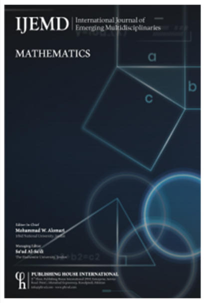
IJEMD

IJEMD-M, 1 (3) (2022) 1-12 *https://doi.org/10.54938/ijemdm.2022.01.3.103*

International Journal of Emerging Multidisciplinaries: Mathematics

Research Paper
Journal Homepage: www.ojs.ijemd.com
ISSN: 2790-1998 (print), 2790-3257 (online)



Axisymmetric Hydromagnetized Heat Transfer with Joule Heating and Radiation Effect: Computational Strategy

Sajeela Bibi[1] and Tahir Naseem[2,*]

[1]*Department of Mathematics, University of Haripur, 22620, Pakistan*
[2]*Basic Sciences Department, University of Engineering and Technology, Taxila, 47050, Pakistan*
**Corresponding author*

Abstract

This investigation thoroughly analyses magnetohydrodynamics axisymmetric fluid flow and heat transfer over an exponentially stretching sheet in the presence of radiation and Joule heating effects. The governing partial differential equations are obtained and converted into coupled ordinary differential equations using a suitable similarity transformation. This transformation is also used to re-model the governing system to modify ODEs and boundary conditions using the BVP4C MATLAB) package. The effects of the involved physical parameters, such as suction/injection parameter, magnetic parameter, Prandtl number, Eckert number, and radiation parameter on velocity and temperature profiles are shown graphically. The effects of various parameters on Nusselt number and skin friction coefficient are shown in tabular form. It has been determined that the presence of a magnetic field improves a fluid's thermal behavior. Furthermore, increasing the magnitude of the magnetic field reduces the fluid's radial velocity.

Keywords: Axisymmetric flow; Magnetic field; Ohmic law; Radiation; Stretching surface; Similarity transformation.

1. Introduction

For practical engineering applications, there have been a lot of studies done on thermal transport of viscous fluids formed by stretching surfaces. Glass fiber production, Paper making, plastic film drawing, wire drawing, polymeric sheet manufacturing, Paper is made by a variety of sectors, including paper manufacturing, polymer extraction from plastic sheets, and paper recycling. Everyone benefits from flow and heat transport evaluations

Email addresses: **khansajjo694@gmail.com (S. Bibi), tahir.naseem@students.uettaxila.edu.pk (T. Naseem)**

on stretched surfaces. During the production of these sheets, molten material passes it is then stretched to the required thickness through a slit. The final product's mechanical qualities are influenced by the rate is determined by the sheet's flexibility at which it cools, and the fluid's rheological features. Sakiadis [1] is credited with developing an axisymmetric flow in two dimensions model and studying On top of a stretched sheet, boundary flow is created. Crane [2] investigated a stretching sheet is used to guide the boundary layer flow and devised a closed form solution for laminar flow. Several researchers broadened their research to include a wide range of physical phenomena. The effects of suction and blowing on a constantly extending surface were investigated by Char [3]. Whereas, Fang and Fang [4] proposed an analytical approach that included a wedge stretching wall as the mass transfer element. The majority of the research [5-7] is focused on a stretching surface with a velocity proportional to the distance from the origin on boundary layer flow. Later on, Xu [8] suggested that plastic sheet stretching isn't always linear, and Kumara provided a generic quadratic sheet stretching velocity. Several scholars [9-12] investigated various elements of difficulties such as Injection of In the presence of suction, a thermal boundary layer flows onto a power-law extending surface streaking velocity across a sheet that was exponentially stretched. Flow and heat transmission has gotten a lot of press recently. Some scholars have looked at the flow and heat transmission across an exponentially growing shield in recent years [13-18]. Ariel [19] developed an accurate and numerical flow that is axisymmetric solution over a sheet that is stretched linearly and radially Mirgolbabaei [20] used the variational iteration method to solve this problem. Ariel [21] second-graduation fluids were added to the axisymmetric flow issue. By employing velocity cr^3 and establishing the optimal solution for axis Sahoo [22] examined a radially extended surface with an electrically conducting viscoelastic fluid flowing in an axisymmetric flow partial slip at a linear speed. By employing velocity cr^3 and constructing the optimum axisymmetric flow on a radially extending nonlinear surface, Shahzad et. al [23] discovered the axisymmetric flow over a nonlinear radially extending surface has the proper solution. Ali et. al [24] studied heat transfer over stretching surface with velocity cr^n in the presence of a magnetic field of viscous fluid with slip condition over nonlinear stretching sheet.

