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Heat and Mass Transfer for a Maxwell Fluid Flow Near a Stagnation Point with Variable Wall Heat and Mass Flux in the Presence of Heat Generation or Absorption

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Abstract – *A theoretical study of the problem of stagnation point flow, heat and mass transfer in a Maxwell fluid over a surface with variable wall heat and mass flux in the presence of heat generation/absorbtion is investigated. This work is extended from the previous published study of Sadeghy et al. [16]. The boundary layer equations describing the problem are transformed to a system of non-linear ordinary differential equations. The resulting system of non-linear ordinary differential equations is solved numerically using Chebyshev spectral method. The results show that the Deborah number has the effect of reducing the temperature and the concentration inside the boundary layer and enhancing the velocity.* ***Copyright © 2013 Praise Worthy Prize S.r.l. - All rights reserved.***

Keywords*: Maxwell Fluid, Heat Generation (Absorption), Stagnation Point, Variable Wall Heat and Mass Flux*

Nomenclature

c_p	Specific heat at constant pressure
C_{f_x}	Friction coefficient local skin
C	The concentration
C_∞	Ambient concentration
D	Diffusion coefficient
D_e	Deborah number
f	Dimensionless velocity
m_w	Rate of mass transfer at the wall
N_{u_x}	Local Nusselt number
n	Exponent parameter
Pr	Prandtl number
Q_0	Heat generation (>0) or absorption (<0) coefficient
q_w	Rate of heat transfer at the wall
Re_x	Local Reynolds number
S_c	Schmidt number
Sh_x	Local Sherwood number
T	Fluid temperature
T_∞	Ambient temperature
u, v	Dimensional components of velocities along and perpendicular to the plate, respectively
$U(x)$	Ambient velocity
x, y	Dimensional distances along and perpendicular to the plate, respectively

Greek symbols

η	Dimensionless distance normal to the plate
γ	Heat generation/absorption parameter
κ	Thermal conductivity
μ	Dynamic viscosity
ν	Kinematic viscosity
ρ	Fluid density
τ_w	Wall shear stress
λ	Relaxation time of the fluid
θ	Dimensionless temperature
φ	Dimensionless concentration

Subscripts

w	Condition at the solid surface
∞	Ambient condition

Superscripts

$/$	Differentiation with respect to η

I. Introduction

The study of non-Newtonian fluids has been analyzed and studied by many investigators due to its numerous applications in many practical engineering problems.

Such situations are encountered in plastic films, artificial fibers, extrusion processes, food processing, paper production, etc. Relationship between stress and rate of strain for non-Newtonian fluids is different from that Newtonian fluids. The non-Newtonian fluids cannot be described by a single constitutive relation.

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In the literature, there are several models for non-Newtonian fluids which suggested and studied by many authors [1]-[5]. In the above studies the non-Newtonian fluid models were concerned with the fluids such as second-order or second grade which are known to be good only for small elastic fluids. The effects of stress relaxation are not taken into consideration in these models. For flows of highly elastic fluids that occur at high Deborah numbers, the Maxwell fluid model is quite appropriate [6]. Maxwell model is type of fluids can predict the stress relaxation.

Phan-Thein [7] studied the plane and axisymmetric stagnation flows in a Maxwell fluid. Sadeghy et al. [8] investigated the flow of an upper-convected Maxwell fluid above a rigid plate moving steadily in an otherwise equiescent fluid. Hayat and Sajid [9] presented analytical solution using homotopy analysis method for the problem of a magnetohydrodynamic boundary layer flow of an upper-convected Maxwell fluid.

Hayat et al. [10] studied the influences of chemical reaction and magnetic field on the steady two dimensional magnetohydrodynamics boundary layer flow and mass transfer of an upper-convected Maxwell fluid past a porous shrinking sheet. Hayat et al. [11] analytically studied the effects of blowing and suction on hydromagnetic boundary layer flow of an upper-convected Maxwell fluid over a porous stretching sheet in the presence of magnetic field. Aliakbar et al. [12] analyzed the effects of thermal radiation on hydromagnetic flow and heat transfer of a Maxwell fluid above a semi-infinite stretching sheet.

