dufour *Du* numbers on temperature and concentration profiles are shown in Figs 5.4 and 5.5, respectively. The Dufour effect, also known as diffusion-thermo, explains how concentration gradients may cause heat fluxes, whereas the Soret effect, also known as thermal diffusion, explains how temperature gradients can cause mass fluxes. The concentration gradient changes as *Sr* increases, suggesting that mass movement is driven by temperature fluctuations. On the other hand, a rise in *Du* raises the temperature, indicating that variations in concentration aid in heat transmission. In systems with large temperature and concentration gradients, such chemical reactors and geothermal reservoirs, where coupled heat and mass transport processes are essential, these phenomena are especially relevant. The efficacy of thermal transport inside the framework is altered by a spike in chemical reaction specifications *K*, which causes heat to build up and the rate at which the fluid climbs. Figure 5.6 illustrates how a rise in a chemical reaction characteristic might lead to an upsurge in stream heat. The performance and response rates of combustion mechanisms can be enhanced by increasing the fluid's temperature. Elevated temperatures have the potential to facilitate more efficient combustibility and minimize the release of detrimental emissions in engines that burn fuel. The Soret impact, also referred to as thermophoresis, occurs when a species concentration variance separates or moves components in a medium. The concentration dependency of the substance or molecule dispersion among the medium evolves into progressively important for higher values of the Soret impact variable *Sr* as shown in Fig.5.7. When the concentration variation of the medium rises due to an elevated Soret effect attribute, it can be inferred that it's the thermophoretic mobility of particles that inhabit the stream is the cause of increased concentration. Enhanced thermal transmission is associated with a higher Dufour number *Du* in comparison to mass dispersion, that impact the fluid's concentration conveyance. Figure 5.8 illustrates that with the enhancement of Dufour effect parameter fluid concentration grows significantly. However, as the chemical reaction characteristic escalates, it is seen that the concentration gradient diminishes, as Fig.5.9 exemplifies.

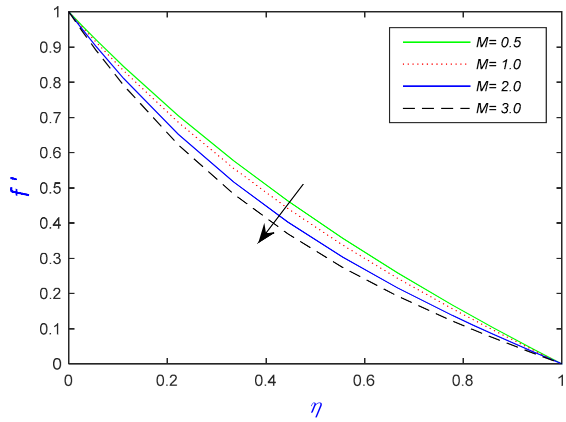

Fig.5.1. Velocity scheme for various *M*.

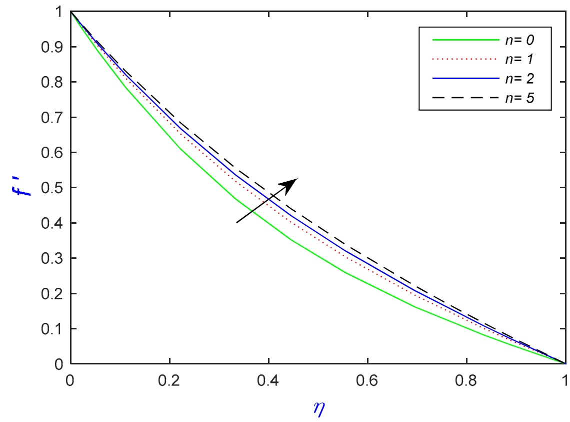

Fig.5.2. Velocity scheme for various *n*.

