Journal of Progressive Research in Mathematics(JPRM)
ISSN: 2395-0218

SCITECH
RESEARCH ORGANISATION|

Volume 8, Issue 2
Published online: July 25, 2016|

Journal of Progressive Research in Mathematics
www.scitecresearch.com/journals

Stagnation point flow of a MHD Powell-Eyring fluid over a nonlinearly stretching sheet in the presence of heat source/sink

Ch.Vittal [1], M. Chenna Krishna Reddy[2] , M. Monica [3]

[1] Department of Mathematics ,Osmania University, Telangana
[2] Department of Mathematics ,Osmania University, Telangana
[3] Department of Mathematics ,Osmania University, Telangana

Abstract

This study investigates the stagnation point flow of a MHD Powell-Eyring fluid over a nonlinearly stretching sheet in the presence of heat source/sink. Similarity transformations are used to convert highly non-linear partial differential equations into ordinary differential equations. The transformed nonlinear boundary layer equations are then solved numerically using Keller Box method. The effects of various physical parameters on the dimensionless velocity and temperature profiles are depicted graphically. Present results are compared with previously published work and the results are found to be in very good agreement. Numerical results for local skin-friction and local Nusselt number are tabulated for different physical parameters.

Keywords: Velocity ratio parameter; Radiation parameter; Stagnation point; Non linear stretching parameter; heat source/sink; Powell-Eyring fluid.

Introduction :

The study of the boundary layer flow of non-Newtonian fluids on a stretching surface has become a popular research area for its commercial importance. Such fluid flows unremarkably appears in several technological process industries, for example, the continuous stretching of plastic films, coal-oil slurries, metal spinning, metal extrusion, continuous casting, glass blowing, extrusion of a polymer sheet from die etc. Due to the flow diversity in nature, the rheological features of non-Newtonian fluids cannot be captured by a single constitutive relationship between stress and shear rate. For this reason, a variety of non-Newtonian fluid models (exhibiting different rheological effects) are available in the literature [1-7]. Eyring-Powell model fluid is one of these models. Eyring-Powell model was first introduced by Powell and Eyring in1944 [8]. However, the literature survey indicates that very low energy has been devoted to the flows of Eyring-Powell model fluid with variable viscosity. It can be used to formulate the flows of modern industrial materials such as powdered graphite and ethylene glycol. Patel and Timol [9] numerically examined the flow past a wedge, using the Powell–Eyring model. The flow and heat transfer of the Powell–Eyring fluid over a continuously moving surface in the presence of a free-stream velocity was investigated by Hayat et al. [10]. The boundary layer flow of the Powell-Eyring fluid over a linearly stretching sheet was analyzed by Javed [11]. The flow and heat transfer of Powell-Eyring fluid over a moving surface was examined by Jalil [12]. Many papers on the boundary layer flow of Powell–Eyring fluid [13–16] are investigated in different situations.

The flow over a stretching plate was first considered by Crane [17] who found a closed form analytic solution of the self-similar equation for steady boundary layer flow of a Newtonian fluid. Wang [18] discussed the three-dimensional flow behavior due to the stretching surface. The uniqueness of the solution obtained by Crane [17] was presented by McLeod and Rajagopal [19]. On the other hand, Chiam [20] investigated the stagnation-point flow towards a stretching sheet and found no boundary layer structure near the sheet. Mahapatra and Gupta [21] reinvestigated the same stagnation-point flow towards a stretching sheet and found two kinds of boundary layer near the sheet depending on the ratio of the stretching and straining rates. Ishak et al.[22] studied the MHD stagnation point flow towards a stretching sheet. Pop et al. [23] studied theoretically the steady two-dimensional stagnation-point flow of an incompressible fluid over a stretching sheet by taking into account of radiation effect. Vajravelu [24] studied flow and heat transfer over a non-linear stretching sheet. Prasad et al.[25] investigated the effects of variable viscosity and variable thermal conductivity on the hydromagnetic flow and heat transfer over a nonlinear stretching sheet. Abel et al. [26] investigated the steady buoyancy-driven dissipative magneto convective flow from a vertical nonlinear stretching sheet. Hayat et al. [27] studied the problem of stagnation-point flow toward a nonlinearly stretching surface in a micropolar fluid. Several other studies have addressed various aspects of heat and flow characteristics[28–31].