Mahmoud [13] investigated the effects of variable viscosity and thermal conductivity on two dimensional steady flow of an electrically conducting, incompressible, upper-convected Maxwell fluid in the presence of a transverse magnetic field and heat generation or absorption.

Abel et al. [14] examined the effect of magnetic field on the boundary layer flow and heat transfer of an upper-convected Maxwell fluid over a stretching sheet.

Hayat et al. [15] examined the steady two-dimensional magnetohydrodynamic flow of an upper-convected Maxwell fluid near a stagnation-point over a stretching sheet. Sadeghy et al. [16] investigated the problem of two-dimensional stagnation-point flow of upper-convected fluids. Abbas et al. [17] studied the steady mixed convection boundary layer flow and heat transfer of an incompressible Maxwell fluid near the two-dimensional stagnation point flow over a vertical stretching surface.

Hayat and Qasim [18] studied the magnetohydrodynamic two-dimensional flow with heat and mass transfer over a stretching sheet in the presence of thermal radiation, thermophoresis and Joule heating.

To the best of the author's knowledge stagnation point heat and mass transfer of Maxwell fluid over a surface with variable heat flux have not been examined.

The purpose of the present paper is to study the two-dimensional stagnation-point flow, heat and mass transfer of a Maxwell fluid over a porous surface in the presence of heat generation or absorption.

II. Formulation of the Problem

Consider the steady two-dimensional boundary layer flow with heat and mass transfer of an incompressible Maxwell fluid near the stagnation point on a semi-infinite porous horizontal flat plate. The origin being the stagnation point, the x and y axes are taken along and perpendicular to the plate, respectively.

The flow configuration and the coordinate system are shown in Fig. 1. It is assumed that the ambient velocity is given by $U(x) = ax$, where a is a positive constant.

The surface has variable heat flux $q_w(x) = bx^n$ and variable mass flux $m_w(x) = cx^n$, where b and c are positive constants and n is the exponent parameter for variable wall heat and mass fluxes.

Under the above assumptions and the boundary layer approximations, the governing equations in the presence of heat generation for mass, momentum, energy and species are [16]:

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \tag{1}$$

$$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + \lambda\left[u^2\frac{\partial^2 u}{\partial x^2} + v^2\frac{\partial^2 u}{\partial y^2} + 2uv\frac{\partial^2 u}{\partial x \partial y}\right] = U(x)\frac{\partial U(x)}{\partial x} + \nu\frac{\partial^2 u}{\partial y^2} \tag{2}$$

$$u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} = \frac{\kappa}{\rho c_p}\frac{\partial^2 T}{\partial y^2} + \frac{Q_0}{\rho c_p}\left(T - T_\infty\right) \tag{3}$$

$$u\frac{\partial C}{\partial x} + v\frac{\partial C}{\partial y} = D\frac{\partial^2 C}{\partial y^2} \tag{4}$$

where u and v are the velocity components along the x and y directions, respectively.

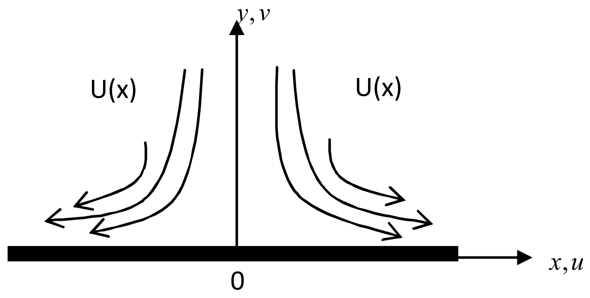

Fig. 1. Flow model and coordinate system

λ is the relaxation time of the fluid, ρ is the fluid density, ν is the kinematic viscosity, T is the temperature of the fluid, C is the concentration, κ is the thermal conductivity and c_p is the specific heat at constant pressure. D is the diffusion coefficient, Q_0 is the heat generation (>0) or absorption (<0) coefficient and T_∞ is the ambient temperature.

The boundary conditions are:

$$u=0,\quad v=0,\quad -\kappa\left(\frac{\partial T}{\partial y}\right)_{y=0}=q_w(x),\quad -\kappa\left(\frac{\partial C}{\partial y}\right)_{y=0}=m_w(x),\quad \text{at}\quad y=0 \tag{5}$$

$$u\to U(x),\quad T\to T_\infty,\quad C\to C_\infty,\quad \text{as}\quad y\to\infty$$

where C_∞ is the ambient concentration.