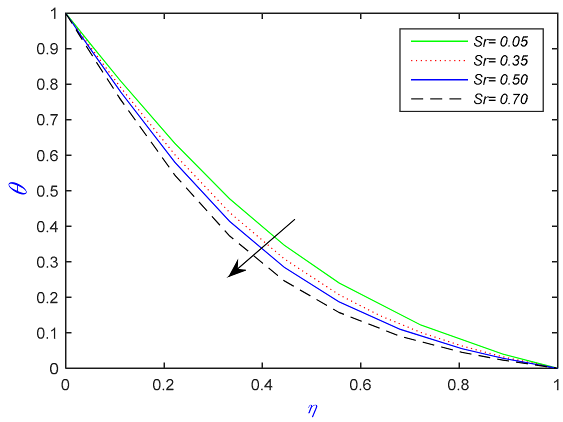

Fig.5.3. Temperature scheme for various *Pr*.

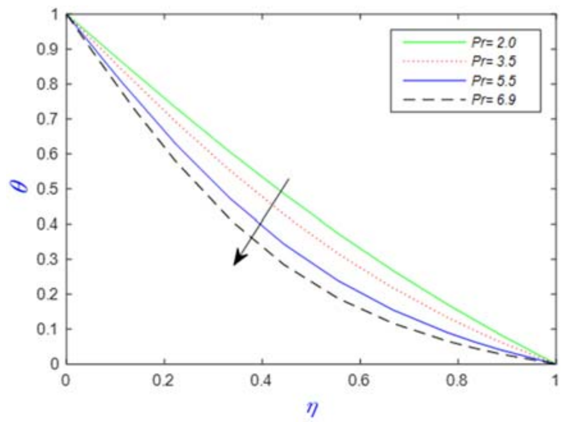

Fig.5.4. Temperature scheme for various *Sr*.

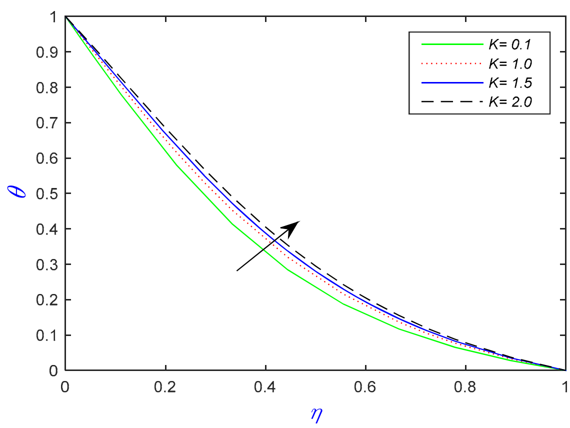

Fig.5.5. Temperature scheme for various *Du*.

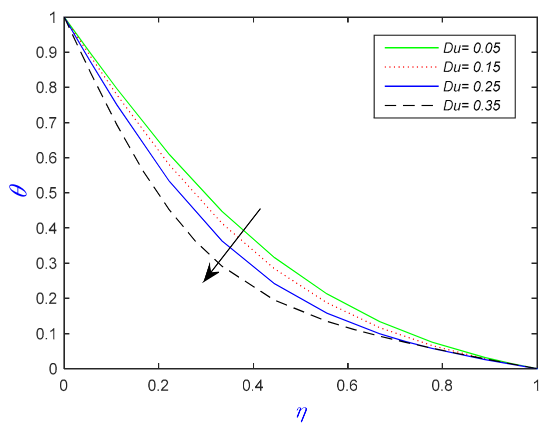

Fig.5.6. Temperature scheme for various *K*.

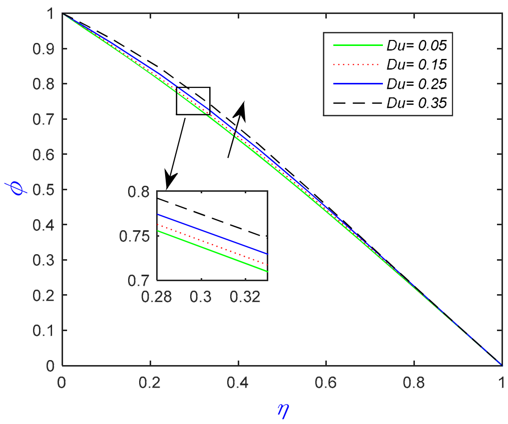

Fig.5.7. Concentration scheme for different *Sr*.