In all these above studies, the flow and temperature fields are considered to be over linear and non-linear stretching sheet. An interesting extension to the problem of stretching sheet has been considered in the present paper is the effect of heat source/sink which is very important in cooling processes. Ibrahim and Shanker [32] have used Quasi-Linearization technique to investigate unsteady MHD boundary layer flow and heat transfer due to stretching sheet in the presence of heat source or sink. Khan [33] studied heat transfer in a viscoelastic fluid flow over a stretching surface with heat source/sink, suction/blowing and radiation. The analytical results were carried out by Vajravelu and Hadjinicolaou[34] who took the effects of viscous dissipation and internal heat generation into account. Veena et al.[35] obtained the solutions of heat transfer in a visco elastic fluid past a stretching sheet with viscous dissipation and internal heat generation. Effects of heat source/sink on the boundary layer flow over a stretching sheet were studied by several authors[36-38].

Motivated by the literature above, the present work aimed to study the stagnation point flow of a MHD Powell-Eyring fluid over a nonlinearly stretching sheet in the presence of heat source/sink To achieve this purpose, we used the well-known numerical technique called the Keller-Box method.

Mathematical Formulation:

Consider the steady laminar flow of a non-Newtonian fluid obeying Powell-Eyring model over a nonlinear stretching surface. For the flow problem, let the x-axis be taken along the surface and y-axis be normal to it. Two equal and opposite forces are applied along the x-axis, keeping the origin fixed. The surface is stretched in the x-direction such that the x-component of the velocity varies non-linearly along it, i.e. $U_w(x) = cx^n$ where c > 0 is constant of proportionality and n is a power index. A magnetic field of uniform strength B_0 is applied perpendicular to the surface. The magnetic Reynolds number is taken to be small enough so that the induced magnetic field can be neglected in comparison to the applied magnetic field. It is also assumed that the ambient fluid is moved with a velocity $U_\infty(x) = ax^n$, where a > 0 is a constant.

The Cauchy stress tensor in Powell-Eyring fluid is given by

$$\tau_{ij} = \mu \frac{\partial u_i}{\partial x_j} + \frac{1}{\beta} \sinh^{-1}\left(\frac{1}{C} \frac{\partial u_i}{\partial x_j}\right) \tag{1}$$

where μ is the viscosity coefficient , β and C are the material fluid parameters.

In this situation under the usual boundary layer approximation, the continuity, momentum, energy equations are :

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \tag{2}$$

$$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = \left(\nu + \frac{1}{\rho\beta C}\right)\frac{\partial^2 u}{\partial y^2} - \frac{1}{2\rho\beta C^3}\left(\frac{\partial u}{\partial y}\right)^2 \frac{\partial^2 u}{\partial y^2} + U_\infty \frac{\partial U_\infty}{\partial x} - \frac{\sigma B^2(x)}{\rho}(u - U_\infty) \tag{3}$$

$$u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} = \frac{\kappa}{\rho C_p}\frac{\partial^2 T}{\partial y^2} - \frac{1}{\rho C_p}\frac{\partial q_r}{\partial y} + \frac{Q_0}{\rho C_p}(T - T_\infty) \tag{4}$$

where u, v are the velocity components in x, y direction respectively, ν is the kinematic viscosity, ρ is the viscosity, κ is the thermal diffusivity of the fluid , C_p is the specific heat and $B = B_0\, x^{\frac{n-1}{2}}$ is the magnetic parameter.

Following Rosseland approximation, the radiative heat flux q_r is modelled as

$$q_r = -\left(\frac{4\sigma^*}{3k^*}\right)\frac{\partial T^4}{\partial y} \tag{5}$$

where σ^* is the Stefan-Boltzmann constant and k^* is the absorption coefficient. Assuming that the differences in temperature within the flow are such that T^4 can be expressed as a linear combination of the temperature, we expand T^4 in a Taylor's series about T_∞ as follows

$$T^4 = T_\infty^4 + 4T_\infty^3(T - T_\infty) + 6T_\infty^2(T - T_\infty)^2 + \cdots, \tag{6}$$

and neglecting the higher order terms beyond first degree in $(T - T_\infty)$ we get

$$T^4 \cong -3T_\infty^4 + 4T_\infty^3 T \tag{7}$$

substituting eq.(7) in eq.(5) we get

$$\frac{\partial q_r}{\partial y} = -\frac{16T_\infty^3\sigma^*}{3k^*}\frac{\partial^2 T}{\partial y^2} \tag{8}$$

using eq.(8) in eq.(4) we obtain

$$u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} = \frac{\kappa}{\rho C_p}\frac{\partial^2 T}{\partial y^2} + \frac{1}{\rho C_p}\frac{16T_\infty^3\sigma^*}{3k^*}\frac{\partial^2 T}{\partial y^2} + \frac{Q_0}{\rho C_p}(T - T_\infty) \tag{9}$$

