MHD Viscous Dissipative Fluid Flows in a Channel with a Stretching and Porous Plate with Radiation Effect

B. Shankar Goud, J. Venkata Madhu, MN. Raja Shekar

Abstract*: *The current study focuses on two-dimensional steady convective fluid flow in the occurrence of heat and mass transfer plates aligned parallelly, involving radiation effect and viscous dissipation. Here the bottom plate is porous and stretching. The governing equations are adapted into non-linear, ordinary linear equations with similarity functions and evaluated by MATLAB in the embedded bvp5c solution. The impacts of the flow factors on the different profiles are investigated and the results are illuminated graphically

Keywords*: *bvp 5c, Viscous Dissipation, Suction, MHD, Stretching sheet.

I. INTRODUCTION

In polymer technology and metallurgy, heat & mass transfer in a channel due to an extending surface plays a significant part. For example, multiple specific polymer processes include cooling coherent strips expelled from a die by illustration through a quiet stretched out. Other patterns include ongoing metal casting, plastic manufacturing, glass blowing and rubber sheets, extruded material subjects through a die and fibre spinning. The flow over a shrinking sheet has taken numerous researchers into account. Gupta and Gupta [1] checked with suction and blowing on a stretching sheet and Acharya et.al [15] analyzed with thermal source on an accelerating surface with heat and mass transfer. Mukhopadhyay and Layek [2] have evaluated the impacts of thermal radiation and varying fluid viscosity on free convective flow and heat transfer over a porous stretching surface. The similarity solutions for MHD were discussed by Ferdows et.al [3] through the perpendicular porous plate with suction. Misra and Adhikary [4] considered MHD oscillating channel flow, heat and mass transfer in the presence of chemical reaction to a physiological fluid. SivaReddy and SrinivasaRaju [5] considered an infinite vertical plate set in a porous medium with viscous dissipation as the transient MHD free convective flow past. Natural convective heat and mass transfer for MHD flow were analyzed by Rashidi et.al [6] via a permeable vertical stretch sheet with radiation and buoyancy impacts. Several investigations Like, BSGoud and Rajashekar [7,13], Prabhakar Reddy [8], Mukhopadhyay [9] and Makinde and Ogulu [10] have used different methods and found certain applications. Sharma and Singh [11] discussed The impacts of heat source / sink on MHD stream close a stagnation point on a variable thermal conductivity linearly stretching sheet. Chemical reaction, radiation effects are analyzed on semi- infinite moving plate with heat source/sink was addressed by Ibrahimet.al [12]. Chamkha and Quadri [14] examined instantaneous heat and mass transmission through natural convection from a plate fixed in a permeable medium with heat dispersion influences. Rajesh and Varma [16] explored the variable temperature, radiation effects on accelerated vertical plate which is exponentially.. B. S Goud and K.S Kumar [18] studied on hydromagnetic flow over a stretching surface with power-law velocity application.

The reason for this analysis is the examination of the thermal radiation effects and suction parameter in the existence of viscous dissipation on two dimensional hydrodynamic fluid flows between two parallel plates, bvp5c approach was efficiently implemented in this examination to solve the nonlinear differential equation.

II. MATHEMATICAL FORMULATION

To formulate this problem, let us consider an incompressible steady fluid flow between the two vertical plates aligned parallelly and electrically conducting in the presence of a lower porous plate and an extending sheet. Plate and the x-direction taken in the same direction and assuming the fluid flow is perpendicular to it as well as the y-axis. In addition, two equivalent force factors are implemented along x-direction the bottom layer considering a steady flux velocity v_0 at $y = 0$ and the top plate to be $y = h$ of a tube maintained in a temperature T_w and T_h.The geometry and governing equations are under these circumstances.

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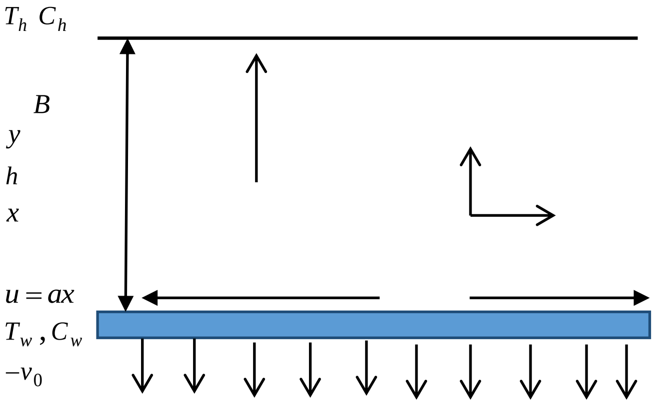