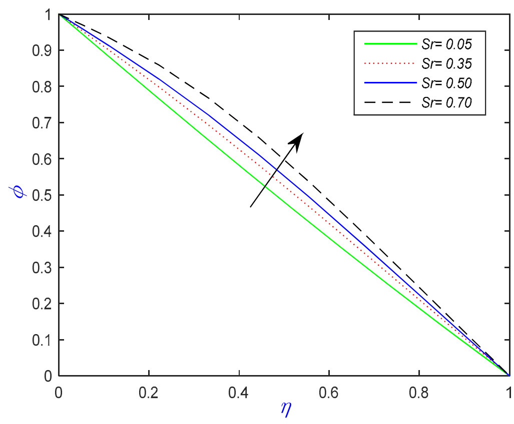

Fig.5.8. Concentration scheme for different *Du*.

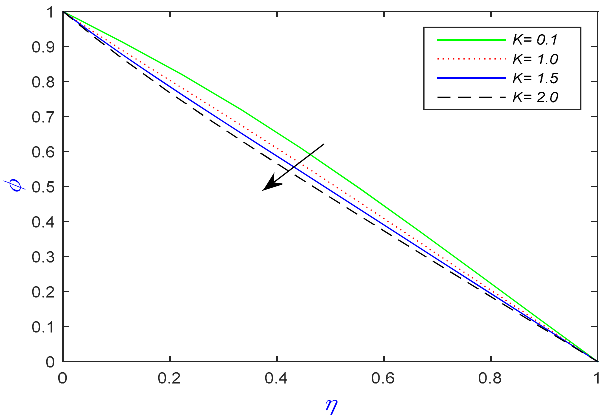

Fig.5.9. Concentration scheme for different *K*.

Distinct values of skin friction, Sherwood number, and Nusselt number based on distinct flow properties are highlighted in Tabs 1, 2, and 3. Table 1 illustrates that increased magnetic fields and non-Newtonian behaviour (at least in this particular instance) result in greater drag, as seen by the fact that skin friction rises with magnetic parameter M and power-law index n. The rate of heat transport is indicated by the Nusselt number Nu. The interaction among the Soret effect, Dufour consequence, and chemical processes is revealed by its dependency on Sr, Du and K. Keep in mind that adverse Nusselt values indicate that heat flows from the fluid's surfaces within the medium.

Table 1. Skin friction.

M	*n*	skin friction
0.5		*-1.4790*
1	*1*	*-1.6108*
2		*-1.8572*
3		*-2.0840*
	0	*-2.1512*
2	***1***	*-1.8572*
	2	*-1.7534*
	5	*-1.6466*

The amount of mass transferred is reflected by the Sherwood number *Sh*, which depends on *Sr*, *Du* and *K*. Its dependency demonstrates the interplay underlying chemical processes, diffusion-thermo and thermodiffusion; lower values indicate mass transport from the fluid's interface. We have compared our graphical output with (Jabeen *et al*. [45]) and found that the trend of the flows is very much symmetrical, which validates the current study.

Table 2. Nusselt number.

Sr	*Du*	*K*	Nusselt number
0.05			*-1.7281*
0.35	*0.15*	*0.1*	*-1.9000*
0.50			*-2.0174*
0.70			*-2.2258*
	0.05		*-1.8552*
0.5	***0.15***	*0.1*	*-2.0174*
	0.25		*-2.2925*
	0.35		*-2.8523*
		0.1	*-2.0174*
0.5	*0.15*	***1.0***	*-1.7602*
		1.5	*-1.6270*
		2.0	*-1.4999*

Table 3. Sherwood number.

