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Free Radiation and Mass Transfer Effects on Mhd Convection Flow Along a Moving Vertical Porous Plate with Suction And Chemical Reaction in Presence of Soret and Dufour Effects

E.Hemalatha, A.Neeraja, R.L.V.Renuka Devi

Abstract: The paper discusses the take a look at of the Radiation and chemical response of the moving vertical permeable plate embedded in a permeable medium at the MHD boundary layer by taking into consideration the impacts of Soret and Dufour and the heat source. Equations supervise the flow are coupled andunraveled numerically utilizing Runge - Kutta fourth request strategy and Newton Raphson shooting method. The impact of different controlling Parameters on the speed, temperature, cognizance, pores and skin-rubbing coefficient, Nusselt range and Sherwood range are pointed out in detail. The findings are compared with available data obtained through analytical procedures and found to be in concurrent with the latter.

Key Words : Radiation, Mass transfer, Chemical reaction, Soret, Dufour.

I. INTRODUCTION

In engineering problems, boundary layers flow past a vertical surface in industry. Some practical areas of application include metal and polymer extrusion processes, wire drawing, chemical coating of flat plates and hot rolling. Many procedures in chemical engineering, such as metallurgical and polymer extrusion, involve molten liquid cooling. Soundalgekar [1] examined outcomes of convection On the Stokes issue past a boundless vertical plate. Later Soundalgekar [2] stretched out his own concern to mass exchange case. Bejan and Khair [3] studied the consequences of warmth and mass transfer on natural convection glide in a porous medium. Cortell [4] studied the radiation effects with heat transfer on power-law fluid past an infinite porous plate in the presence of suction and viscous dissipation.

Kafoussias and Williams [5] presented the Soret and Dufuor consequences on a blended convective constant laminar boundary layer waft past a vertical flat plate.Ibrahim et al. [6] studied the effects of chemical reaction on hydromagnetic flow along a continuously moving permeable surface in the presence of heat source with time dependent suction and radiation absorption. Kandaswamy et al. Ibrahim and Makinde [7] studied the impact of chemical reaction on MHD boundary layer go
along with the drift of heat and mass switch along a shifting vertical Sucking tray. In the presence of suction, Srinivasa Rao et al[8] described the affects of Soret and Dufour at the magneto hydrodynamic boundary layer float beyond a shifting porous plate.. However, no effort has been made to study the radiation and chemical response consequences on the MHD boundary layer waft of a moving vertical porous plate embedded in a porous medium, taking into account the effects of Soret & Dufour and the heat source.Hence an attempt is made to study this problem.

II. MATHEMATICAL ANALYSIS

Two-dimensional ongoing boundary layer flow of an incompressible viscous solution that conducts, radiates and chemically reacts.

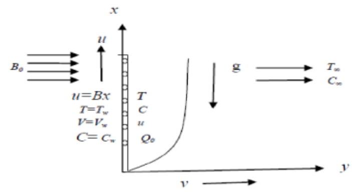

Fig. 1: Schematic diagram of the physical model

Under these speculations alongside normal Boussinesq and limit layer approximations the arrangement of conditions, which models the stream is given by

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

Momentum equation

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$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=\upsilon\frac{\partial^2 u}{\partial y^2}+g\beta\left(T-T_\infty\right)+g\beta^*\left(C-C_\infty\right)-\frac{\sigma B_0^2}{\rho}-\frac{\upsilon}{K'}u \quad (2)$$

Energy equation

$$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=\alpha\frac{\partial^2 T}{\partial y^2}+\frac{Q_0}{\rho C_p}(T-T_\infty)\frac{D_m K_T}{C_s C_p}\frac{\partial^2 C}{\partial y^2}-\frac{1}{\rho C_p}\frac{\partial q_r}{\partial y} \quad (3)$$

$$u\frac{\partial C}{\partial x}+v\frac{\partial C}{\partial y}=D_m\frac{\partial^2 C}{\partial y^2}+\frac{D_m K_T}{T_m}\frac{\partial^2 T}{\partial y^2}-Kr'C$$

Species equation

(4)

The limit conditions for the fields of speed, temperature and fastening

$u = B x$, $v = V$, $T = Tw = T_\infty + ax$, $C= C_w= C_\infty+bx$ at $y=0$

$u\rightarrow 0$, $T \rightarrow T_\infty$, $C \rightarrow C_\infty$ as $y\rightarrow\infty$ (5)