Fig. 1: Geometry of the physical Problem

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \qquad \ldots(1)$$

$$u\frac{\partial u}{\partial x} + v\frac{\partial v}{\partial y} + \frac{\sigma B_0^2}{\rho}u = \upsilon\frac{\partial^2 u}{\partial y^2} \qquad \ldots(2)$$

$$u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} = \frac{1}{\rho C_p}\left[k\frac{\partial^2 T}{\partial y^2} + \upsilon\left(\frac{\partial u}{\partial y}\right)^2 - \frac{\partial q_r}{\partial y}\right] \ldots(3)$$

$$u\frac{\partial C}{\partial x} + v\frac{\partial C}{\partial y} = D\frac{\partial^2 T}{\partial y^2} \qquad \ldots(4)$$

Where (u, v) are the components of the velocity along with (x, y) direction, C, T are the respective concentration and temperature.

The proper boundary conditions are given by

$$\left.\begin{array}{l} u = U(x) = ax, \\ v = -\upsilon_0, \\ T = T_w, \\ C = C_w \end{array}\right\} at\ y \to 0,\ \& \quad \left.\begin{array}{l} u \to 0, \\ v = 0, \\ T \to T_h, \\ C \to C_h \end{array}\right\} as\ y \to h \ldots(5)$$

By employing theRosseland approximation, consider q_r is the radiative thermal flux of the fluid is provided as

$$q_r = -\frac{4}{3}\frac{\sigma^*}{k^*}\frac{\partial T^4}{\partial y} \qquad \ldots(6)$$

Where Stefan-Boltzmann σ^* is the constant and k^* is the mean absorption coefficient. Assuming that the temperature variations within the flow are low enough to consent the free stream temperature T^4 to be elaborated in Taylor's series about the free flow temperature T_∞ to produce

$$T^4 \cong 4T_h^3 T - 3T_h^4 \,. \qquad \ldots(7)$$

By using the following similarity conversions $\eta = y/h$, $u = axf'(\eta)$, $\theta(\eta) = T - T_h / T_w - T_h$, $C - C_h = (C_w - C_h)\phi(\eta)$ and the dimensionless form of temperature and concentration factors as

$$M = \frac{\sigma B^2 h^2}{\rho\upsilon},\ \mathrm{Re} = \frac{ah^2}{\upsilon},\ R = \frac{kk^*}{4\sigma T_h^3},$$

$$\Pr = \frac{\mu C_p}{k}, Ec = \frac{(ax)^2}{C_p\left(T_w - T_h\right)},\ S = \frac{v_0}{ah},\ Sc = \frac{\upsilon}{D}$$

Eqns. (2) - (4) changes to the following form:

$$f''' + \mathrm{Re}\left(ff'' - (f')^2\right) = Mf' \qquad \ldots(8)$$

$$\theta'' + \frac{3\Pr\mathrm{Re}}{3R+4}\left(Rf\theta' + Ec(f'')^2\right) = 0 \qquad \ldots(9)$$

$$\phi'' + \mathrm{Re}\,Scf\phi' = 0 \qquad \ldots(10)$$

The suitable boundary conditions become in the following formula:

$$\begin{array}{l} at\ \eta \to 0:\ f = S,\ f' - 1, = 0 \quad \theta = 1,\ \phi = 1, \\ as\ \ \eta \to 1: f' \to 0,\ f \to 0,\ \theta \to 0,\ \phi \to 0, \end{array} \qquad \ldots(11)$$

On the bottom stretching sheet the local skin-friction coefficient (τ), Nusselt number (Nu), and Sherwood number (Sh) are specified by

$$\tau = \mu\left(\frac{\partial u}{\partial \eta}\right)_{\eta=0} = \frac{\tau_w}{\rho(ax)^2} \Rightarrow \frac{\mathrm{Re}\,x}{h}\tau = f''(0) \ \ldots(12)$$

$$Nu = h\left(\frac{\frac{\partial T}{\partial y}}{\left(T_h - T_w\right)}\right)_{\eta=0} \qquad \ldots(13)$$

$$Sh = h\left(\frac{\frac{\partial C}{\partial y}}{\left(T_h - T_w\right)}\right)_{\eta=0} \qquad \ldots(14)$$