Thermal radiation and heat transfer studies serve all industries, including electrical power generation, astrophysical fluxes, solar power technologies, and others. There is currently a large body of work in the presence of radiation fluxes impacts. Elbashbeshy and Dimian [25] investigated boundary layer flow and heat transfer over a wedge with a viscosity coefficient. Cortell also used a fourth-order Runge-Kutta approach to tackle a problem regarding the effect of radiation on Blasius flow [26]. Similarly, many researchers [27-30] explored the effect of radiation on viscous fluid over stretching surfaces. Heat transmission in the flow Gupta and Gupta [31] investigated various aspects of the problem while investigating various facets of the problem. The boundary layers on a continuously stretched continuous surface with an exponential temperature distribution were studied by Raptis et al. [32]. For the stagnation point, heat transmission with and without viscous dissipation, and Joule heating, Jat et al. [33] investigated MHD boundary layer flow across a stretching sheet. Ishak [34] explored the effect of heat radiation on the hydro-magnetic flow of an exponentially stretched sheet.

Shehzad et. al [35] investigated that how the suction injection parameter affected axisymmetric flow on a surface that stretches exponentially. The purpose of this investigation to extend the above work by considering the joule heating radiation effects on temperature profiles. The structure of the manuscript is as: the mathematical formulation of a physical phenomenon is described in section 2, section 3 elaborate the numerical procedure adopted to solve the problem in hand, and numerical findings are given in part 4. Finally, section 5 provides final observations.

2. Mathematical form of Physical Phenomena

Here, we consider the incompressible electrically conducting viscous fluid over exponentially stretching surface that coincides with the $Z = 0$ plane. There is fluid in the area $Z > 0$. The flow phenomenon is caused by the sheet's radial stretching velocity $U_0 e^{\frac{r}{l}}$. In addition, a magnetic field with the intensity $B(r) = B_0 e^{\frac{r}{2l}}$ is applied. It is assumed that the induced magnetic field is insignificant for modest Reynolds numbers. As indicated in the image, the sheet is maintained at a constant temperature T_w, whereas the ambient temperature is presented by T_∞. The basic steady 2D conservation of mass, momentum, and thermal energy equations, using the above assumptions and applying the boundary-layer approximation, can be written in the form of [35]

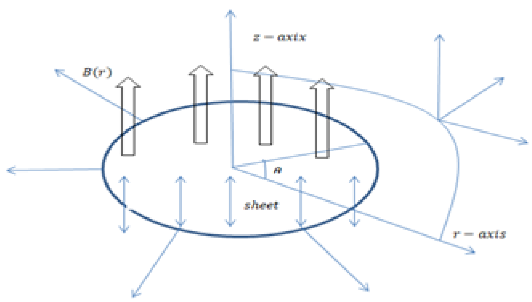


Fig. 1. The flow diagram with coordinates

$$\frac{\partial u}{\partial r} + \frac{u}{r} + \frac{\partial w}{\partial z} = 0, \tag{1}$$

$$u\frac{\partial u}{\partial r}+w\frac{\partial u}{\partial z}=\vartheta\frac{\partial^2 u}{\partial z^2}-\frac{\sigma}{\rho}(B(r))^2u \tag{2}$$

$$u\ \frac{\partial T}{\partial r}\ +\ w\ \frac{\partial T}{\partial z}\ =\ \frac{k}{\rho Cp}\ \frac{\partial^2 T}{\partial z^2}+\frac{\vartheta}{\rho Cp}\left(\frac{\partial u}{\partial z}\right)^2-\frac{1}{\rho Cp}\ \frac{\partial q_r}{\partial z}-\frac{\sigma}{\rho Cp}(B(r)^2u^2), \tag{3}$$

where q_r is the radiative heat flux and the Rosseland approximation describes it so that

$$q_r\ =\ -\frac{4}{3}\frac{\sigma_s}{k_e}\frac{\partial T^4}{\partial y}=-\frac{4}{3}\frac{\sigma_s}{k_e}T^3\frac{\partial T}{\partial y}, \tag{4}$$

Here, σ_s represents the Stefan-Boltzmann constant and k_e represents the average absorption coefficient. If the temperature variations within the flow are small enough, expending T^4 about T_∞ by using Taylor's series, equation (4) takes the form $T^4\cong 4T_\infty^3T-3\,T_\infty$.