The suitable boundary conditions are given by

$$u = U_w = cx^n, \quad v = 0, \quad T = T_w, \quad \text{at } y = 0$$

$$u \to U_\infty, \quad T \to T_\infty \quad \text{at } y \to \infty$$

Here, $c\ (c > 0)$ is the surface stretching sheet related parameter. T_w, T_∞ are the uniform temperature at the sheet, free stream temperature respectively and n is the power index related to the surface stretching speed.

With the help of following similarity transformations

$$u = cx^n f'(\eta)\,, \quad v = \sqrt{c\,\nu\ \frac{(n+1)}{2}}\, x^{\frac{n-1}{2}}\left[\, f(\eta) + \frac{n-1}{n+1}\,\eta\, f'(\eta)\right],$$

$$\theta(\eta) = \frac{T - T_\infty}{T_W - T_\infty} \quad , \qquad \eta = y\sqrt{\frac{c(n+1)}{2\nu}}\, x^{\frac{n-1}{2}}$$

The equations (3) and (4) are transformed into coupled non linear ordinary differential equations as follows.

$$(1+\Gamma)f''' - \Gamma\beta f''^{2} f''' + ff'' - \frac{2n}{n+1}\left(f'^{2} - \lambda^2\right) + M(\lambda - f') = 0$$

$$(1 + \frac{4R}{3})\ \theta'' + \Pr(f\theta' + \frac{2}{n+1}Q\theta) = 0$$

and the boundary conditions are transformed into

$$f'(\eta) = 1,\ \ f(\eta) = 0,\ \ \theta(\eta) = 1\ \ at\ \ \eta = 0$$

$$f'(\eta) \to \lambda, \qquad \theta(\eta) \to 0 \quad at\ \ \eta = \infty$$

Where $Pr = \frac{\mu c_p}{\kappa}$ is the Prandtl Number, $Q = \frac{Q_0 x}{U_w \rho c_p}$ is the Heat source for $Q > 0$, and for sink $Q < 0$ parameter and $R = \frac{4\sigma^* {T_\infty}^3}{kk^*}$ is the Radiation parameter, $\lambda = \frac{a}{c}$ is the velocity ratio parameter, $\Gamma = \frac{1}{\mu\beta C}$ and $\beta = \frac{\rho {U_w}^3}{2\mu x C^2}\frac{(n+1)}{2}$ are dimensionless material fluid parameters

Hence the dimensionless form of Skin friction C_f and the Local Nusselt number Nu_x are given by

$$C_f\,(Re_x)^{1/2} = (1+\Gamma)f''(0) - \frac{\Gamma}{3}\beta f''^{3}(0)\,, \qquad (Re_x)^{-1/2}Nu_x = -(1+\frac{4R}{3})\ \theta'(0)$$

where $Re_x = \frac{U_w\, x}{\nu}$ is the local Reynolds number.

Results and Discussion :

The stagnation point flow of a magnetohydrodyanamic Powell-Eyring fluid over a nonlinearly stretching sheet in the presence of heat source/sink were solved by applying Keller Box method. In this section, we concentrate for the variations of emerging parameters on the velocity and temperature, the skin friction and the local Nusselt number. In particular, the variations of parameters like Magnetic parameter(M), Velocity Ratio parameter (λ), Prandtl number (Pr) , Radiation parameter (R), Heat source(Q)and the nonlinear stretching parameter(n), dimensionless material fluid parameters (Γ and β) are analyzed. The values of the parameters are fixed as $\beta = 0.5$, $\lambda = R = Q = \Gamma = 0.2$, $Pr = 0.71$, $n = 2$, $M = 1$, unless otherwise specified.