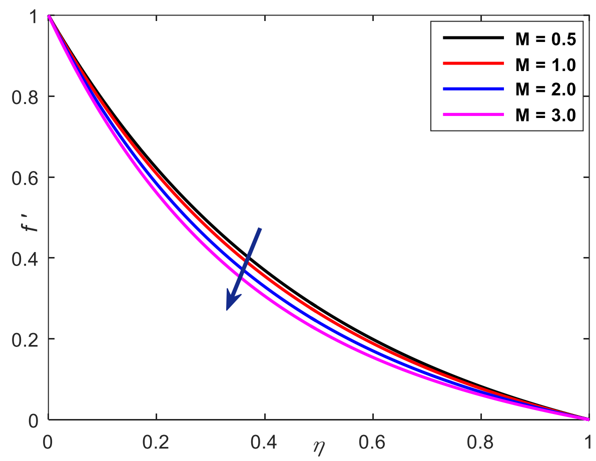

Fig. 2: **Velocity** v/s**M**

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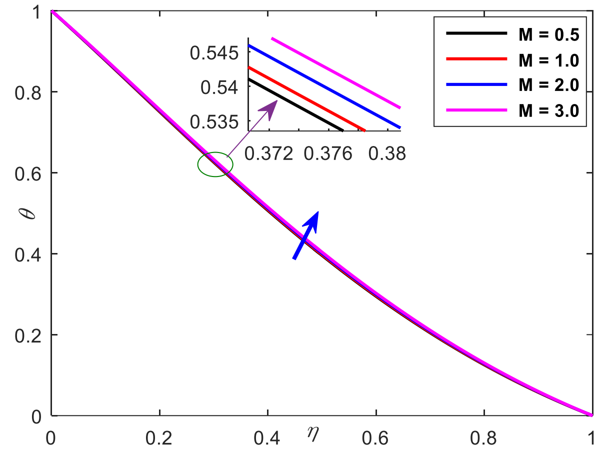