The corresponding boundary conditions are

$$\boldsymbol{u=U=U_0e^{\frac{r}{l}},w\ =\ -v_0e^{\frac{r}{2l}}\,,T=T_w\,at\,z=0},$$
$$\boldsymbol{u\to\ 0\,,T\ =T_\infty,as\,z\ \to}\ \infty. \tag{5}$$

To make the aforementioned equations dimensionless, we proposed the following additional similarity transformations:

$$u=Uf\acute{}(\eta),w=\frac{1}{2}U(Re)^{-\frac{1}{2}}[f\ +\ \eta f],\eta=(Re)^{\frac{1}{2}}\frac{z}{l},\theta(\eta)=\frac{T-T_\infty}{T_w-T_\infty},Re=\frac{lU}{\vartheta} \tag{6}$$

Equation (1) is identically fulfilled after the application of the preceding similarity transformation, and Equation (2-5) has the form

$$\frac{d^3f(\eta)}{d\eta^3}+\frac{1}{2}\big(f(\eta)\big)\frac{d^2f(\eta)}{d\eta^2}-\mathrm{M}\left(\frac{df(\eta)}{d\eta}\right)^2-\frac{df(\eta)}{d\eta}=0 \tag{7}$$

$$(1+R)\frac{d^2\theta}{d\eta^2}+\frac{1}{2}Prf\frac{d\theta}{d\eta}+PrEc\left(\frac{d^2f}{d\eta^2}\right)^2\ +PrEcM(f')^2=0, \tag{8}$$

$$f(\eta)=s,f'(\eta)=1,\theta(\eta)=1\ at\,\eta\to 0 \tag{9}$$
$$f'(\eta)=0,\theta(\eta)=0\ as\,\eta\to\infty$$

The magnetic parameter is $M=\frac{\sigma B_0^2 l}{\rho u_0}$, the Prandtl number is $Pr=\frac{\mu c_p}{k}$, the Eckert number is $Ec=\frac{u^2}{c_p(T_w-T_\infty)}$, and the suction/injection parameter is $S=\frac{\nu}{\sqrt{\frac{u_0\nu}{4l}}}$ $(s>0$ for injection$)$. The At the surface, dimensionless skin friction and Nusselt number are defined as $c_f=\frac{2T_w}{\rho u^2}$ and $N_u=\frac{r(1+R)q_w}{k(T_w-T_\infty)}$

respectively, where $T_w = \left[\mu \frac{\partial u}{\partial z}\right]_{z=0}$ the wall shear stress and $q_w = -K\left[\frac{\partial T}{\partial z}\right]_{z=0}$ the wall heat flux, are physical parameters of importance.The above equations transforms variable in terms can be expressed as $\frac{1}{2}Re^{-1/2}C_f = f''(0)$ and $Re^{-1/2}\,Nu = -(1+Rd)\theta'(0)$.

3. Solution Methodology

Using similarity transformation, nonlinear partial differential equations with applied boundary conditions are transformed into ordinary differential equations, which are then solved using the Shooting method. Here, the third order nonlinear ordinary differential equations (7) and the second order nonlinear ordinary differential equations (8) are turned into difference equations as follows:

$$f = y_1, f' = y_2, f'' = y_3, f''' = yy1$$

$$yy1 = -\frac{1}{2}y_1y_3 + \mathrm{M}(y_2)^2 + y_2 = 0, \tag{10}$$

$$\theta = y_4, \theta' = y_5, \theta'' = yy2,$$

$$yy2 = \frac{1}{(1+R)}\left[-\frac{1}{2}Pry_1y_5 - PrEc(y_3)^2 - PrEcM(y_2)^2\right], \tag{11}$$

4. Results and Discussions

This work investigates a thorough analysis of magnetohydrodynamics axisymmetric in the presence of the Joule heating effect, fluid movement, and heat transmission across an exponentially stretching sheet. To find the solution we used a numerical method (BVP4C MATLAB package). Effect of fluid parameters such as S is the suction/injection parameter. About skin friction and Nusselt number, the magnetic parameter M, Eckert number Ec, Prandtl number Pr, and radiation parameter R were detected. The effects on the rate of heat transport and the dimensionless there is shear stress at the surface, which is represented graphically and numerically. The tables (1-4) show the effect of M as a magnetic parameter, suction/injection parameter S, Prandtl number Pr on skin fraction and Nusselt number.