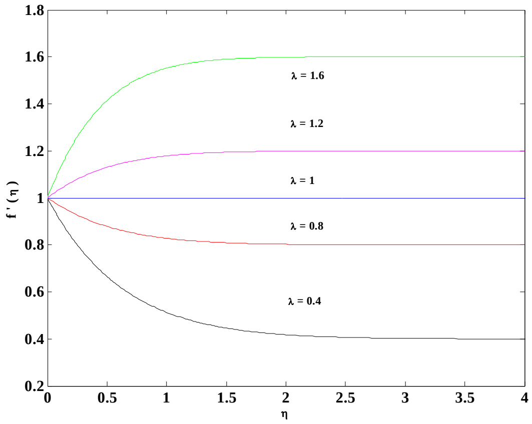

Fig 1: Effect of λ on velocity profile

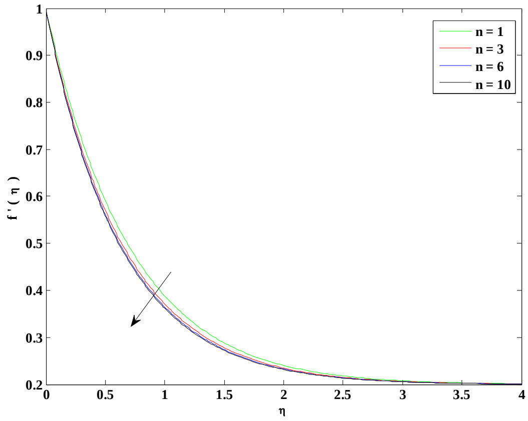

Fig 2 : Effect of nonlinear stretching parameter on velocity profile

Figure 1 illustrates the influence of velocity ratio parameter λ on velocity graph. When $\lambda > 1$ i.e., the free stream velocity exceeds the stretching sheet velocity , the flow velocity increases and the boundary layer thickness decreases with increase in λ. Moreover for $\lambda < 1$, when the free stream velocity less than stretching velocity, the flow field velocity increases and boundary layer thickness also increases. When $\lambda = 1$ (the velocity of the stretching sheet equals to free stream velocity) there is no flow near the sheet.

Figure 2 shows the influence of n on the velocity profile. Increasing the value of n decreases velocity of the fluid. The boundary layer thickness also decreases as n increases.

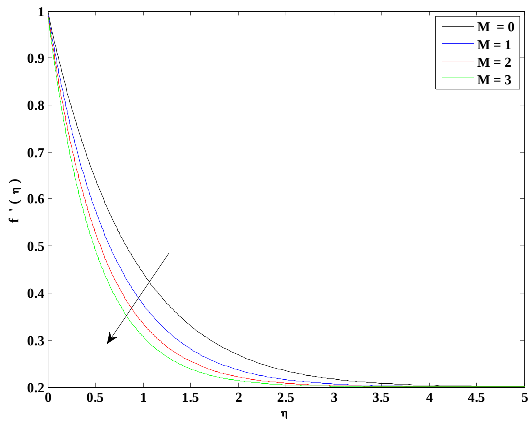

Fig 3: Effect of M on velocity profile

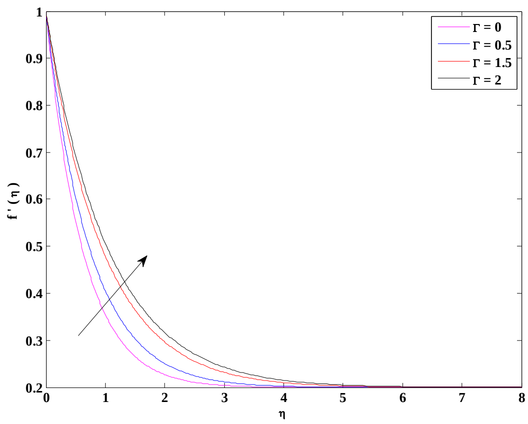

Fig 4 : Effect of Γ on velocity profile

Fig. 3 exhibits the effect of magnetic parameter on the dimensionless velocity. It is observed that the velocity profile is reduced with increasing values of M .An increase in magnetic parameter M results in a strong reduction in dimensionless velocity. This is due to the fact that magnetic field introduces a retarding body force which acts transverse to the direction of the applied magnetic field. This body force, known as the Lorentz force, decelerates the boundary layer flow.

Figures 4 and 5 shows the influence of fluid parameter Γ for velocity and temperature profiles Variation in the x-component of velocity with an increase in the fluid parameter Γ can be described from Fig. 4. Here, the velocity field increases with an increase in Γ.