It is convenient to introduce the following similarity transformations:

$$\eta=\sqrt{\tfrac{a}{\nu}}\,y,\quad u=axf'(\eta),\quad v=-\sqrt{a\nu}\,f(\eta) \tag{6}$$

$$\theta(\eta)=\frac{(T-T_\infty)}{\left(bx^n/\kappa\sqrt{\tfrac{a}{\nu}}\right)},\quad \varphi(\eta)=\frac{(C-C_\infty)}{\left(cx^n/\kappa\sqrt{\tfrac{a}{\nu}}\right)}$$

into Eqs. (1)-(5). Eq. (1) is satisfied automatically and Eqs. (2)-(4) are:

$$f'''+ff''-f'^2+1-D_e\left[f^2f'''-2ff'f''\right]=0 \tag{7}$$

$$\theta''+Pr\left[f\theta'-nf'\theta+\gamma\theta\right]=0 \tag{8}$$

$$\varphi''+Sc\left[f\varphi'-nf'\varphi\right]=0 \tag{9}$$

where $D_e=\lambda a$ is the Deborah number, $\gamma=\dfrac{Q_0}{a\rho c_p}$ is the heat generation/absorption parameter, $Pr=\dfrac{\mu c_p}{\kappa}$ is the Prandtl number and $Sc=\dfrac{\nu}{D}$ is the Schmidt number.

The transformed boundary conditions are:

$$f=0,\quad f'=0,\quad \theta'=-1,\quad \varphi'=-1\quad \text{at}\quad \eta=0 \tag{10}$$

$$f'\to 1,\quad \theta\to 0,\quad \varphi\to 0,\quad \text{as}\quad \eta\to\infty$$

The physical quantities of interest for the problem are the local skin-friction coefficient Cf_x, the local Nusselt number Nu_x and the local Sherwood number Sh_x which are defined as:

$$Cf_x=\frac{2\tau_w}{\rho(ax)^2},\quad Nu_x=\frac{xq_w}{\kappa(T_w-T_\infty)},\quad Sh_x=\frac{xm_w}{D(C_w-C_\infty)} \tag{11}$$

where τ_w is the wall shear stress, q_w is the rate of heat transfer at the wall and m_w is the rate of mass transfer at the wall. Using Eq. (6), Eq. (11) can be written in the form:

$$\frac{1}{2}Cf_x\,Re_x^{1/2}=-f''(0),\quad Nu_x\,Re_x^{-1/2}=\frac{1}{\theta(0)},\quad Sh_x\,Re_x^{-1/2}=\frac{1}{\varphi(0)} \tag{12}$$

where $Re_x=\left(\dfrac{xU(x)}{\nu}\right)$ is the local Reynolds number.

III. Method of Solution

The domain of the governing boundary layer Eqs (7)-(9) is the unbounded region $[0,\infty)$. However, for all practical reasons, this could be replaced by the interval $0\le\eta\le\eta_\infty$, where η_∞ is one end of the user specified computational domain. Using the algebraic mapping:

$$\chi=2\frac{\eta}{\eta_\infty}-1$$

The unbounded region $[0,\infty)$ is mapped into the finite domain [-1,1], and the problem expressed by Eqs. (7) - (9) is transformed into:

$$f'''(\chi)-D_e\begin{bmatrix}f^2(\chi)f'''(\chi)+\\-2f(\chi)f'(\chi)f''(\chi)\end{bmatrix}+\left(\frac{\eta_\infty}{2}\right)\begin{pmatrix}f(\chi)f(\chi)''+\\-f'^2(\chi)\end{pmatrix}+\left(\frac{\eta_\infty}{2}\right)^3=0 \tag{13}$$

$$\theta''(\chi)+\left(\frac{\eta_\infty}{2}\right)Pr\left[f(\chi)\theta'(\chi)-nf'(\chi)\theta(\chi)\right]+\gamma\left(\frac{\eta_\infty}{2}\right)^2Pr\,\theta(\chi)=0 \tag{14}$$

$$\varphi''(\chi)+\left(\frac{\eta_\infty}{2}\right)Sc\begin{bmatrix} f(\chi)\varphi'(\chi)+ \\ -nf'(\chi)\varphi(\chi)\end{bmatrix}=0 \qquad (15)$$