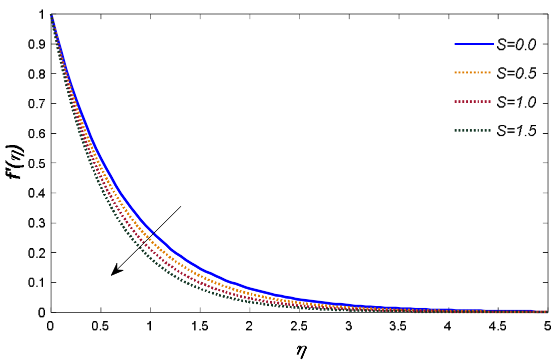


Fig. 2. For varying values of the suction parameter S, the velocity $f'(\eta)$ changes when $M = 1.0$ is fixed.

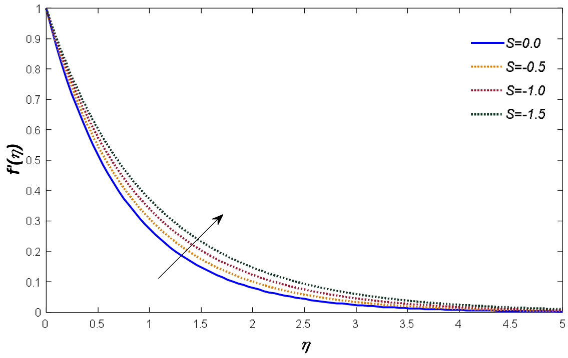


Fig. 3. For varying values of the injuction parameter S, the velocity $f'(\eta)$ varies when $M = 1.0$ is fixed.

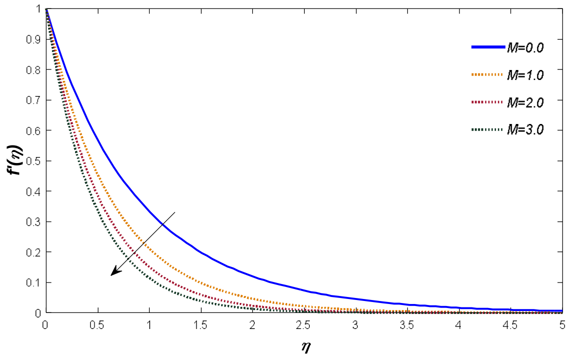


Fig. 4. For varying values of the magnetic parameter M, the velocity $f'(\eta)$ varies when $S = 1.0$ is fixed.

Figs. 2 and 3 explain how suction and injection parameters affect the velocity profile. Fig. 2 depicts the s > 0 affects the suction parameter. The velocity $f'(\eta)$ drops when the suction parameter is increased, and the well shear stress falls. Buoyancy forces may serve to slow the hot fluid being pushed against the wall due to the large influence of velocity on the fluid; this behavior occurs in the case of suction. The velocity profile corresponding to different values of injection parameters $S < 0$ is shown in fig. 3. This graph shows the reverse pattern of velocity increasing with injection. Fig. 3 shows the velocity increasing in the opposite direction as an injection (s > 0). Fig. 4 shows the impact of the magnetic parameter M as the Lorentz force opposes the flow; hence raising M lowers the velocity profile.

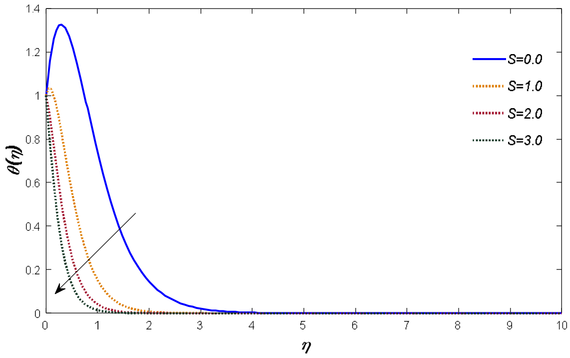


Fig. 5. Temperature variation $\theta(\eta)$ for different suction parameter S values when $M = 1.0, Pr = 6.0, Ec = 0.8,$ and $R = 0.5$ are fixed.