Temperature profiles for different values of Γ are shown in Fig 5. It is seen that temperature profile is an decreasing function of Γ.

Variation in temperature profile with an increase in β can be seen from Fig. 6. It is noticed that the temperature decreases and boundary layer thins when β is increased.

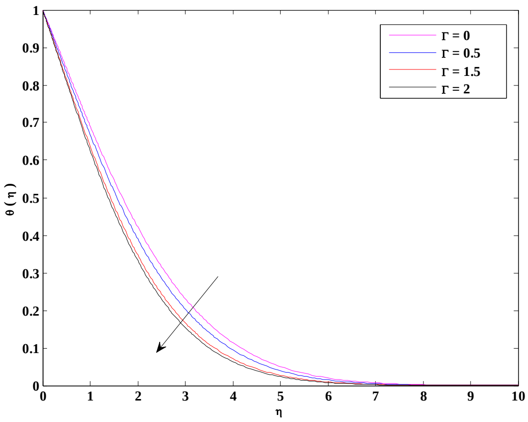

Fig 5 : Effect of Γ on temperature profile

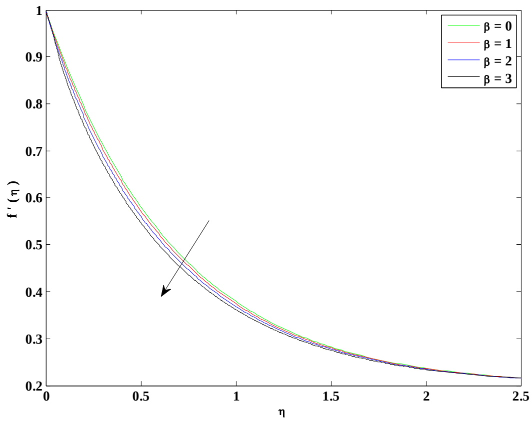

Fig 6 : Effect of β on temperature profile

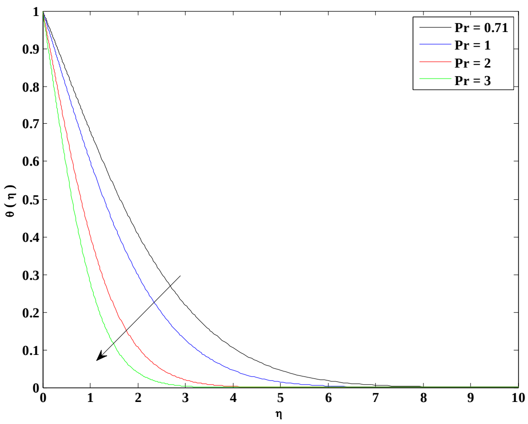

Fig 7 : Effect of Pr on temperature profile

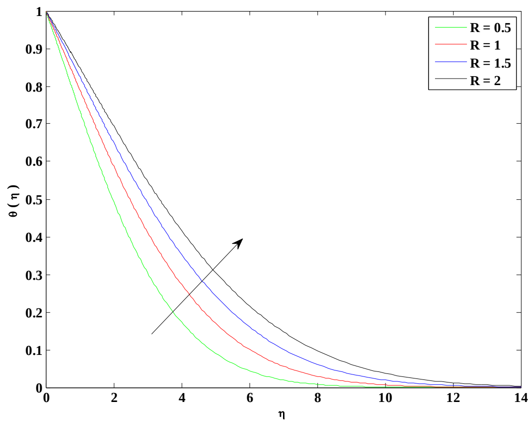

Fig 8 : Effect of R on temperature profile

Fig. 7 represents the variation of temperature graph with respect to Prandtl number Pr. The graph depicts that the temperature decreases when the values of Prandtl number Pr increases This is due to the fact that a higher Prandtl number fluid has relatively low thermal conductivity, which reduces conduction and thereby the thermal boundary layer thickness; and as a result, temperature decreases. Increasing Pr is to increase the heat transfer rate at the surface because the temperature gradient at the surface increases.

The influence of the thermal radiation on temperature is depicted in Fig. 8. It is interesting to note that thermal radiation has a major influence on the temperature distribution in the fluid. We observed that the fluid temperature increases by increasing thermal radiation. This is due to the fact that increase in the values of the thermal radiation parameter increases radiation in the boundary layer, and hence increases the values of the temperature profiles in the thermal boundary layer.

