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EFFECTS OF CHEMICAL REACTIONS IN THE PRESENCE OF TEMPERATURE VARIATIONS AND ISOTHERMAL MASS DIFFUSION OVER AN INCLINED PLATE

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A detailed study of the erratic circulation around an unbounded inclined plate under fluctuating temperature and isothermal mass dispersion was carried out with a chemical reaction. This work concentrated on the harmonic inclination of the plate in its plane, and the accurate solution of the non-dimensional governing formulations was made possible by the Laplace transform technique. To evaluate their impact on different profiles, the investigation examined a variety of physical factors, including phase inclination, chemical response variable, Schmidt number, thermal Grashof number, mass Grashof number, and duration. Notably, the speed per second increased with decreasing phase angle. Furthermore, a decrease in either the thermal radiation variable or the chemical response variable induced an increase in velocity.

Key words: tilted surface; thermal transfer; mass transmission.

1. Introduction

The study of chemical reactions on inclined surfaces, when temperature changes and isothermal mass diffusion occurs, has several real-world applications. Chemical engineering may aid in the improvement of reactions in mass-transfer and thermal-related industrial processes. Environmental science aids in understanding natural processes where temperature variations and geological activity occur. Materials science develops materials for coatings and corrosion protection. The Energy Sector improves the energy storage system's resilience and efficiency. Geological studies help in the understanding of chemical processes in natural formations and geological characteristics. Aerospace engineering helps to study the aircraft or spacecraft's surface reaction to temperature variations. Food and medicines are useful for process optimization and product safety and quality. Environmental remediation is required for technology development to clean the contaminated groundwater or soil. Climatic science advances environmental understanding by offering insight into climatic zone's reactions to sloped surfaces.

Fluid dynamics researchers have made major advances in magnetohydrodynamics (MHD), spontaneous convection, and mass transport within porous media. Jha [1] analyzed the interactions of

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magnetohydrodynamics with unrestricted convection and magnitude in porous materials. Chamkha *et al.* [2] examined the natural convection caused by solar radiation on a tilted slab immersed in a variable permeable element. Chen [3] analyzed the mass and thermal transmission in ordinary convective scenarios in permeable media, accounting for MHD effects on an inclined surface as well as fluctuations in concentration and temperature. Alam *et al.* [4] analyzed the magnetohydrodynamic-induced unrestricted convective modalities, focusing on thermal energy and mass transmission across an inclined surface. Finally, Bego *et al.* [5] investigated the dynamics of empirically functioning coupled active thermal and material transfer over tilted and straight surfaces, taking the Soret and Dufour influences into consideration. Muthucumaraswamy *et al.* [6] analyzed the HMT in the circulation around vertically driven surfaces, taking into consideration the fluctuations in mass diffusion. Uddin and Kumar [7] examined the dynamics of unstable unrestricted circulation in a liquid that is flowing across a slanted surface submerged in a perforated material. Kesavaiah *et al.* [8] analyzed the influence of molecular processes and radiation uptake on an unstable magnetohydrodynamic convection movement of thermal energy and material. The flow occurred past a partially endless perpendicular perforated surface immersed in a permeable environment. The researchers also considered the effects of thermal origin and aspiration. Shivaiah and Anandrao [9] examined the impact of reactant processes on fluctuating magnetohydrodynamic unrestricted convective circulation across a perpendicular exterior. Singh and Makinde [10] analyzed the computational dynamics of magnetohydrodynamic unrestricted circulation down a slanted exterior with Newtonian and volumetric thermal production. Makinde [11] also investigated the complexities of unsteady flow in a hydromagnetic radiating liquid across a perpendicular exterior with a consistent thermal fluctuation. Muthucumaraswamy *et al.* [12] analyzed the combined influence of emanation across a vertically alternating surface, with incalescence variations as well as material dispersion. Ibrahim and Reddy [13] investigated the interaction of emission and material transmission in a magnetohydrodynamic unrestricted convective surge over an elastic exterior, with viscid dispersal and thermal production.