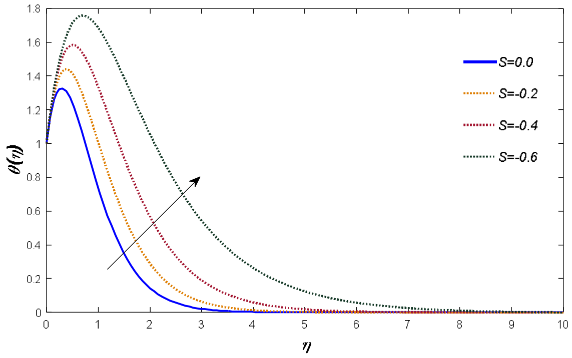


Fig. 6. Temperature variation $\theta(\eta)$ for different injection parameter S values when $M = 1.0, Pr = 6.0, Ec = 0.8,$ and $R = 0.5$ are fixed.

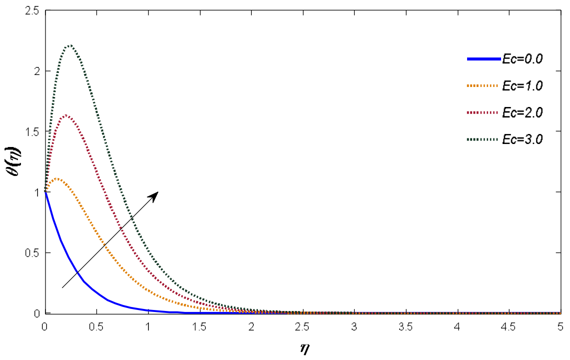


Fig. 7. Temperature variation $\theta(\eta)$ for different Eckert number Ec values when $M = 1.0, Pr = 6.0, S = 1.0,$ and $R = 0.5$ are fixed.

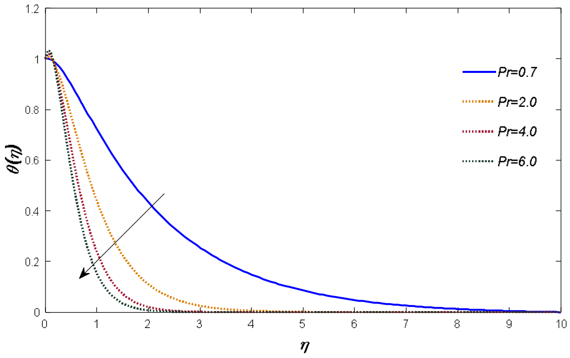


Fig. 8. Temperature variation $\theta\ (\eta)$ for various Prandtl numbers Pr when $M\ =\ 1.0,\ \ S\ =\ 1.0,\ \ Ec\ =\ 0.8,$ and $Rd\ =\ 0.5$ are fixed**.**

The effects of physical parameters on temperature have been observed and are presented in (figs. 5-8). A brief discussion is made on the obtained figures. Fig. 5 is influenced by the suction parameter $S\ >\ 0$. As the suction parameter increases, the temperature drops. This is due to boundary forces which intervene to slow the hot fluid as it approaches the wall due to the large influence of velocity. Because velocity is so important in suction, this behavior occurs as a result of the hot fluid being forced against the wall, when boundary forces exist could step in and slow down the flow.

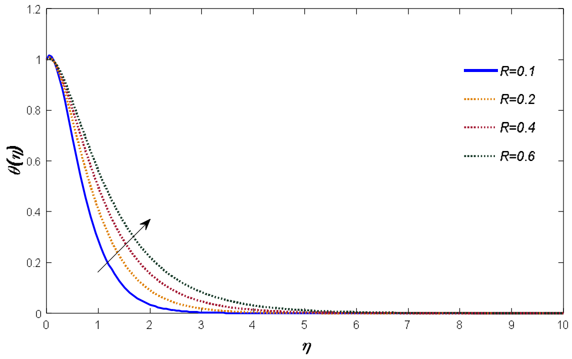


Fig. 9. Temperature variation $\theta(\eta)$ for different radiation parameter R values when $M\ =\ 1.0,\ \ S\ =\ 1.0,$ $Ec\ =\ 0.8,$ and $Pr\ =\ 6.0$ are fixed.