The transformed boundary conditions are then given by:

$$\begin{aligned} &f(-1)=0,\quad f'(-1)=0,\quad f'(1)=\left(\frac{\eta_\infty}{2}\right) \\ &\theta'(-1)=-\left(\frac{\eta_\infty}{2}\right),\ \theta(1)=0 \end{aligned} \qquad (16)$$

$$\varphi'(-1)=-\left(\frac{\eta_\infty}{2}\right),\quad \varphi(1)=0$$

where now differentiation in Eqs. (13)-(16) will be with respect to the new variable χ.

Our technique is accomplished by starting with a Chebyshev approximation for the highest order derivatives, f''', θ'' and φ'' and generating approximations to the lower order derivatives f'', f', f, θ', θ, φ' and φ as follows:

Setting $f'''=\phi(\chi)$, $\theta''=\psi(\chi)$ and $\varphi''=\zeta(\chi)$, then by integration we obtain:

$$f''(\chi)=\int_{-1}^{\chi}\phi(\chi)d\chi+C_1^f \qquad (17)$$

$$f'(\chi)=\int_{-1}^{\chi}\int_{-1}^{\chi}\phi(\chi)d\chi d\chi+C_1^f(\chi+1)+C_2^f \qquad (18)$$

$$\begin{aligned} f(\chi)=&\int_{-1}^{\chi}\int_{-1}^{\chi}\int_{-1}^{\chi}\phi(\chi)d\chi d\chi d\chi+ \\ &+C_1^f\frac{(\chi+1)^2}{2}+C_2^f(\chi+1)+C_3^f \end{aligned} \qquad (19)$$

$$\theta'(\chi)=\int_{-1}^{\chi}\psi(\chi)d\chi+C_1^\theta \qquad (20)$$

$$\theta(\chi)=\int_{-1}^{\chi}\int_{-1}^{\chi}\psi(\chi)d\chi d\chi+C_1^\theta(\chi+1)+C_2^\theta \qquad (21)$$

$$\varphi'(\chi)=\int_{-1}^{\chi}\zeta(\chi)d\chi+C_1^\varphi \qquad (22)$$

$$\varphi(\chi)=\int_{-1}^{\chi}\int_{-1}^{\chi}\zeta(\chi)d\chi d\chi+C_1^\varphi(\chi+1)+C_2^\varphi \qquad (23)$$

From the boundary condition (18), we obtain:

$$C_1^f=-\frac{1}{2}\int_{-1}^{1}\int_{-1}^{\chi}\phi(\chi)d\chi d\chi+\left(\frac{\eta_\infty}{4}\right)$$

$$C_2^f=0,\ C_3^f=0$$

$$C_1^\theta=-\frac{\eta_\infty}{2}$$

$$C_2^\theta=-\int_{-1}^{1}\int_{-1}^{\chi}\psi(\chi)d\chi d\chi+\eta_\infty$$

$$C_1^\varphi=-\frac{\eta_\infty}{2}$$

$$C_2^\varphi=-\int_{-1}^{1}\int_{-1}^{\chi}\zeta(\chi)d\chi d\chi+\eta_\infty$$

Therefore, we can give approximations to Eqs. (17)-(23) as follows:

$$\begin{aligned} &f_i(\chi)=\sum_{j=0}^{N}l_{ij}^f\phi_j+d_i^f,\ f_i'(\chi)=\sum_{j=0}^{N}l_{ij}^{f_1}\phi_j+d_i^{f_1} \\ &f_i''(\chi)=\sum_{j=0}^{N}l_{ij}^{f_2}\phi_j+d_i^{f_2} \end{aligned} \qquad (24)$$

$$\theta_i(\chi)=\sum_{j=0}^{N}l_{ij}^\theta\psi_j+d_i^\theta,\ \theta_i'(\chi)=\sum_{j=0}^{N}l_{ij}^{\theta_1}\psi_j+d_i^{\theta_1} \qquad (25)$$

$$\varphi_i(\chi)=\sum_{j=0}^{N}l_{ij}^\varphi\zeta_j+d_i^\varphi,\ \ \varphi_i'(\chi)=\sum_{j=0}^{N}l_{ij}^{\varphi 1}\zeta_j+d_i^{\varphi 1} \qquad (26)$$