Fig. 3: Temperature v/s**M**

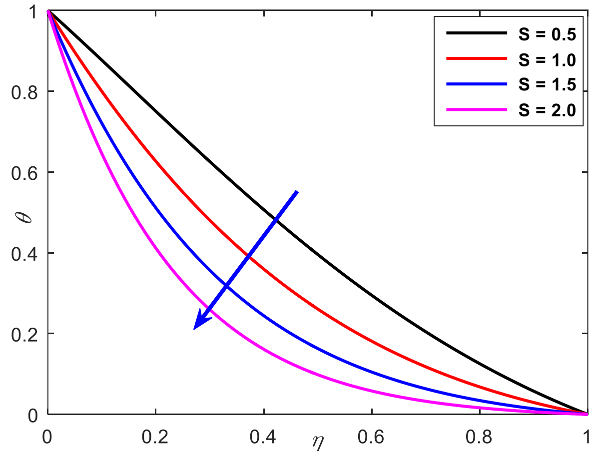

Fig. 6: Temperature v/s **S**

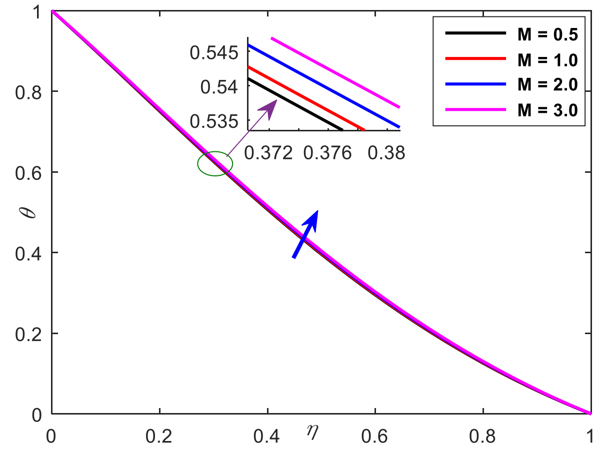

Fig. 4: Concentrationv/s **M**

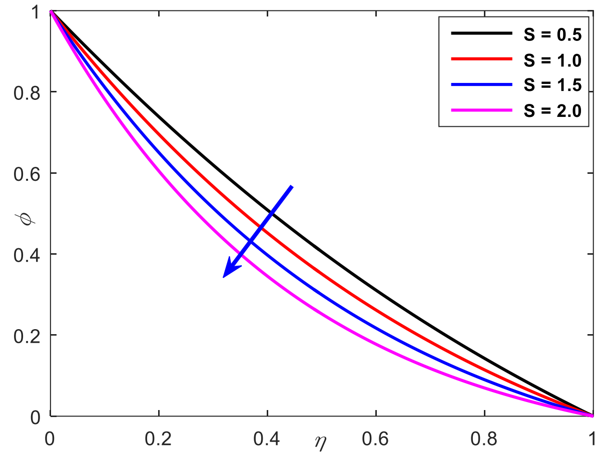

Fig. 7: **S** v/s **Concentration**

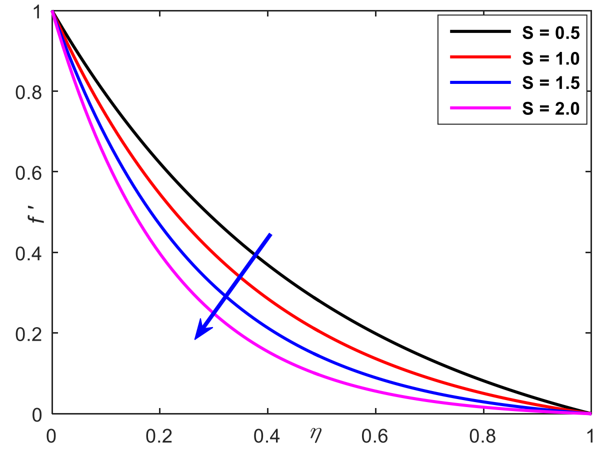

Fig. 5: Velocityv/s**S**

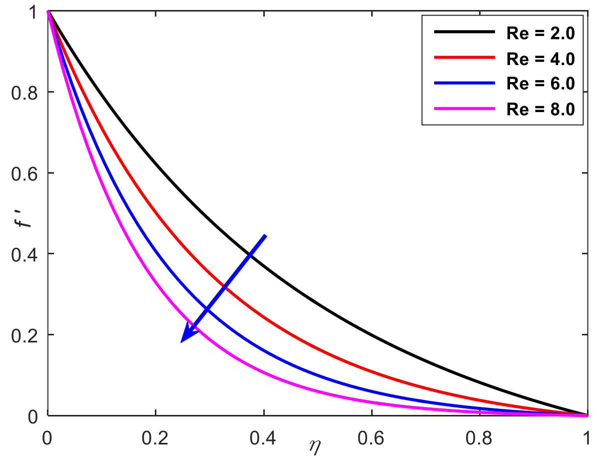

Fig. 8: Velocity v/s**Re**

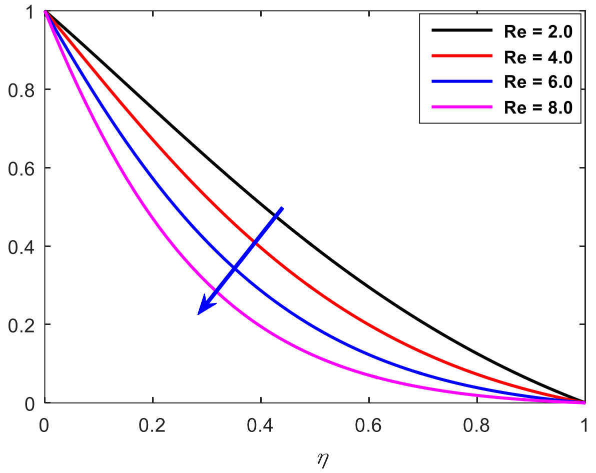

Fig. 9: Temperature v/s**Re**

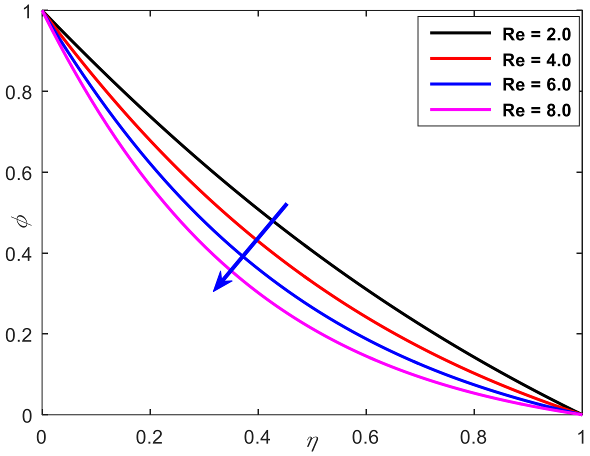

Fig. 10: Concentration v/s**Re**

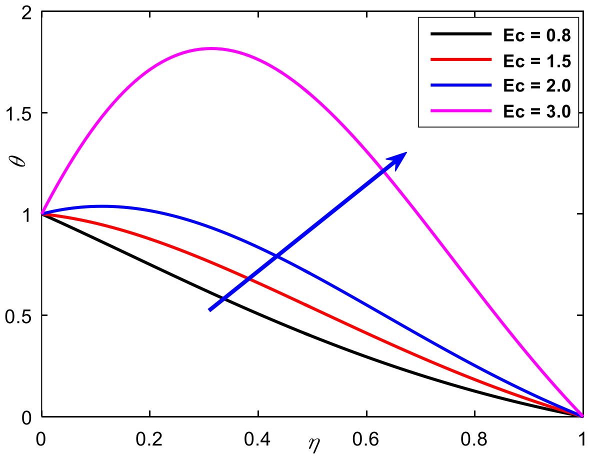

Fig. 11: Temperaturev/s **Ec**

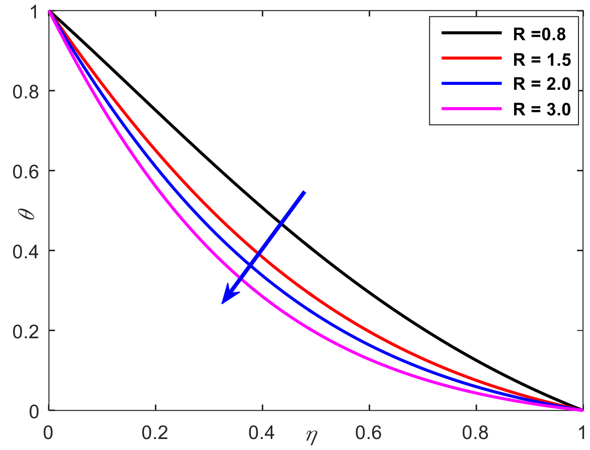

Fig. 12:Temperaturev/s**R**