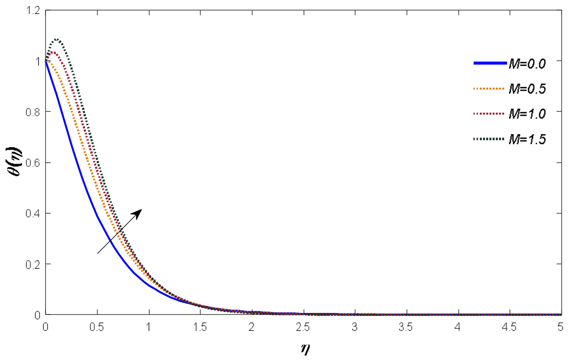


Fig. 10. Temperature variation $\theta(\eta)$ for different magnetic parameter M values when $R = 0.5$, $S = 1.0$, $Ec = 0.8$, and $Pr = 6.0$ are fixed.

Table 1. Effect of Suction/Injection Parameter on $\theta'(0)$ and $f''(0)$.

S	M	P_r	E_c	R_d	$-\theta'(0)$	$f''(0)$
0	1.0	6.0	0.8	0.1	1.090646	−3.01553
0.1	1.0	6.0	0.8	0.1	1.056821	−2.40948
0.2	1.0	6.0	0.8	0.1	1.030493	−1.80490

Table 2. Effect of Magnetic Parameter on $\theta'(0)$ and $f''(0)$.

S	M	P_r	E_c	R_d	$-\theta'(0)$	$f''(0)$
1.0	0.0	6.0	0.8	0.1	0.396711	−1.022434
1.0	0.5	6.0	0.8	0.1	0.283448	−0.7702971
1.0	1	6.0	0.8	0.1	0.1942725	−0.6210683

Table 3. Effect of Prandtl Number on $\theta'(0)$ and $f''(0)$.

S	M	P_r	E_c	R_d	$-\theta'(0)$	$f''(0)$
1.0	1.0	0.5	0.8	0.1	0.999653	8.077643
1.0	1.0	1.0	0.8	0.1	0.999649	8.077642
1.0	1.0	1.5	0.8	0.1	0.999644	8.077641

Table 4. Effect of Radiation Parameter on $\theta'(0)$ and $f''(0)$.

S	M	P_r	E_c	R_d	$-\theta'(0)$	$f''(0)$
1.0	1.0	6.0	0.8	0.1	0.999904	6.334784
1.0	1.0	6.0	0.8	1	0.993024	6.349548
1.0	1.0	6.0	0.8	2	0.982357	6.349431

Fig. 6 depicts the effect of injection parameters $S < 0$ on dimensionless temperature. The temperature rises with injection. The effect Eckert number on temperature is displayed in Fig. 7. Due to the thermal energy contained in the fluid, when the Eckert number rises, the temperature profile rises as well. The Prandtl number represents the momentum to thermal diffusivity ratio, increase in Pr reduces the temperature as shown in fig.

8. Fig. 9 shows how the temperature is affected by the radiation parameter (Rd), demonstrating their inextricable link. The temperature transfer increases as the value of a parameter for radiation is increased as seen in the figure. The impact of magnetic parameter M on temperature is shown in fig. 10. The Lorentz force, which opposes flow, is responsible for this. It has been demonstrated that increasing the magnetic parameter raises the temperature profile while lowering the thickness of the thermal boundary layer. Table 4.1 demonstrates dimensionless for various values of the suction parameters, Shear stress and heat transfer rate at the surface are calculated.

The heat transfer rate $\theta'(0)$ falls as the suction parameter s increase in this table. The suction parameters increased to minimize the surface shear stress f'' (0). Table 2 displays the influence of the effect of the magnetic parameter on the Nusselt number and skin friction; as the magnetic parameter is increased, the Nusselt number decreases but skin friction rises. Furthermore, table 3 demonstrates the effect of Prandtl number and Nusselt number on skin friction. It can be seen that both have an inverse relationship with Prandtl number, i.e., both drop as Prandtl number increases. Similarly, table 4 demonstrates how the Nusselt number and skin friction are affected by the radiation parameter. With an increase in the value of the radiation parameter, the Nusselt number decreases, however, skin friction increases.