Sundar Raj *et al.* [14] analyzed the magnetized environment on the movement around an accelerating, homogeneous perpendicular surface, with thermal and material dispersion. Ismail *et al.* [15] researched the influence of MHD on natural circulation in a permeable material close to an inclined plate with varying wall temperatures. Barik [16] investigated the material transmission and radiative influences in a magneto-hydrodynamic circulation through an aggressively expedited tilted permeable surface with varying temperatures, heat sources, as well as chemical processes. Venkateswarlu *et al.* [17] examined the interaction of thermal dispersion along with radiative influences in unstable magneto hydrodynamics over a directly expedited flat permeable surface having thermal and material dispersion. Furthermore, Sathies Kumar and Gangadhar [18] researched the role of reactant processes in the slippage circulation of a magnetohydrodynamic liquid across an elastic sheet, with an emphasis on heat and mass transfer. Muthucumaraswamy and Jeyanthi [19] examined the MHD circulation close to an endless perpendicular exterior with a circulatory liquid. The research included a changeable material, thermal diffusion and, I-level reactant interactions. Additionally, Rajput and Gaurav Kumar [20,21] researched the impacts of chemical processes in an unpredictable MHD circulation through a spontaneously developed oscillating inclined surface having changing temperature and mass diffusion, while including Hall current influences. Their investigation also included the influences of Hall effects and reactant responses on magnetohydrodynamic circulation through a permeable substance via an alternating tilted surface with changing thermal levels along with material dispersion. Lastly, Khalid *et al.* [22] investigated the consistency along with chemical processes happening in a Casson solution magnetohydrodynamic flow.

Sheikh *et al.* [23] used a unique Caputo-Fabrizi duration-oriented technique to investigate the magnetohydrodynamic unrestricted convective circulation of a universal II^{nd}-level liquid in a permeable media. Mondal and colleagues [24] investigated the combined material transmission on a tilted surface with inconsistent thermal sources, chemical processes, and along sinks. Venkateswarlu *et al.* [25] analyzed various complexities in a radiative hydromagnetic circulation with chemically interacting fluids across an infinitely expedited tilted permeable surface, allowing for thermal assimilation as well as viscid dispersion. Shah *et al.* [26] investigated various parameters in a permeable material over an unstable vertical surface. Ahmad [27] researched the natural convection flow, taking into account heat sources and first-order chemical interactions. Endalew and Nayak [28] investigated the heat radiation and angled magnetism interaction in a magnetohydrodynamic flow through a directly expedited tilted surface inside a permeable environment having changing thermal levels. Usharani *et al.* [29] investigated the magnetohydrodynamic flow over a perpendicular surface that is tilted continuously. The study considered the presence of first-level reactive responses, adjustable material dispersion, and heat emission. Riaz *et al.* [30] analyzed the convective circulation of a magnetohydrodynamic liquid over a vertical support. They considered a ramping barrier heating and included chemical reactions that accounted for non-singular kernel effects. Furthermore, Fatecau *et al.* [31] investigated IInd-level fluids with computational duration outcomes, finding non-solitary core circulation across a travelling surface. Darapuneni Purna Chandra Rao *et al.* [32] investigated the Darcy-Forchheimer circulation of a Ree-Eyring liquid across a tilted surface using statistical techniques, while Suresh Babu *et al.* [33] investigated the complexities of erratic natural convective circulation across a tilted vertical exterior within the confines of a co-ordinated environment, considering chemical reactions, diffusion-thermo effects, and radiation.

Using fractional operators, Nazish Iftikhar *et al.* [34] investigated thermal and mass transport inside natural convection flow under a tilted magnetic field. Asogwa *et al.* [35] analyzed various liquid circulation patterns across an angled surface, taking into account thermal intake and elemental responses, which provided outcomes on altering wall temperature and surface concentration. Shahzad *et al.* [36] conducted a study on the impact of non-Newtonian circulation with heat-oriented characteristics on a sloped exterior. The study also considered the influence of elemental procedures, Brownian movement, and thermal analysis. Raghunath *et al.* [37] investigated unsteady magnetohydrodynamic liquid circulation across a tilted perpendicular permeable surface with chemical processes, a supported magnetic environment, emission, and Soret influences. Sheri and colleagues [38] investigated the transient magnetohydrodynamic flow over a slanted plate with Hall current, chemical processes, and radiation. Raghunath and Mopuri [39] investigated the uneven cyclic circulation of a Casson liquid with magnetic field effects across a slanted perpendicular permeable surface. The study also considered chemical reactions, heat absorption, and Soret impacts. In their study, Mopuri *et al.* [40] examined the dynamic motion of a Newtonian liquid with magnetic properties as it flowed over a raised surface. The study considered various factors such as heat sources, elemental responses, absorption of emission, and the Dufour influence. Mohana Ramana *et al.* [41] examined the dynamic magnetohydrodynamics circulation of a Kuvshinski liquid across an angled perforated exterior. Sivakumar and Muthucumaraswamy [42] examined the impact of radiation on conical circulation using an ideal direct surface with rapid material dispersion along with elemental response. Nagesh Gulle and Raghunathkodi [43] analyzed the influence of Soret emission and elemental processes on magnetohydrodynamics Jeffrey liquid circulation across a perforated material through a tilted perpendicular surface. The effect of thermal extension on circulation across an expedited segmented slope surface including purposeful material dispersion was analyzed by Nagarajan *et al.* [44]. Tad and Ahmed [45] investigated the magnetohydrodynamic unrestricted convective circulation over a sloping permeable surface with a thermal origin, the Soret influence, elemental response, viscid dispersion, and ohmic incineration. Finally, Bharathi *et al.* [46] analyzed the rotation, electromagnetic fields, and variable thermal efficiency that affect convection circulation across an endlessly perpendicular permeable surface. Sundar Raj *et al.* [47] made significant contributions to our understanding of the impacts of chemical processes on inclined isothermal vertical plates, with a particular emphasis on isothermal mass diffusion and changeable temperature.