Fig. 9 shows the variation of temperature with respect to heat source/ sink When heat sink (Q < 0) increases more heat removed from the sheet which reduce the thermal boundary-layer thickness. This reduce the temperature of the sheet. It is observed that when heat source (Q > 0) increases the temperature increases. This due to the fact that heat source can add more heat to the stretching sheet which increases its temperature. This increases the thermal boundary layer thickness.

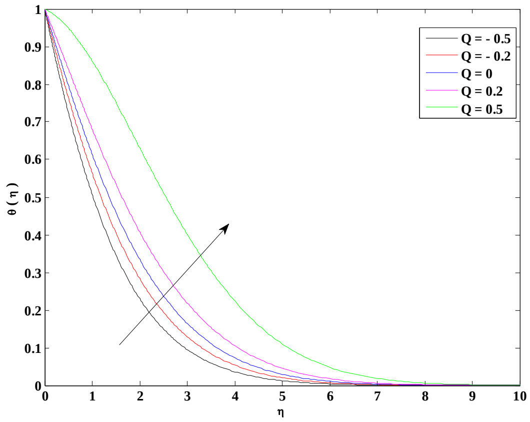

Fig 9 : Effect of Q on temperature profile

Table 1: Comparison of Wall temperature gradient $-\theta'(0)$ for different values of Pr

Pr	Grubka and Bobba [39]	Chen[40]	K.V.Prasad et.al [41]	Present Work
0.72	0.4631	0.46315	0.463146	0.46314
1	0.587	0.58199	0.58267	0.58198
3	1.1652	1.16523	1.165171	1.1652
5	-	-	1.568008	1.5681
10	2.308	2.30796	2.308028	2.3081
100	7.7657	-	7.769666	7.7697

Table 2: Computed values of Local Nusselt number $-\theta\,'(0)$ for various values of Pr, R and Q

Pr	R	Q	$-(1+\frac{4R}{3})\ \theta'(0)$
1			0.50037
2			0.80778
3			1.05467
	0.1		0.37951
	0.5		0.422
	1		0.4619
		-0.2	0.63234
		-0.1	0.58097
		0.1	0.46236
		0.2	0.39148

Table 3 : Computed values of skin friction coefficient $Re_x^{\frac{1}{2}}C_f$ for various parameters

Γ	β	λ	M	n	$Re_x^{\frac{1}{2}}C_f$
0.2					1.4021
0.4					1.50607
0.6					1.60573
	0.2				1.41146
	0.6				1.39885
	0.8				1.39212
		0.2			1.4021
		0.4			1.3294
		0.6			0.80611
			1		1.4021
			2		1.64117
			3		1.84599
				1	1.3189
				3	1.44181
				5	1.4804

In order to find the accuracy of our work, a comparison has been made with the previous results of Grubka and Bobba [39], Chen[40] , K.V.Prasad et.al [41] and we obtained excellent agreement which are displayed in Table 1.Table 2 presents the variation in Local Nusselt number with respect to various flow parameters. It shows that heat transfer rate $-\theta'(0)$ increases for radiation parameter R and Prandtl number but for heat source/sink $-\theta'(0)$ decreases.Table 3 shows the variations of skin friction coefficient $Re_x^{\frac{1}{2}}C_f$ for various parameters. It can be observed from the table that the values of skin friction coefficient increases for all parameters except for velocity ratio parameter λ and dimensionless fluid parameter β.

Conclusion:

The stagnation point flow of a MHD Powell-Eyring fluid over a nonlinearly stretching sheet in the presence of heat source/sink has been analyzed. The transformed nonlinear ordinary differential equations are solved by using the well-known Keller Box method. The numerical results obtained are in excellent agreement with the previously published data available in the literature in limiting condition for some particular cases of the present study. The following important observations can be derived from the numerical results:

- For the free stream velocity dominating the stretching velocity ($\lambda > 1$), the velocity field increases and momentum boundary layer thickness decreases; however, the boundary layer thickness and flow field velocity increases for $\lambda < 1$.
- Influence of both magnetic and nonlinear stretching parameters decreases the velocity profile.
- As the fluid parameter Γ increases, the velocity profile increases whereas the temperature profile decreases.
- The thermal boundary layer thickness decreases with the effect of Prandtl number but quite opposite effect is observed for radiation parameter.
- The thermal boundary layer thickness decreases for heat sink ($Q < 0$) and increases for heat source ($Q > 0$).