5. Conclusion

This study examined the heat transmission features of an axisymmetric fluid flow with exponential stretching velocity according to Newtonian theory. Using novel similarity transformations, nonlinear partial differential equations were reduced to a system of ordinary differential equations (ODE). Numerical solutions to equations for motion and energy were found. The influence of significant factors on the dimensionless radial velocity $f'(\eta)$ and the dimensionless temperature profile $\theta(\eta)$ was visually displayed and carefully examined. Here are some of the most significant findings:

- As we increase the value of the suction parameter ($S > 0$), the fluid temperature falls. .
- By raising the value of injection parameter S, the temperature profile rises.
- Increasing the Eckert number further enhances the temperature profile.
- It is noticed that when the Prandtl number increases, temperature falls.
- Increasing the parameter value for radiation reduces the temperature profile.
- Moreover, the temperature profile increases as the magnetic parameter increases.

References

[1] Sakiadis, B.C. Boundary-layer behavior on continuous solid surfaces: I. Boundary-layer equations for two-dimensional and axisymmetric flow. *AIChE Journal*, **7**(1), 26-28 (1961).

[2] Crane, L.J. Flow past a stretching plate. *Zeitschrift für angewandte Mathematik und Physik ZAMP*, **21**(4), pp. 645-647 (1970).

[3] Char, M.I. Heat transfer of a continuous, stretching surface with suction or blowing. *Journal of Mathematical Analysis and Applications*, **135**(2), 568-580 (1988).

[4] Fang, T. and Zhang, J. An exact analytical solution of the Falkner-Skan equation with mass transfer and wall stretching, *International Journal of Non-Linear Mechanics*, **43**(9), 1000-1006 (2008).

[5] Hayat, T., Abbas, Z. and Sajid, M. Series solution for the upper-convected Maxwell fluid over a porous stretching plate. *Physics Letters A*, **358**(5-6), 396-403 (2006).

[5] Ali, M.E. On thermal boundary layer on a power-law stretched surface with suction or injection. *International Journal of Heat and Fluid Flow*, **16**(4), 280-290 (1995).

[6] Magyari, E. and Keller, B. Heat and mass transfer in the boundary layers on an exponentially stretching continuous surface. *Journal of Physics D: Applied Physics*, **32**(5), 577 (1999).

[7] Kumaran, V. and Ramanaiah, G. A note on the flow over a stretching sheet. *Acta Mechanica*, **116**(1), 229-233 (1996).

[8] Xu, H. and Liao, S.J. Series solutions of unsteady magnetohydrodynamic flows of non-Newtonian fluids caused by an impulsively stretching plate. *Journal of Non-Newtonian Fluid Mechanics*, **129**(1), 46-55 (2005).

[9] Cortell, R. Effects of viscous dissipation and work done by deformation on the MHD flow and heat transfer of a viscoelastic fluid over a stretching sheet. *Physics Letters A*, **357**(4-5), 298-305 (2006).

[10] Vajravelu, K. and Cannon, J.R. Fluid flow over a nonlinearly stretching sheet. *Applied Mathematics and Computation*, **181**(1), 609-618 (2006).

[11] Hayat, T., Abbas, Z. and Sajid, M. Series solution for the upper-convected Maxwell fluid over a porous stretching plate. *Physics Letters A*, **358**(5-6), 396-403 (2006).

[12] Mahmood, A., Ahmed, S. and Iram, H. Joule and Viscous Dissipation Effects on MHD Boundary Layer Flow over a Stretching Sheet with Variable Thickness. *International Journal of Emerging Multidisciplinaries: Mathematics*, **1**(2), 1-10 (2022).

[13] Usman, K. Numerical Analysis Of a Falling Circular Particle Passing through a Fluid Channel having Diamond Shaped Obstacles. *International Journal of Emerging Multidisciplinaries: Mathematics*, **1**(2), 11-22 (2022).

[14] Khan, U., Abbasi, A., Ahmed, N. and Ullah, B. Effects of Thermal Radiation on Jeffery Hamel Flow for Stretchable Walls of Newtonian Fluid: Analytical Investigation. *International Journal of Emerging Multidisciplinaries: Mathematics*, **1**(2), 71-83 (2022).

[15] Hussain, A., Afzal, A. and Mahmood, R. Numerical Investigation of Viscous Fluid Flow and Heat Transfer in the Closed Configuration Installed with Baffles. *International Journal of Emerging Multidisciplinaries: Mathematics*, **1**(2), 49-57 (2022).