for all $i=0(1)N$, where:

$$l_{ij}^\varphi=b_{ij}^2-b_{Nj}^2,\quad d_i^\varphi=-\frac{\eta_\infty}{2}(\chi_i+1)+\eta_\infty$$

$$l_{ij}^{\varphi 1}=b_{ij},\quad d_i^{\varphi 1}=-\frac{\eta_\infty}{2}$$

$$l_{ij}^\theta=b_{ij}^2-b_{Nj}^2,\quad d_i^\theta=-\frac{\eta_\infty}{2}(\chi_i+1)+\eta_\infty$$

$$l_{ij}^{\theta 1}=b_{ij},\quad d_i^{\theta 1}=-\frac{\eta_\infty}{2}$$

$$l_{ij}^f=b_{ij}^3-\frac{(\chi_i+1)^2}{4}b_{Nj}^2,\quad d_i^f=\left(\frac{\eta_\infty}{8}\right)(\chi_i+1)^2$$

$$l_{ij}^{f_1} = b_{ij}^2 - \frac{(\chi_i + 1)}{2} b_{Nj}^2, \quad d_i^{f_1} = \left(\frac{\eta_\infty}{4}\right)(\chi_i + 1)$$

$$l_{ij}^{f_2} = b_{ij} - \frac{1}{2} b_{Nj}^2, \quad d_i^{f_2} = \left(\frac{\eta_\infty}{4}\right)$$

where:

$$b_{ij}^2 = (\chi_i - \chi_j) b_{ij}, \quad i = 0(1)N$$

and b_{ij} are the elements of the matrix B, as given in Ref. [41], [42].

By using Eqs. (24)-(26), one can transform Eqs. (13)-(15) to the following system of nonlinear equations in the highest derivatives:

$$\begin{aligned}
&\phi_i \left[1 - D_e \left(\sum_{j=0}^{N} l_{ij}^{f} \phi_j + d_i^{f}\right)^2\right] - 2D_e \left(\sum_{j=0}^{N} l_{ij}^{f} \phi_j + d_i^{f}\right) \cdot \\
&\cdot \left(\sum_{j=0}^{N} l_{ij}^{f_2} \phi_j + d_i^{f_2}\right)\left(\sum_{j=0}^{N} l_{ij}^{f_1} \phi_j + d_i^{f_1}\right) + \\
&+ \left(\frac{\eta_\infty}{2}\right) \left[\begin{array}{l} \left(\sum_{j=0}^{N} l_{ij}^{f} \phi_j + d_i^{f}\right) \cdot \\ \cdot \left(\sum_{j=0}^{N} l_{ij}^{f_2} \phi_j + d_i^{f_2}\right) + \\ - \left(\sum_{j=0}^{N} l_{ij}^{f_1} \phi_j + d_i^{f_1}\right)^2 \end{array}\right] + \left(\frac{\eta_\infty}{2}\right)^3 = 0
\end{aligned} \tag{27}$$

$$\begin{aligned}
&\psi_i + \left(\frac{\eta_\infty}{2}\right) \cdot \\
&\cdot Pr \left[\begin{array}{l} \left(\sum_{j=0}^{N} l_{ij}^{f} \phi_j + d_i^{f}\right)\left(\sum_{j=0}^{N} l_{ij}^{\theta_1} \psi_j + d_i^{\theta_1}\right) + \\ -n \left(\sum_{j=0}^{N} l_{ij}^{f_1} \phi_j + d_i^{f_1}\right)\left(\sum_{j=0}^{N} l_{ij}^{\theta} \psi_j + d_i^{\theta}\right) \end{array}\right] + \\
&+ \gamma \left(\frac{\eta_\infty}{2}\right)^2 Pr \left(\sum_{j=0}^{N} l_{ij}^{\theta} \psi_j + d_i^{\theta}\right) = 0
\end{aligned} \tag{28}$$

$$\begin{aligned}
&\zeta_i + \left(\frac{\eta_\infty}{2}\right) \cdot \\
&\cdot Sc \left[\begin{array}{l} \left(\sum_{j=0}^{N} l_{ij}^{f} \phi_j + d_i^{f}\right)\left(\sum_{j=0}^{N} l_{ij}^{\theta_1} \zeta_j + d_i^{\theta_1}\right) + \\ -n \left(\sum_{j=0}^{N} l_{ij}^{f_1} \phi_j + d_i^{f_1}\right)\left(\sum_{j=0}^{N} l_{ij}^{\theta} \zeta_j + d_i^{\theta}\right) \end{array}\right] = 0
\end{aligned} \tag{29}$$

This system is solved using Newton's iteration. The computer program of the numerical method was executed in MATHEMATICA 4 running on PC.