2. Analysis

In the context of unsteady circulation, the movement of a viscid liquid through a continuously advancing linearly inclined plate positioned at an inclination α relative to the vertical plane is taken into consideration. Initially, both ($t_2' \le 0$) surfaces share similar thermal levels at E_∞'. At $t_2' > 0$, when the surface undergoes an acceleration $u = u_0 t_2'$ within its level, its temperature rises to a new level denoted as E_w'. This results in material transmission from the plate to the nearby fluid. To mathematically describe this complex flow pattern, we employ the following equations, utilizing the Boussinesq's approximation:

$$\frac{\partial u}{\partial t_2'} = g\cos\alpha\left(E' - E_\infty'\right)\beta_1 + g\cos\alpha(J' - J_\infty')\,\beta_1^* + \nu\frac{\partial^2 u}{\partial y^2},$$

$$\rho C_p \frac{\partial E'}{\partial t_2'} = k\,\frac{\partial^2 E'}{\partial y^2}, \tag{2.1}$$

$$\frac{\partial J'}{\partial t_2'} = D\,\frac{\partial^2 J'}{\partial y^2} - K_1 J'.$$

In the initial and peripheral situations:

For all $\quad y, t_2' \le 0,\quad u = 0,\quad E' = E_\infty',\quad J' = J_\infty',$

$$u = u_0 t_2',\quad E' = E_w',\quad J' = J_w' \quad \text{at} \quad y = 0 \quad \text{when} \quad t_2' > 0, \tag{2.2}$$

when $\quad t_2' > 0,\quad u \to 0,\quad E' \to E_\infty',\quad J' \to J_\infty' \quad$ as $\quad y \to \infty$

where, $A = \left(\dfrac{u_0^2}{\nu}\right)^{\frac{1}{3}}$.

Upon introducing the pertinent dimensionless parameters:

$$P_1' = \frac{u}{(\nu u_0)^{\frac{1}{3}}},\quad t = t_2'\left(\frac{u_0^2}{\nu}\right)^{\frac{1}{3}},\quad Y = y\left(\frac{u_0}{\nu^2}\right)^{\frac{1}{3}},\quad K_1' = K_1\left(\frac{\nu}{u_0^2}\right)^{\frac{1}{3}},$$

$$\sigma' = \frac{E' - E_\infty'}{E_w' - E_\infty'},\quad Gr = \frac{g\beta_1(E_w' - E_\infty')}{u_0},\quad B_1' = \frac{J' - J_\infty'}{J_w' - J_\infty'}, \tag{2.3}$$

$$Gc = \frac{g\beta_1^*\,(J_w' - J_\infty')}{u_0},\quad \Pr = \frac{\mu C_p}{k},\quad Sc = \frac{\nu}{D}.$$

in Eqs (2.1) and (2.4) results in

$$\frac{\partial P_1'}{\partial t} = \sigma'\,Gr\cos\alpha + B_1'\,Gc\cos\alpha + \frac{\partial^2 P_1'}{\partial Y^2},$$

$$\frac{\partial \sigma'}{\partial t} = \frac{1}{Pr}\frac{\partial^2 \sigma'}{\partial Y^2}, \tag{2.4}$$

$$\frac{\partial B_1'}{\partial t} = \frac{1}{sc}\frac{\partial^2 B_1'}{\partial Y^2} - K_1' B_1'.$$

Regarding the dimensionless terms, the commencement and limit constraints can be stated as shown below:

$$P_1' = 0, \quad \sigma' = 0, \quad B_1' = 0 \qquad \text{for all} \quad Y, t \le 0,$$

$$t > 0: \quad P_1' = t, \quad \sigma' = t, \quad B_1' = 1 \qquad \text{at} \quad Y = 0, \tag{2.5}$$

$$P_1' \to 0, \quad \sigma' \to 0, \quad B_1' \to 0 \quad \text{as} \quad Y \to \infty.$$