[16] Naseem, T., Fatima, U., Munir, M., Shahzad, A., Kausar, N., Nisar, K.S., Saleel, C.A. and Abbas, M. Joule heating and viscous dissipation effects in hydromagnetized boundary layer flow with variable temperature. *Case Studies in Thermal Engineering*, **35**, p.102083 (2022).

[17] Bidin, B. and Nazar, R. Numerical solution of the boundary layer flow over an exponentially stretching sheet with thermal radiation. *European journal of scientific research*, **33**(4), 710-717 (2009).

[18] Naseem, T., Nazir, U., Sohail, M., Alrabaiah, H., Sherif, E.S.M. and Park, C. Numerical exploration of thermal transport in water-based nanoparticles: A computational strategy. *Case Studies in Thermal Engineering*, **27**, p.101334 (2021).

[19] Ariel, P.D. Axisymmetric flow of a second grade fluid past a stretching sheet. *International Journal of Engineering Science*, **39**(5), 529-553 (2001).

[20] Mirgolbabaei, H., Ganji, D.D., Etghani, M.M. and Sobati, A. Adapted variational iteration method and axisymmetric flow over a stretching sheet. *World Journal of Modelling and Simulation*, **5**(4), 307-314 (2009).

[21] Ariel, P.D. Axisymmetric flow due to a stretching sheet with partial slip. *Computers & Mathematics with Applications*, **54**(7-8),1169-1183 (2007).

[22] Sahoo, B. Effects of partial slip on axisymmetric flow of an electrically conducting viscoelastic fluid past a stretching sheet. *Open Physics*, **8**(3), 498-508 (2010).

[23] Shahzad, A., Ali, R. and Khan, M. On the exact solution for axisymmetric flow and heat transfer over a nonlinear radially stretching sheet. *Chinese Physics Letters*, **29**(8), p. 084705 (2012).

[24] Ali, R., Shahzad, A., Khan, M. and Ayub, M. Analytic and numerical solutions for axisymmetric flow with partial slip. *Engineering with Computers*, **32**(1), 149-154 (2016).

[25] Elbashbeshy, E.M.A. and Dimian, M.F. Effect of radiation on the flow and heat transfer over a wedge with variable viscosity. *Applied Mathematics and Computation*, **132**(2-3), 445-454 (2002).

[26] Cortell, R. A note on flow and heat transfer of a viscoelastic fluid over a stretching sheet. *International Journal of Non-Linear Mechanics*, **41**(1), 78-85 (2006).

[27] Jat, R.N. and Chaudhari, S. Magnetohydrodynamics boundary layer flow near the stagnation point of a stretching sheet. *Nuovo Cimento della Societa Italiana di Fisica. B, General Physics, Relativity, Astronomy and Mathematical Physics and Methods*, **123**(5), 555-566 (2008).

[28] Mukhopadhyay, S. and Gorla, R.S.R. Effects of partial slip on boundary layer flow past a permeable exponential stretching sheet in presence of thermal radiation. *Heat and Mass Transfer*, **48**(10), 1773-1781 (2012).

[29] Nadeem, S., Zaheer, S. and Fang, T. Effects of thermal radiation on the boundary layer flow of a Jeffrey fluid over an exponentially stretching surface. *Numerical Algorithms*, **57**(2), 187-205 (2011).

[30] Carragher, P. and LJ, C. Heat transfer on a continuous stretching sheet (1982).

[31] Gupta, P.S. and Gupta, A.S. Heat and mass transfer on a stretching sheet with suction or blowing. *The Canadian journal of chemical engineering*, **55**(6), 744-746 (1977).

[32] Raptis, A., Perdikis, C. and Takhar, H.S. Effect of thermal radiation on MHD flow. *Applied Mathematics and computation*, **153**(3), 645-649 (2004).

[33] Jat, R.N. and Chaudhary, S. Radiation effects on the MHD flow near the stagnation point of a stretching sheet. *Zeitschrift für angewandte Mathematik und Physik*, **61**(6), 1151-1154 (2010).

[34] Ishak, A. Radiation effects on the flow and heat transfer over a moving plate in a parallel stream. *Chinese Physics Letters*, **26**(3), p. 034701 (2009).

[35] Shahzad, A., Ali, R., Kamran, M., Khan, S.U.D., Khan, S.U.D. and Farooq, A. Axisymmetric flow with heat transfer over exponentially stretching sheet: A computational approach. *Physica A: Statistical Mechanics and its Applications*, **554**, p. 124242 (2020).