By using the Rosseland approximation

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

$$T^4=4T_\infty^3 T-3T_\infty^4 \quad (7)$$

From the equations (6) and (7), the equation (3) is derived

$$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=\alpha\frac{\partial^2 T}{\partial y^2}+\frac{Q_0}{\rho C_p}(T-T_\infty)+\frac{D_m K_T}{C_s C_p}\frac{\partial^2 C}{\partial y^2}+\frac{16\sigma^* T_\infty^3}{3k^*\rho c_p}\frac{\partial^2 T}{\partial y^2} \quad (8)$$

The continuity equation (1) is fulfilled by the Cauchy Riemann equations

$$u=\frac{\partial\psi}{\partial y},\quad v=-\frac{\partial\psi}{\partial x} \quad (9)$$

where $\psi(x,y)$ is function of stream.

Using following similarity variables and dimensionless quantities are brought in to compose the overseeing conditions and the limit conditions in the dimensionless structure,.

$$\eta=\sqrt{\frac{B}{\upsilon}}y,\qquad f(\eta)=\frac{\psi}{x\sqrt{B\upsilon}},\qquad \theta(\eta)=\frac{T-T_\infty}{T_f-T_\infty},$$

$$\phi(\eta)=\frac{C-C_\infty}{C_w-C_\infty},$$

$$f_w=\frac{V}{\sqrt{B\upsilon}},$$

$$Gc=\frac{g\beta^*(C_w-C_\infty)}{xB^2},\ M=\frac{\sigma B_0^2}{\rho B},$$

$$Du=\frac{D_m K_T}{C_s C_p\upsilon}\frac{(C_w-C_\infty)}{(T_w-T_\infty)},$$

$$S=\frac{Q_0}{B\rho C_p},\ Sr=\frac{D_m K_T(T_w-T_\infty)}{T_m\upsilon(C_w-C_\infty)},\ \Pr=\frac{\upsilon}{\alpha},$$

$$Sc=\frac{\upsilon}{D},\ Kr=\frac{Kr'}{B}, \quad (10)$$

$$K=\frac{\upsilon}{K'B},\ Nc=\frac{C_\infty}{C_w-C_\infty},\ R=\frac{4\sigma^* T_\infty^3}{3k^* k}$$

In consideration of similarity transformations, the equations (2), (3) and (6) reduce to

$$f'''+ff''-(f')^2+Gr\theta+Gc\phi-(M+K)f'=0 \quad (11)$$

$$(4R+1)\theta''+\Pr(f\theta'-f'\theta)+Du\Pr\varphi''+\Pr S\theta=0, \quad (12)$$

$$\varphi''+Sc(f\varphi'-f'\varphi)+ScSr\theta''-ScKr(\varphi+Nc)=0 \quad (13)$$

Limiting conditions are

$$f'=1,\ f=-f_w,\ \theta=1,\ \varphi=1 \quad \text{at} \quad \eta=0$$

$$f'(\infty)\rightarrow 0,\quad \theta(\infty)\rightarrow 0\quad \varphi(\infty)\rightarrow 0 \quad \text{as} \quad \eta\rightarrow\infty \quad (14)$$

III. NUMERICAL SOLUTION OF PROBLEM

Conditions administering the stream are coupled with non-linear differential equations and Solved numerically via the usage of the Newton–Raphson capturing approach in conjunction with Runge–Kutta fourth order. First of all, the writing of the collection of non-linear differential equations of greater order (12), (13) and (14) is as follows.

Let $f = y_1$, $f' = y_2$, $f'' = y_3$, $\theta = y_4$, $\theta' = y_5$, $\varphi = y_6$, $\varphi' = y_7$.