3. Approach to solution

The governing equations (2.4) are examined using the usual Laplace-Transform approach.

$$\sigma' = t\left[(1 + 2Z_1^{*2}\,\mathrm{Pr})\,erfc(Z_1^*\sqrt{\mathrm{Pr}}) - \left(\frac{2Z_1^*\sqrt{\mathrm{Pr}}}{\sqrt{\pi}}\right)e^{-Z_1^{*2}\,\mathrm{Pr}}\right], \tag{3.1}$$

$$\begin{aligned} B_1' = \frac{1}{2}\Big[&\exp\left(2Z_1^*\sqrt{K_1' t\,sc}\right)erfc\left(Z_1^*\sqrt{sc} + \sqrt{K_1' t}\right) + \\ &+\exp\left(-2Z_1^*\sqrt{K_1' t\,sc}\right)erfc\left(Z_1^*\sqrt{sc} - \sqrt{K_1' t}\right)\Big], \end{aligned} \tag{3.2}$$

$$\begin{aligned} P_1' = {} & t\left[\left(1 + 2Z_1^{*2}\right) erfc\left(Z_1^*\right) - \frac{2Z_1^*}{\sqrt{\pi}}e^{-Z_1^{*2}}\right] + e_1\, erfc\left(Z_1^*\right) + \\ & -\frac{d\,t^2}{6}\left[\left(3 + 12Z_1^{*2} + 4Z_1^{*4}\right)erfc(Z_1^*) - \frac{Z_1^*}{\sqrt{\pi}}\left(10 + 4Z_1^{*2}\right)e^{-Z_1^{*2}}\right] + \\ & -e_1\frac{e^{ct}}{2}\left[\exp\left(2Z_1^*\sqrt{ct}\right) erfc(Z_1^* + \sqrt{ct}\,) + \exp\left(-2Z_1^*\sqrt{ct}\right)erfc\left(Z_1^* - \sqrt{ct}\,\right)\right] + \\ & +\frac{d\,t^2}{6}\left[\left(3 + 12Z_1^{*2}\,\mathrm{Pr} + 4Z_1^{*4}\,\mathrm{Pr}^2\right)erfc\left(Z_1^*\sqrt{\mathrm{Pr}}\right) - \frac{Z_1^*\sqrt{\mathrm{Pr}}}{\sqrt{\pi}}\left(10 + 4Z_1^{*2}\,\mathrm{Pr}\right)e^{-Z_1^{*2}\,\mathrm{Pr}}\right] + \\ & -\frac{e_1}{2}\Big[\exp\left(2Z_1^*\sqrt{K_1' t\,sc}\right) erfc\left(Z_1^*\sqrt{sc} + \sqrt{K_1' t}\,\right) + \\ & +\exp\left(-2Z_1^*\sqrt{K_1' t\,sc}\right) erfc\left(Z_1^*\sqrt{sc} - \sqrt{K_1' t}\,\right)\Big] + \\ & +e_1\frac{e^{ct}}{2}\Big[\exp\left(2Z_1^*\sqrt{sc(K_1' + c)t}\right) erfc\left(Z_1^*\sqrt{sc} + \sqrt{(K_1' + c)t}\right) + \\ & + \exp\left(-2Z_1^*\sqrt{sc(K_1' + c)t}\right) erfc\left(Z_1^*\sqrt{sc} - \sqrt{(K_1' + c)t}\right)\Big] \end{aligned} \tag{3.3}$$

where $c = \dfrac{K_1' sc}{1 - sc}$, $d = \dfrac{Gr\cos\alpha}{1 - \mathrm{Pr}}$, $e_1 = \dfrac{Gc\cos\alpha}{c(1 - sc)}$, $Z_1^* = \dfrac{y}{2\sqrt{t}} = \eta.$

Skin friction (τ)

Based on investigation findings, the skin friction (τ) is:

$$\tau=-\left[\frac{\partial P_1'}{\partial y}\right]_{y=0},$$

$$\tau=\frac{2(1-d)\sqrt{t}}{\sqrt{\pi}}+\frac{b}{K_1' sc\sqrt{\pi t}}-\frac{b e^{ct}}{4K_1' sc\sqrt{\pi t}}\left[4e^{ct}-2\sqrt{\pi ct}\left(erfc\left(\sqrt{ct}\right)-erfc\left(-\sqrt{ct}\right)\right)\right]+$$
$$+\frac{2\sqrt{\Pr}}{\sqrt{\pi t}}\left(\frac{at}{1-\Pr}\right)-\frac{b}{2K_1'\sqrt{\pi sct}}\left[2e^{-K_1' t}-\sqrt{\pi K_1' t}\left(erfc\left(\sqrt{K_1' t}\right)-erfc\left(-\sqrt{K_1' t}\right)\right)\right]+ \tag{3.4}$$
$$-\frac{b e^{ct}}{2K_1'\sqrt{\pi sct}}\left[2e^{-L_2}-\sqrt{L_2\pi}\left(erfc\left(\sqrt{L_2}\right)-erfc\left(-\sqrt{L_2}\right)\right)\right]$$

where $L_2=(K_1'+c)t$.