References:

[1] Harris J (1977) Rheology and non-Newtonian flow, Longman.

[2] Bird RB, Curtiss CF, Armstrong RC, Hassager O (1987) Dynamics of polymeric liquids. Wiley.

[3] K. R. Rajagopal, "A note on unsteady unidirectional flows of a non-Newtonian fluid," International Journal of Non-Linear Mechanics,vol.17,no.5-6,pp.369–373,1982.

[4] K.R.Rajagopal and R.K.Bhatnagar,"Exact solutions for some simple flows of an Oldroyd-B fluid," Acta Mechanica, vol. 113, no. 1–4, pp. 233–239, 1995.

[5] K. R. Rajagopal, "On the creeping flow of the second-order fluid," Journal of Non-Newtonian Fluid Mechanics,vol.15,no. 2, pp. 239–246, 1984.

[6] T. Hayat, S. Asghar, and A. M. Siddiqui, "Periodic unsteady flows of a non-Newtonian fluid," Acta Mechanica,vol.131,no.3-4, pp. 169–175, 1998.

[7] T. Hayat, S. Asghar, and A. M. Siddiqui, "Some unsteady unidirectional flows of a non-Newtonian fluid," International Journal of Engineering Science,vol.38,no.3,pp.337–346,2000.

[8] R. E. Powell and H. Eyring, "Mechanism for Relaxation Theory of Viscosity," Nature 154, 427–428 (1944)

[9] M. Patel and M. G. Timol, "Numerical Treatment of Powell–Eyring Fluid Flow Using Method of Asymptotic Boundary Conditions," Appl. Numer. Math. 59, 2584–2592 (2009).

[10] T. Hayat, Z. Iqbal, M. Qasim, and S. Obaidat, "Steady Flow of an Eyring–Powell Fluid over a Moving Surface with Convective Boundary Conditions," Int. J. Heat Mass Transfer. 55, 1817–1822 (2012).

[11] T. Javed, N. Ali, Z. Abbas, M. Sajid, Flow of an Eyring-Powell Non-Newtonian Fluid over a Stretching Sheet Chemical Engineering Communications 200 (2013) 327-336.

[12] M. Jalil, S. Asghar, S. M. Imran, Self similar solutions for the flow and heat transfer of Powell-Eyring fluid over a moving surface in a parallel free stream, International Journal of Heat and Mass Transfer 65 (2013) 73-79.

[13] Mushtaq A, Mustafa M, Hayat T, Rahi M, Alsaedi A (2013) Exponentially stretching sheet in a Powell-Eyring fluid: Numerical and series solutions. Z.Naturforsch. 68a: 791–798.

[14] Khader MM, Megahed AM (2013) Numerical studies for flow and heat transfer of the Powell-Eyring fluid thin film over an unsteady stretching sheet with internal heat generation using the chebyshev finite difference method. J. Applied Mechanics Technical Phys, 54: 440–450.

[15] V. Sirohi, M. G. Timol, and N. L. Kalathia, “Numerical Treatment of Powell–Eyring Fluid Flow Past a 90 degree Wedge,” Reg. J. Energy Heat Mass Transfer 6 (3), 219–228 (1984).

[16] Zaman H (2013) Unsteady Incompressible Couette Flow Problem for the Eyring-Powell Model with Porous Walls. American J. Computational Math, 3:313–325.

[17] Crane L J. Flow past a stretching plate. Zeitschrift für Angewandte Mathematik und Physik, 1970, 21(4): 645–647

[18] Wang C Y. The three dimensional flow due to a stretching flat surface. Physics of Fluids, 1984, 27(8): 1915–1917

[19] McLeod J B, Rajagopal K R. On the uniqueness of flow of a Navier–Stokes fluid due to a stretching boundary. Archive for Rational Mechanics and Analysis, 1987, 98(4): 385–393

[20] Chiam TC. Stagnation-point flow towards a stretching plate. J Phys Soc Jpn 1994;63:2443–4.

[21] Mahapatra TR, Gupta AS. Magnetohydrodynamic stagnation-point flow towards a stretching sheet. Acta Mech 2001;152:191–6.