Thus, 1st order D.E. are

$$\frac{dy_1}{d\eta} = y_2, \qquad \frac{dy_2}{d\eta} = y_3,$$

$$\frac{dy_3}{d\eta} = -\{y_1 y_3 - y_2^2 + Gry_4 + Gcy_6 - (M+K)y_2\},$$

$$\frac{dy_4}{d\eta} = y_5,$$

$$\frac{dy_5}{d\eta} = \frac{-1}{(4R+1)}\{\Pr(y_1 y_5 - y_2 y_4) + Du\Pr(\frac{dy_7}{d\eta}) + \Pr Sy_4\},$$

$$\frac{dy_6}{d\eta} = y_7,$$

$$\frac{dy_7}{d\eta} = -\{Sc(y_1 y_7 - y_2 y_6) + SrSc(\frac{dy_5}{d\eta}) - ScKr(y_6 + Nc)\},$$

based on the following initial conditions

$$y_1(0) = -f_w,\ y_2(0) = 1, \quad y_4(0) = 1,\ y_6(0) = 1,$$

$$y_2(\infty) = 0,\ y_4(\infty) = 0,\ y_6(\infty) = 0$$

Then the set of above equations converted into preliminary price trouble with the aid of applying by means of the usage of the Newton Raphson capturing technique. In almost all the cases a step size of $\Delta\eta = 0.01$ is selected to satisfy the convergence criterion of 10^{-6}. $f''(0)$, $-\theta'(0)$, and $-\varphi'(0)$ values are also sorted out and displayed in tabular form.

In almost all cases, to meet the convergence criterion of 10^{-6}, a step size of $\Delta\eta = 0.01$ is selected. The values of $f''(0)$, $-\theta'(0)$, and $-\varphi'(0)$ are also sorted and displayed in tabular form.

IV. RESULTS

To get a bodily perception into the hassle, a parametric have a look at is conducted to interpret The impacts on speed, temperature and concentration of distinct control parameters on the nature of flow and transport and the same is presented graphically in Figs. 2-30. Here the value of Pr is selected as 0.71 and Sc is selected as 0.62, for water vapor and the other parameters are chosen randomly

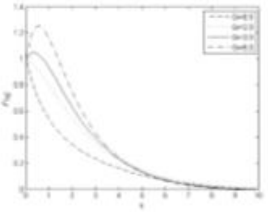

Fig. 2 Velocity profiles for Gr

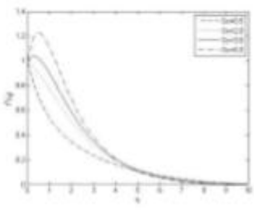

Fig. 3 Velocity profiles for *Gc*

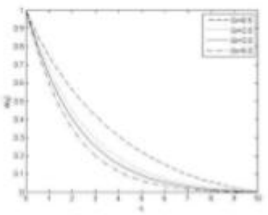

Fig. 4 Temperature profiles for *Gr*

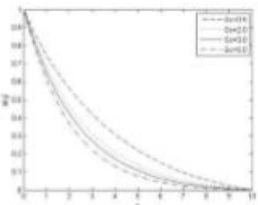

Fig. 5 Temperature profiles for *Gc*

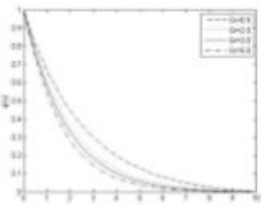

Fig. 6 Concentration profiles for *Gr*

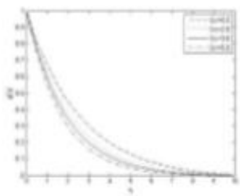

Fig. 7 Concentration profiles for *Gc*

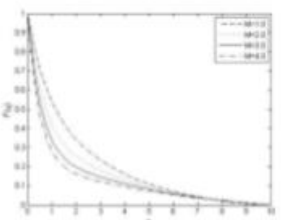

Fig. 8 Velocity profiles for *M*

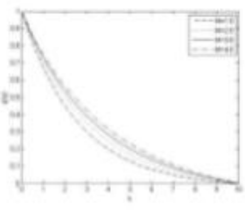

Fig. 9 Temperature profiles for *M*

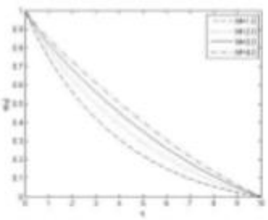

Fig. 10 Concentration profiles for *M*

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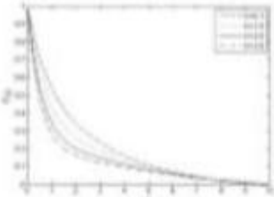