Sherwood number (Sh)

$$Sh=-\left[\frac{dB_1'}{dy}\right]_{y=0},$$
$$Sh=\sqrt{\frac{sc}{\pi t}}e^{-K_1' t}-\frac{\sqrt{K_1' sc}}{2}\left[erfc\left(\sqrt{K_1' t}\right)-erfc\left(-\sqrt{K_1' t}\right)\right], \tag{3.5}$$

Nusselt number (Nu)

$$Nu=-\left[\frac{d\sigma'}{dy}\right]_{y=0}, \qquad Nu=\frac{\sqrt{\Pr}}{\sqrt{\pi t}}. \tag{3.6}$$

4. Results and discussion

The examination of different scenarios is intended to emphasize various factors in circulation characteristics. The temperature spread, intensity, and dimensionless velocity factors for various values of *sc*, *Pr*, *Gr*, *Gc*, *α*, K_1' and *t* have been presented in Figs 1-13.

Figure 1 illustrates the influence of velocity on a variety of *Gr* values at *45*°. An elevation in *Gr* produces a proportionate enhancement in velocity. The significance of velocity on a range of *Gr* at *60*° is depicted in Fig.2. There is a clear correlation between an enhancement in *Gr* and a subsequent gain in velocity. Figure 3 illustrates the influence of velocity on *Gr* at *30*°. It is plainly stated that a rise in Gr causes an increment in velocity.

The influence of velocity on different *α* values is demonstrated in Figs 4 and 5. As α decreases, the velocity increases. Figures 6 and 7 display data for different duration intervals at *30*° and *60*°, respectively. It has been determined that velocity exhibits a positive correlation with time.

The temperature variation depicted in Fig.8 decreases as Pr increases, which is consistent with the discovery of the reverse relationship between temperature and Pr. As Pr increases, the thermal transfer also augments and the limit zone tip is attained more rapidly. Similarly, the temperature circulation for air $(\Pr=0.71)$ is more than water $(\Pr=0.7)$.

The influence of the various patterns is demonstrated in Fig.9 for various K_1' levels. A chemical-based response has resulted in a decrease in wall thickness. The impact of the modeling limits at different Sc values is illustrated in Fig.10. The effect of intensity is significant in the area. Across all identities, the intensity consistently decreases from the outer region to a zero value at a significant length in the uncontrolled flow. An increase in wall thickness is seen as the Schmidt number decreases. The intensity patterns in various duration intervals are examined in Fig.11. The data reveals that as time decreases, the composition of the wall grows.

Table 1 displays the impact of local skin friction for various variables, inclusive of $sc, \Pr, Gr, Gc, \alpha, K_1', t$. The Pr, sc, and α, lead to an elevation in skin friction. But it has the opposite impact on Gr and Gc under time.

Table 2 shows the influence of Sh on sc, K_1' along with t. The Sh grows proportionate with sc. While the material transmission rises, the sc increases.

The Nu is depicted in Tab.3 for different $\Pr$ and t. While Pr is raised, the Nu also rises.

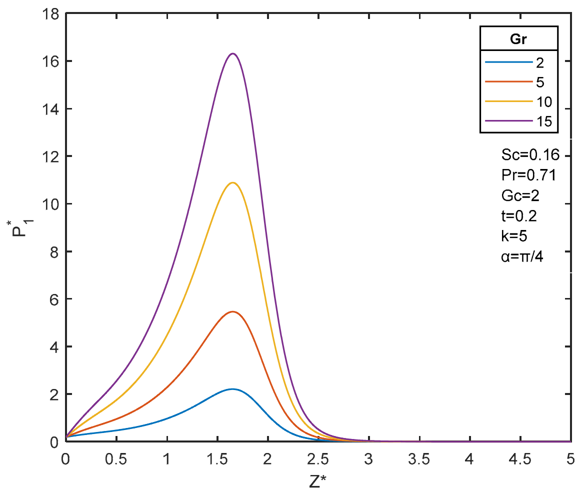

Fig.1. Velocity patterns vs. Gr .