[22] A. Ishak, K. Jafar, R. Nazar, I. Pop, MHD stagnation point flow towards a stretching sheet, Physics A 388 (2009) 3377–3383.

[23] S.R. Pop, T. Grosan, I. Pop, Radiation effects on the flow near the stagnation point of a stretching sheet, Tech. Mech. 29 (2004) 100–106.

[24] K. Vajravelu, Viscous flow over a nonlinearly stretching sheet, Appl. Math. Comput. 124 (2001) 281–288.

[25] K.V. Prasad, K. Vajravelu, P.S. Dattri, Mixed convection heat transfer over a non-linear stretching surface with variable fluid properties, Int. J. Non-linear Mech. 45 (2010) 320–330.

[26] M.S. Abel, K.A. Kumar, R. Ravikumara, MHD flow and heat transfer with effects of buoyancy, viscous and joule dissipation over a nonlinear vertical stretching porous sheet with partial slip, Engineering 3 (2011) 285–291.

[27] T. Hayat, T. Javed, and Z. Abbas, “MHD flow of a micropolar fluid near a stagnation-point towards a non-linear stretching surface,” Nonlinear Analysis: Real World Applications, vol.10, no.3, pp. 1514–1526, 2009.

[28] P. Rana, R. Bhargava, Flow and heat transfer of a nanofluid over a nonlinearly stretching sheet: a numerical study, Commun.Nonlinear Sci. Numer. Simul. 17 (2012) 212–226.

[29] Z. Abbas,T. Hayat, Stagnation Slip Flow and Heat Transfer over a Nonlinear Stretching Sheet.

[30] T. Hayat,T. Javed, Z. Abbas MHD flow of a micropolar fluid near a stagnation-point towards a non-linear stretching surface Volume 10, Issue 3, June 2009, Pages 1514–1526

[31] Mabood, F., Khan, W.A. and Ismail, A.I.M. (2015) MHD Boundary Layer Flow and Heat Transfer of Nanofluids over a Nonlinear Stretching Sheet: A Numerical Study. Journal of Magnetism and Magnetic Materials, 374, 569-576.

[32] W Ibrahim and B. Shanker Int. J. Appl. Math. Mech. 8 18 (2012)

[33] Khan, S.K.: Heat transfer in a viscoelastic fluid flow over a stretching surface with heat source/sink, suction/blowing and radiation. Int. J. Heat Mass Tran. 49, 628–639 (2006).

[34] Vajravelu, K. and Hadjinicolaou, A. Heat transfer in a viscous fluid over a stretching sheet with viscous dissipation and internal heat generation. International Communications in Heat and Mass Transfer, 20(3), 417–430 (1993)

[35] Veena, P. H., Subhas-Abel, M., Rajagopal, K., and Pravin, V. K. Heat transfer in a visco-elastic fluid past a stretching sheet with viscous dissipation and internal heat generation. Zeitschrift f ur Angewandte Mathematik und Physik (ZAMP), 57(3), 447–463 (2006)

[36] Abo-Eldahab Emad, M., El Aziz Mohamed, A., 2004. Blowing suction effect on hydro magnetic heat transfer by mixed convection from an inclined continuously stretching surface with internal heat generation/absorption. Int. J. Therm. Sci. 43, 709–719.

[37] Sharma, P. R. and Singh, G. 2008. Effect of variable thermal conductivity and heat source/sink on Magnetohydrodynamic flow near a stagnation point on a linearly stretching sheet. Journal of Applied Fluid Mechanics, 1: 13-21.

[38] Mohamed RA, Abo-Dahab SM. Influence of chemical reaction and thermal radiation on the heat and mass transfer in MHD micropolar flow over a vertical moving porous plate in a porous medium with heat generation. Int J Thermal Science 2009;48:1800–13.

[39] Grubka LG, and Bobba KM (1985). Heat transfer characteristics of a continuous stretching surface with variable temperature. ASME J. Heat Transfer. 107, pp. 248–250.

[40] Chen CK, and Char MI (1988). Heat transfer of a continuous stretching surface with suction or blowing. J. Math. Anal. Appl.135, pp. 568–580.

[41] K. V. Prasad , P. S. Datti and B. T. Raju, "Momentum and Heat transfer of a Non-Newtonian Eyring-Powell fluid over a non-isothermal stretching sheet". International Journal of Mathematical Archive- 4(1), 2013, 230-241.