Fig. 11 Velocity profiles for *K*

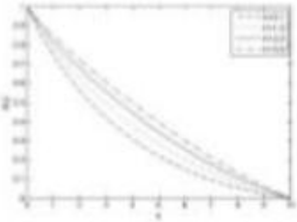

Fig. 12 Temperature profiles for *K*

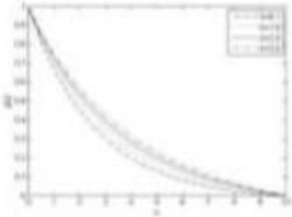

Fig. 13 Concentration profiles for *K*

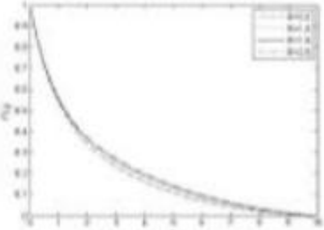

Fig. 14 Velocity profiles for *R*

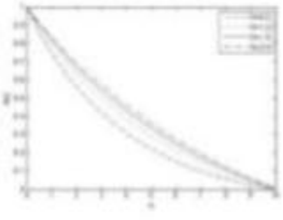

Fig. 15 Temperature profiles for *R*

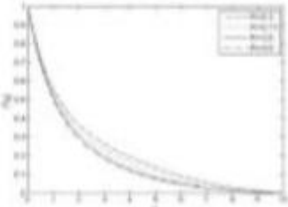

Fig. 16 Velocity profiles for *Pr*

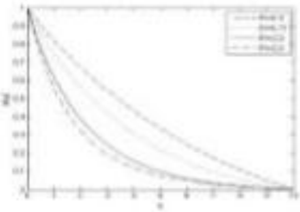

Fig. 17 Temperature profiles for *Pr*

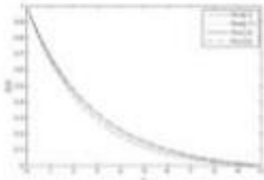

Fig. 18 Concentration profiles for *Pr*

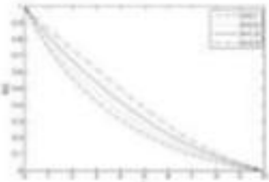

Fig. 19 Temperature profiles for *S*

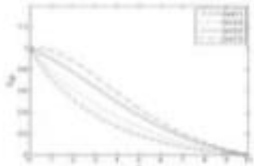

Fig. 20 Velocity profiles for *Du*

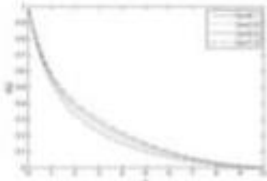

Fig. 21 Temperature profiles for *Du*

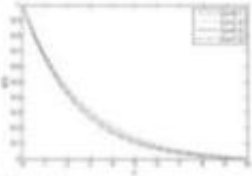

Fig. 22 Concentration profiles for *Du*

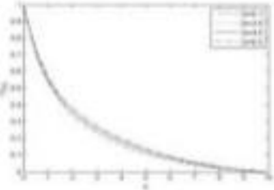

Fig. 23 Velocity profiles for *Sr*

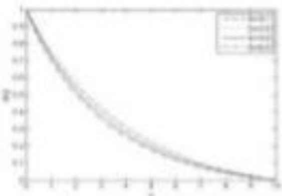

Fig. 24 Temperature profiles for *Sr*

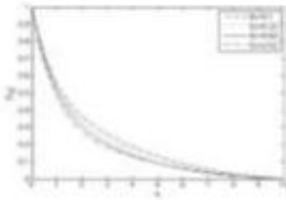

Fig. 25 Velocity profiles for *Sc*

Table 1: Comparison of $f''(0)$, $-\theta'(0)$, $-\varphi'(0)$ when $Gr=Gc=0.1$, $Du=0.1$, $Sr=1.0$, $f_w=0.1$ for different values of M, K and Pr

M	*K*	*Pr*	*Srinivasa Rao et al*			*Present results*		
			$-f''(0)$	$-\theta'(0)$	$-\varphi'(0)$	$-f''(0)$	$-\theta'(0)$	$-\varphi'(0)$
0.1	0.1	0.72	0.915677	0.793711	0.260249	1.915675	0.793713	0.260249

0.5	0.1	0.72	1.09468	0.753282	0.242587	1.094677	0.753279	0.242588
0.1	1.0	0.72	1.28898	0.710393	0.226773	1.288978	0.710392	0.226774
0.1	0.1	1.0	0.920067	0.965159	0.224252	0.920067	0.965159	0.224253