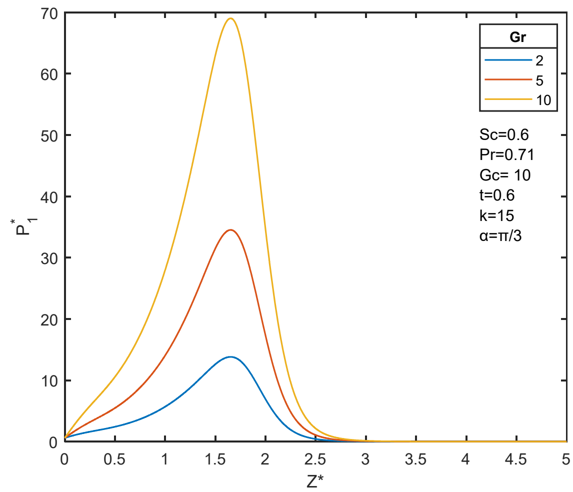

Fig.2. Velocity patterns vs. Gr .

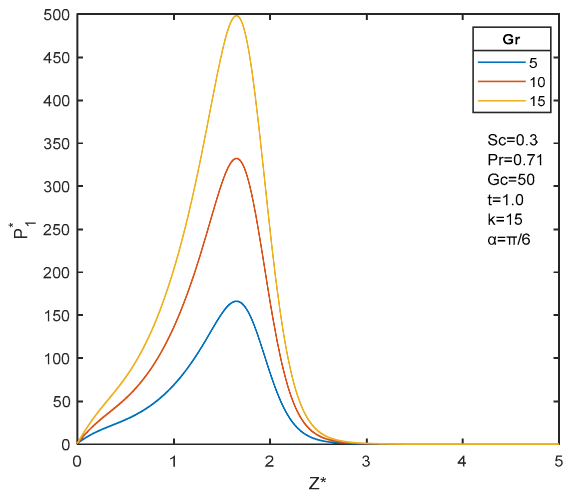

Fig.3. Velocity patterns vs. Gr .

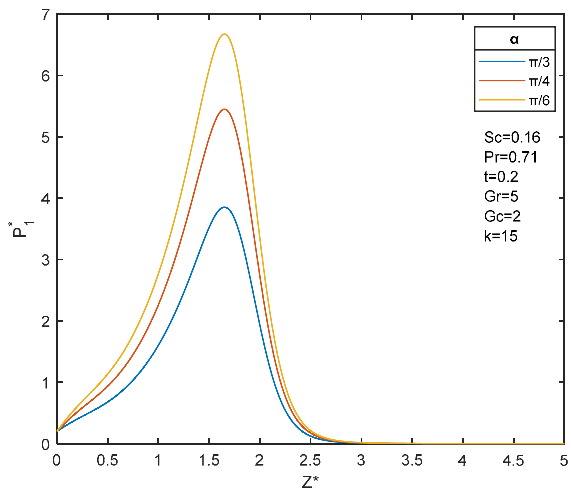

Fig.4. Velocity patterns vs. α .

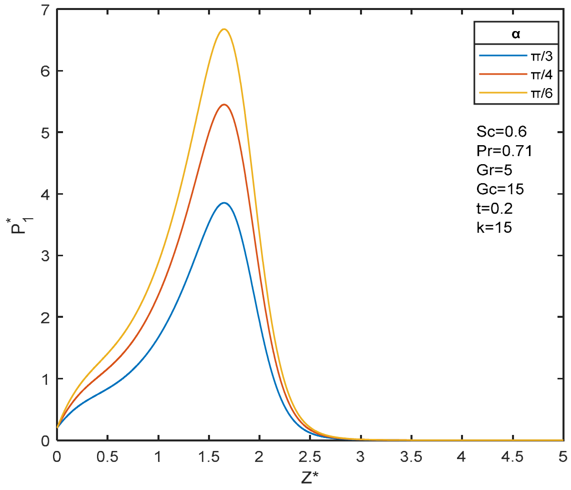

Fig.5. Velocity patterns vs. α .

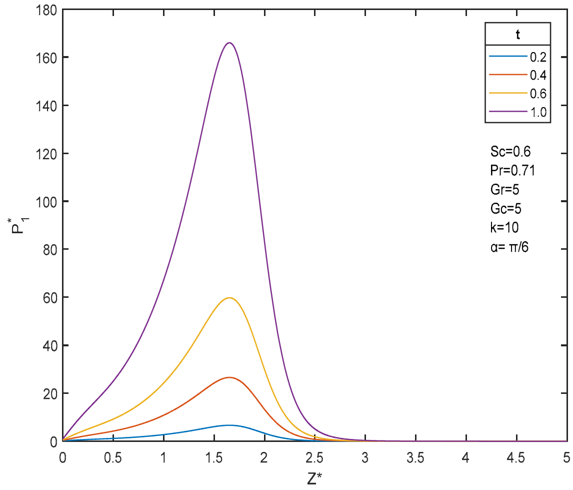

Fig.6. Velocity patterns vs. *t*.