Sr	*Du*	*K*	Sherwood number
0.05			*-1.0632*
0.35	*0.15*	*0.1*	*-0.8963*
0.50			*-0.7804*
0.70			*-0.5717*
	0.01		*-0.8428*
0.5	***0.10***	*0.1*	*-0.8074*
	0.20		*-0.7455*
	0.30		*-0.6327*
		0.1	*-0.8074*
0.5	*0.10*	***1.0***	*-1.0331*
		1.5	*-1.1508*
		2.0	*-1.2637*

5. Conclusion

This study investigates the adverse effect of viscous dispersion, chemical reaction, Soret-Dufour effects, and variable magnetic field on the flow of mass and heat boundary layer over a semi-infinite upright axial surface in an opaque medium. The non-linear partial differential equations of the evaluation are transformed into a dimensionless representation while considering many physical restrictions. The numerical solution of similarity mathematical expressions is achieved using the bvp4c technique in MATLAB estimate scheme. By analysing the physical components, one may make future deductions:

- The Lorentz effect's repulsive force causes fluid velocity to decrease as the magnetic parameter *M* increases.
- The velocity distribution is influenced by the fluid's rheological behavior, revealed by the power-law index *n*; non-Newtonian fluids exhibit departures from $n = 1$.
- Indicating more effective momentum diffusion than energy diffusion, higher Prandtl numbers *Pr* provide smaller thermal separation layers and more pronounced temperature changes close to the surface.

- The increasing significance of transmission of mass resulting from thermal dispersion is indicated by an upsurge in the Soret effect parameter. A growing variation in temperature indicates that there are more significant temperature gradients occurring in the existing system. Further noticeable variation in the amounts of different factors throughout the flow is shown by an elevation in concentration spectra.
- An exceedingly elevated inflation of temperatures seems to be the outcome of the amalgamated impact of the variable magnetic field and the chemical reaction attribute.
- The concentration gradient rises when the Dufour effect index rises, indicating that temperature variations' impact on conveyance of mass is growing in importance. Concentrations profile gradually decrease as the chemical interaction factor rises, usually indicating an elevated rate of reaction.
- When the Soret effect, Dufour consequence, and chemical processes interact to influence the rate of heat transfer, adverse Nusselt values show that heat moves from the fluid's surfaces inside the medium.
- The increase in skin friction indicates that higher drag is caused by non-Newtonian behavior and increased magnetic fields. Their crucial significance in heat and mass transmission is demonstrated by the enormous influence of the interaction of Soret, Dufour, and chemical reaction effects on the Nusselt and Sherwood numbers.

Owing to these results, controlling magnetic fields and chemical reactions may provide strategies to regulate fluid properties, lower energy costs, and cut emissions. For certain technical purposes, such improving combustion efficiency and lowering pollutant production, more study should concentrate on optimizing these characteristics.

Future Scope

Different numerical methods have also proved effective in fixing this problem. We may generalize this method to other complex geometrical structures. A number of non-Newtonian models might be added to this situation. Changing the flow fluid's behavior is as simple as applying a number of important physical qualities. So, a lot of possible research is sitting dormant.

Nomenclature

C – is fluid accumulation close to the plate
C_P – is the specific heat at persistent pressure
C_∞ – is distant field concentration
D – is variable magnetic field
Du – is Dufour effect phenomenon
g – is gravitational acceleration
K – is chemical reaction parameter
K_T – is thermal diffusion ration
K_1 – is permeability of porous medium
M – is magnetic aspect
Pr – is Prandtl number
Sc – is Schmidt parameter
Sr – is Soret number
T – is temperature of the fluid close to the plate
T_∞ – is far-field temperature
u, v – are velocity component along and perpendicular to the plane respectively
β – is dimensional growth for transmitting heat
η – is dimensionless co-ordinate,
θ – is non-dimensional temperature
κ – is thermal efficiency

μ − is dynamic viscosity

ν − is kinematic viscosity

σ − is electric conductivity

ρ − is fluid density

ϕ − is dimensionless concentration

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