Table 2: Comparison of $f''(0)$, $-\theta'(0)$, $-\varphi'(0)$ when $Gr=Gc=0.1$, $M=0.1$, $K=0.1$, $Pr=0.72$, Sr=1.0 for different values of Du, Sc and f_w

Du	*Sc*	f_w	*Srinivasa Rao et al*			*Present results*		
			$-f''(0)$	$-\theta'(0)$	$-\varphi'(0)$	$-f''(0)$	$-\theta'(0)$	$-\varphi'(0)$
1.0	0.22	0.1	0.912726	0.73387	0.273729	0.912725	0.733871	0.273729
0.1	0.62	0.1	0.925313	0.771746	0.422095	0.925471	0.778447	0.418680
0.1	0.22	0.5	0.758705	0.672326	0.263817	0.758703	0.672322	0.263820

Table 1 and Table 2 shows a comparison of $f''(0)$, $-\theta'(0)$ and $-\varphi'(0)$ between the present results and the results obtained by Srinivasa Rao *et al.* [33] for the reduced case $R=S=Kr=Nc=0$ and found that there is a good agreement.

Table 3: Numerical values of $f''(0)$, Nusselt number $-\theta'(0)$ & $\varphi'(0)$ for $R=0.5$, $Pr=0.71$, $S=0.1$, $Du=1.0$, $Sr=0.1$, $Sc=0.22$, $Kr=0.1$ and $Nc=0.01$

Gr	*Gc*	*M*	*K*	f_w	$f''(0)$	$-\theta'(0)$	$-\varphi'(0)$
0.5	0.5	1.0	0.1	0.5	−0.725034	0.303159	0.408861
2.0	0.5	1.0	0.1	0.5	−0.071571	0.387802	0.480307
3.0	0.5	1.0	0.1	0.5	0.329528	0.423252	0.512401
5.0	0.5	1.0	0.1	0.5	1.082561	0.475534	0.561335
0.5	0.5	1.0	0.1	0.5	−0.725034	0.303159	0.408861
0.5	2.0	1.0	0.1	0.5	−0.096652	0.377842	0.472762
0.5	3.0	1.0	0.1	0.5	0.293020	0.411553	0.503195
0.5	5.0	1.0	0.1	0.5	1.027620	0.462321	0.550455
0.5	0.5	1.0	0.1	0.5	−0.725034	0.303159	0.408861
0.5	0.5	2.0	0.1	0.5	−1.084967	0.255532	0.370205
0.5	0.5	3.0	0.1	0.5	−1.386501	0.219656	0.341598
0.5	0.5	4.0	0.1	0.5	−1.649319	0.191944	0.319700
0.5	0.5	1.0	0.1	0.5	−0.725034	0.303159	0.408861
0.5	0.5	1.0	1.0	0.5	−1.052040	0.259697	0.373551
0.5	0.5	1.0	2.0	0.5	−1.358326	0.222827	0.344113
0.5	0.5	1.0	3.0	0.5	−1.624421	0.194425	0.321655
0.5	0.5	1.0	0.1	0.5	−0.725034	0.303159	0.408861
0.5	0.5	1.0	0.1	1.0	−0.600602	0.257632	0.370567
0.5	0.5	1.0	0.1	2.0	−0.428277	0.231095	0.306210
0.5	0.5	1.0	0.1	2.5	−0.369269	0.212796	0.279407

Table 4: Numerical values of $f''(0)$, $-\theta'(0)$ & $-\varphi'(0)$ for $Gr=Gc=0.5$, $M=1.0$, $K=0.1$, $Sr=0.1$, $Sc=0.22$, $Kr=0.1$ and $Nc=0.01$

R	*S*	*Pr*	*Du*	$f''(0)$	$-\theta'(0)$	$-\varphi'(0)$
0.5	0.1	0.71	1.0	−0.725034	0.303159	0.408861
1.5	0.1	0.71	1.0	−0.716828	0.237456	0.414328
1.5	0.1	0.71	1.0	−0.712548	0.204416	0.417203
2.0	0.1	0.71	1.0	−0.709898	0.184348	0.418986
0.5	0.1	0.71	1.0	−0.725034	0.303159	0.408861
0.5	0.1	0.71	1.0	−0.719597	0.262643	0.412347
0.5	0.2	0.71	1.0	−0.713188	0.216581	0.416423
0.5	0.3	0.71	1.0	−0.705527	0.163364	0.421209
0.5	0.4	0.3	1.0	−0.712387	0.203184	0.417311
0.5	0.1	0.71	1.0	−0.725034	0.303159	0.408861