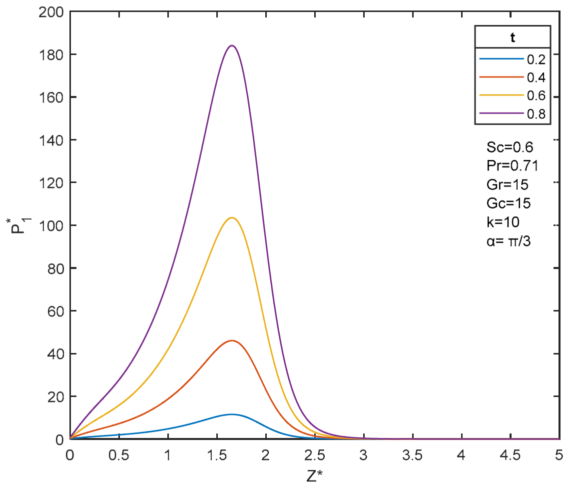

Fig.7. Velocity patterns vs. *t*.

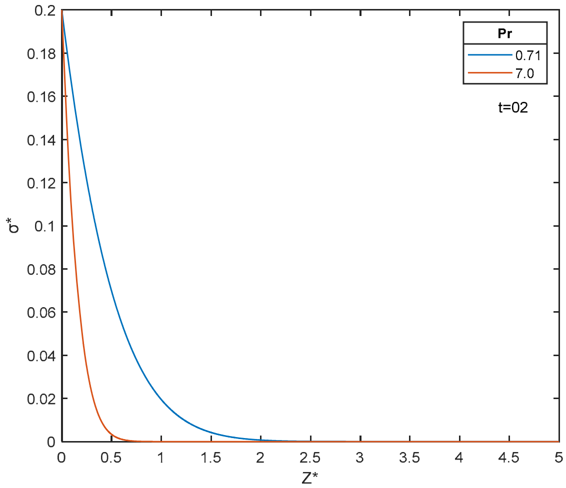

Fig.8. Temperature patterns vs. Pr .

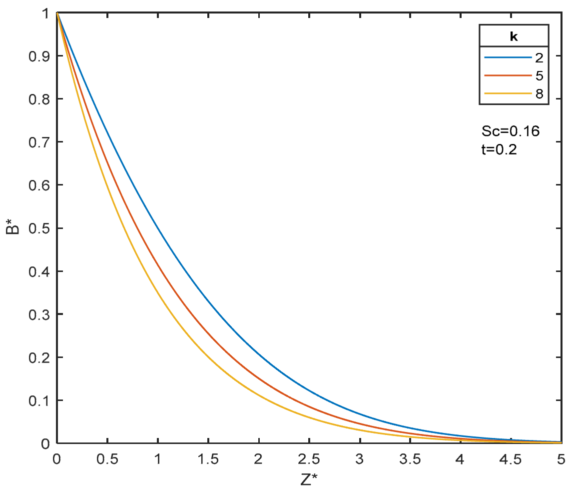

Fig.9. Concentration levels vs. K_1'.

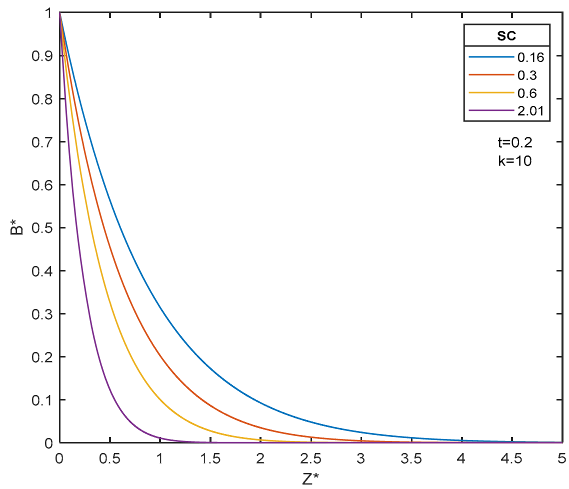

Fig.10. Concentration levels vs. *sc*.