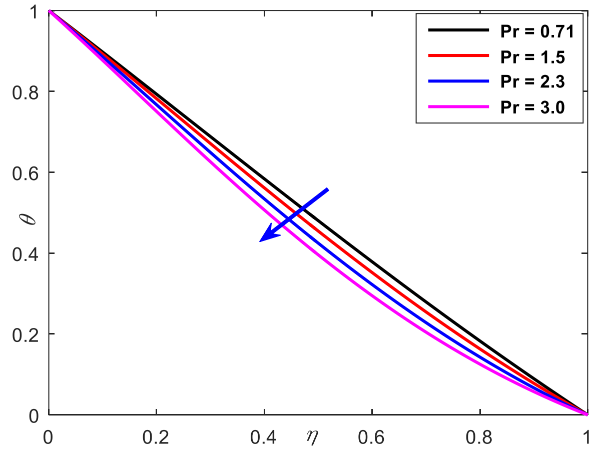

Fig. 13: Temperaturev/s**Pr**

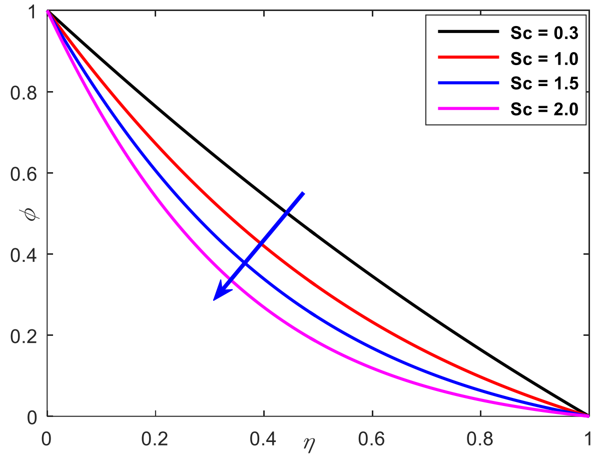

Fig. 14: Concentrationv/s**Sc**

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Table 1: **Impacts of varied flow factors on τ & Nu at the bottom plate**

M	Re	S	R	Pr	Ec	τ	Nu
0.5	2	0.5	0.8	3	0.8	-2.310000	1.197212
2.0						-2.645713	1.178006
3.0						-2.850523	1.166787
	4					-3.410354	1.663076
	6					-4.486997	2.405248
		1.0				-2.980710	2.13713
		1.5				-3.747520	3.195153
			1.5			-2.310000	1.922016
			2.0			-2.310000	2.241810
				2.3		-2.310000	1.117296
				1.5		-2.310000	1.053541
					1.5	-2.310000	0.273843
					2	-2.310000	-0.689033