0.5	0.1	2.0	1.0	−0.747303	0.500829	0.394875
0.5	0.1	3.0	1.0	−0.757193	0.601008	0.389290
0.5	0.1	0.71	0.1	−0.730770	0.351073	0.405242
0.5	0.1	0.71	2.0	−0.718623	0.249458	0.412779
0.5	0.1	0.71	5.0	−0.699198	0.085445	0.423953
0.5	0.1	0.71	7.0	−0.686107	0.026337	0.430994

Table 5: Numerical values of $f''(0)$, $-\theta'(0)$ & $-\varphi'(0)$ for Gr=Gc=0.5, M=1.0, K=0.1, *R*=0.5, *Pr*=0.71, *S*=0.1 and *Du*=1.0

Sc	Sr	Kr	Nc	$f''(0)$	$-\theta'(0)$	$-\varphi'(0)$
0.1	0.1	0.1	0.01	−0.711758	0.339232	0.271937
0.22	0.1	0.1	0.01	−0.725034	0.303159	0.408861
062	0.1	0.1	0.01	−0.74855	0.232978	0.689894
2.62	0.1	0.1	0.01	−0.785018	0.096587	1.276235
0.22	0.1	0.1	0.01	−0.725034	0.303159	0.408865
0.22	2.0	0.1	0.01	−0.719224	0.319705	0.346172
0.22	4.0	0.1	0.01	−0.712116	0.339256	0.269175
0.22	6.0	0.1	0.01	−0.703831	0.361517	0.178016
0.22	0.1	0.1	0.01	−0.725034	0.303159	0.408861
0.22	0.1	2.0	0.01	−0.753518	0.213953	0.769920
0.22	0.1	4.0	0.01	−0.767888	0.156309	1.015446
0.22	0.1	6.0	0.01	−0.777462	0.110697	1.212027
0.22	0.1	0.1	0.01	−0.725034	0.303159	0.408861
0.22	0.1	0.1	0.1	−0.725732	0.301155	0.414792
0.22	0.1	0.1	0.5	−0.728843	0.291902	0.441517
0.22	0.1	0.1	0.8	−0.731187	0.284548	0.461979

V. CONCLUSIONS

- Increasing the buoyancy parameters (Gc or Gr) will increase pace, $f''(0)$, $-\theta'(0)$ & variety of $-\varphi'(0)$ however reduces temperature and awareness.

  An increase in the magnetic parameter or parameter of permeability results in an increase in temperature and concentration and a decrease in velocity, $f''(0)$,$-\theta'(0)$ and$-\varphi'(0)$.

  The velocity, temperature , concentration boom even as coefficient of skin-friction, $-\theta'(0)$ and $-\varphi'(0)$ lower with an increase in the parameter of suction.As the radiation parameter or the heat source parameter will increase, there's an Increase the coefficient of temperature, pores and $f''(0)$ and $-\varphi'(0)$ and decrease within the range of $-\theta'(0)$ .An boom inside the radiation parameter additionally ends in a decrease within the speed.
- With expansion in Pr and $-\theta'(0)$ increment, while speed, temperature, skin grating coefficient and $-\varphi'(0)$ diminishing
- An expansion in the quantity of Dufour brings about an increment in the speed, temperature, coefficient of skin rubbing and number of Sherwood while the fixation and number of $-\theta'(0)$ diminishes. An expansion in the Sr builds the speed, skin rubbing coefficient and $-\theta'(0)$ while diminishes the temperature and $-\varphi'(0)$.
- The concentration, $f''(0)$, & $-\theta'(0)$ decrease while $-\varphi'(0)$ increases with an increase in Sc or chemical reaction parameter or concentration difference parameter.
- An growth within the suction parameter enhances the velocity, temperature, attention and skin friction co-green however reduces the $-\theta'(0)$ and $-\varphi'(0)$ wide variety.

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