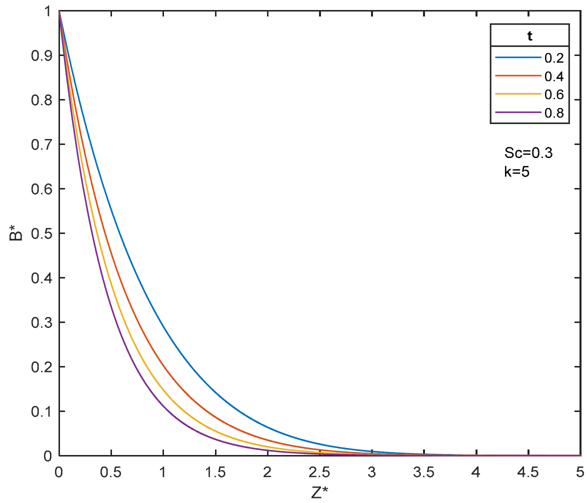

Fig.11. Concentration characteristics vs. t .

Table 1. Skin – friction (τ) for varying factors.

α (in degrees)	t	Gr	Gc	sc	K_1'	τ
60	0.8	5	2	0.16	5	-4.4946
30	0.2	2	5	0.3	10	-2.8122
45	0.6	2	2	0.6	2	-4.911
30	0.8	5	5	0.16	10	-7.3232
45	0.6	2	5	0.6	5	-7.4437
60	0.4	2	2	0.6	2	-2.7299
30	0.2	5	5	0.16	5	-5.6138
60	0.8	5	2	0.3	2	-6.9154
45	0.4	2	3	0.16	10	-4.3153

Table 2. *Sh* for varying factors.

t	sc	K_1'	Sh
0.8	0.16	5	0.7753
0.4	0.3	2	0.8060
0.6	2.01	10	0.7884
0.2	0.6	5	0.8604
0.6	0.16	10	0.7884
0.4	2.01	5	0.8060
0.8	0.16	2	0.7763

Table 3. *Nu* for varying factors.

t	*Pr*	*Nu*
0.8	0.71	8.6207
0.4	7	8.6207
0.6	0.71	8.6207
0.2	7	8.6207
0.6	0.71	8.6207
0.4	0.71	8.6207
0.8	7	8.6207

5. Conclusion

A study has been conducted on the exact solution of a first-order chemical process, where an inconsistent flow interacts with a linearly accelerating flow over a continuous isothermal sloped surface. Various elements such as sc, Gr, Gc, α, K_1' and t, as well as the impact of velocity, E' and concentration, were investigated. The conclusions of the investigation are outlined below:

1. As α, sc duration decreases, the velocity experiences an upsurge.
2. The velocity increases concurrently with Gr, Gc and t.
3. The sc and chemical responsiveness exhibit a decline, leading to an escalation in wall intensity.
4. With the progression of t, the temperature of the plate undergoes an increase.

Nomenclature

A – constant
B_1', C – dimensionless concentration
C_p – specific heat at constant pressure $J.kg^{-1}.K^{-1}$
D – mass diffusion coefficient $m^2.s^{-1}$
erfc – complementary error function
E_w' – fluid temperature near the plate
E_∞' – Temperature away from the plate
E', T – fluid temperature closer to the plate
Gc – Grashof number (mass)
Gr – Grashof number (thermal)
g – accelerrated due to gravity $m.s^{-2}$
J' – species concentration in the fluid mol. m^{-1}
J_∞' – species concentration away from the plate
J_w' – species concentration near the plate
K, K_1' – chemical reaction
K_1 – chemical reaction parameter
k – thermal conductivity $J.m^{-1}.K^{-1}$
Nu – Nusselt number
Pr – Prandtl number

sc – Schmidt number
Sh – Sherwood number
t – dimensionless time
t_2' – time
U, P_1' – dimensionless velocity
u – fluid velocity in vertical direction $m.s^{-1}$
u_0 – velocity of the plate $m.s^{-1}$
x – spatial coordinate along the plate
y' – coordinate axis normal to the plate m
y – dimensionless coordinate axis normal to the plate
Z_1^* – similarity parameter
α – angle of inclination
β_1 – volumetric coefficient of thermal expansion K^{-1}
β_1^* – volumetric coefficient of expansion with concentration K^{-1}
η – similarity parameter
μ – coefficient of viscosity $Pa.s$
υ – kinematic viscosity $m^2.s^{-1}$
ρ – density of the fluid $kg.m^{-3}$
τ – dimensionless skin-friction $kg.m^{-1}.s^2$
σ', θ – dimensionless temperature

Subscripts

w – conditions at the wall
∞ – conditions in the free stream

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