Table 2: **Impacts of changed flow factors on Sh at the bottom plate.**

M	Re	S	Sc	Sh
0.5	2	0.5	0.3	1.222486
2				1.219292
3				1.217433
	4			1.447784
	6			1.679041
		1		1.39223
		1.5		1.575779
			1	1.829958
			1.5	2.321268

III. RESULTS AND DISCUSSION

Using similarity transformations on equations (1) -(4), a model of ordinary differential equations are obtained. The newly obtained equations are (9) -(11). Using MATLAB inbuilt solver bvp5c, these equations are solved numerically. Programmatically, the computations are performed using MATLAB for $Sc = 0.3, R = 0.8, S = 0.5, Re = 2, Pr = 3, Ec = 0.8, M = 0.5$.

Figures (2)-(14) are graphical illustrations of non-dimensional parameters specifically, Eckert number(Ec), suction parameter(S), magnetic parameter(M), Reynolds number (Re), Prandtl number (Pr), radiation parameter (R), etc., on temperature, velocity and concentration profiles. Tabular results are depicted in Nusselt number, skin friction coefficient, and Sherwood number,Figures (2)-(4) describe temperature, velocity and concentration profiles for varied magnetic field parameters(M). Velocity is found to decrease on increasing magnetic parameter (M) as higher transverse magnetic field creates Lorentz force that acts in the opposite direction of the stream. This apparently reduces the velocity but increases the thermal boundary layer thickness. As shown in Figures 3 and 4, concentration and temperature curves rise with a magnetic field increases. The impact of the suction parameter (S) in the concentration, velocity and temperature profiling is demonstrated in Figures (5) -(7). As known, suction parameter S carries the fluid closer to the surface end thereby reducing the width of the thermal boundary layer. This behavior is clearly depicted in figures 5-7 as higher suction parameter decreases the velocity, thermal and concentration distributions.

Velocity, Concentration and temperature profiles tend to decrease for increased Reynolds number as shown in Figures 8-10.

The differences in temperature distribution for various Eckert number(Ec) are shown in Figure (11). It specifies that the increase in the Ec indicates that the viscous dissipation increases and therefore the fluid temperature increases by adding energy to the fluid with the dissipative force.

Figures 12 & 13 demonstrate the distribution of temperature for varying radiation parameter (R) & Prandtl number(Pr) values. On increasing Prandtl number and radiation factor, the temperature is found to decrease. The temperature reduces because the greater numbers of the radiation parameter are the same as a rise in the conductivity over radiation, which causes the density of the thermal boundary layer to decrease.The amount of Prandtl describes the fraction of diffusivity of momentum to thermal diffusivity.

The concentration profile of various Schmidt number(Sc) values is presented in Figure (14). Clearly, with an increase in the Schmidt number, the fluid concentration decreases. On increasing Schmidt number (Sc), concentration boundary layer thickness tends to decrease with all parameters fixed. This behavior is due to increased Schmidt number implying a decrease in molecular diffusion.

Local skin friction coefficient values $f''(0)$, Sherwood number $-\phi'(0)$ and Nusselt number $-\theta'(0)$ for varying physical factors at lower stretching plate are tabulated in tables 1 and 2. On enhancing the values of Re, M, and S,There is a decrease in the skin friction coefficient. The Nusselt number increases on an increase in $Re, S, R,$ and Pr. Alternatively, a decrease with increasing M and Ec is observed. Table 2 illustrated the rise in Sherwood number due to an increase in Schmidt number (Sc), suction parameter (S), Reynolds number(Re) and while it is found to decrease on increasing the value of the magnetic parameter(M).

IV. CONCLUSION

Numerical results of concentration, velocity and temperature profiles, and this analysis made use of MATLAB inbuilt solver bvp5c. To summarize, the results can be listed as below:

- On increasing Re and variable suction parameter, concentration, velocity, and temperature outlines are noticed to decrease.
- The velocity profile is found to decrease with M.
- The temperature curves upturns with a rise in the M, Ec and Pr, but alternative behavior is seen on increasing R.

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- The concentration field rises with an increase in M and Sc.
- Local skin friction for stretching wall tends to fall with an increase in S, Re, and M. Also, for upper walls, local skin friction has been increased.
- Nussult number reduces with a rise of Ec, M rises while it rises with growing values of Re, S, R and Pr for the wall.
- Sc, S and also Re have the ability to boost mass transfer rate while M tends to drop the same.

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