IV. Results and Discussion

Sadeghy et al. [16] pointed out that the method of the shooting method is rather sensitive to the initial guess and the method also suffers from some sort of numerical instability at large D_e perhaps because of the highly nonlinear nature of Eq. (7).

Therefore they used spectral methods. For this reason the non-linear ordinary differential Eqs. (7)-(9), satisfying the boundary condition (10) are solved numerically using Chebyshev spectral method for several values of D_e, n and Sc.

In order to assess the accuracy of the present numerical method (with $D_e = 0$), comparison with the results obtained by Wu et al. b[19] are shown in Table I.

Where the results show good agreement.

Numerical results for the local skin-friction coefficient, the local Nusselt number and the local Sherwood number are illustrated in Figs. 2-4 for various values of the Deborah number. From Fig. 2 it is shown that the local skin-friction coefficient increases with the increase of D_e.

Fig. 3 displays the local Nusselt number for the various values of D_e. From this figure it can be seen that the local Nusselt number increases with the increase of D_e. It is noted from Fig. 4 that an increase in the values of D_e, leads to a rise in the local Sherwood number.

TABLE I
COMPARISON OF $f''(0)$, $f'(0)$ AND $f(0)$ FOR VARIOUS VALUES OF η WITH $D_e = 0$

M	$f''(0)$		$f'(0)$		$f(0)$	
	Wu et al. [24]	Present Work	Wu et al. [24]	Present Work	Wu et al. [24]	Present Work
0.0	1.233	1.2328	0.000	0.0000	0.000	0.0000
0.2	1.034	1.0344	0.227	0.2266	0.023	0.0233
0.4	0.846	0.8463	0.414	0.4144	0.088	0.0881
0.6	0.675	0.6752	0.566	0.5660	0.187	0.1867
0.8	0.525	0.5251	0.686	0.6859	0.312	0.3124
1.0	0.398	0.3980	0.778	0.7779	0.459	0.4592
1.2	0.294	0.2938	0.847	0.8467	0.622	0.6220
1.4	0.211	0.2110	0.897	0.8968	0.797	0.7967
1.6	0.147	0.1473	0.932	0.9324	0.980	0.9797
1.8	0.100	0.0999	0.957	0.9568	1.169	1.1689
2.0	0.066	0.0658	0.973	0.9732	1.362	1.3619
2.2	0.042	0.0423	0.984	0.9839	1.558	1.5578
2.4	0.026	0.0260	0.991	0.9908	1.755	1.7552
2.6	0.016	0.0156	0.995	0.9946	1.954	1.9538
2.8	0.009	0.0090	0.997	0.9970	2.153	2.1530
3.6	0.001	0.0010	1.000	0.9999	2.952	2.9522
4.4	0.000	0.0000	1.000	1.000	3.752	3.7521

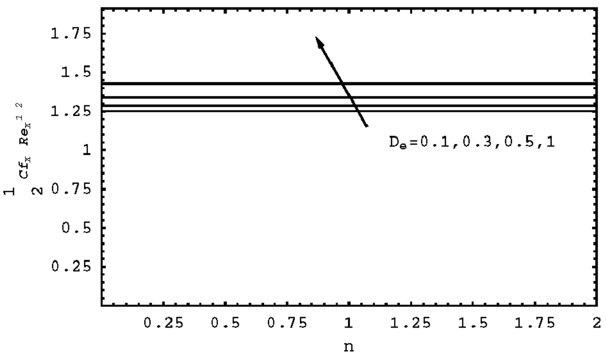

Fig. 2. Local skin-friction coefficient as a function of n for various values of D_e with $Pr = 3$, $Sc = 2.5$ and $\gamma = 0.1$

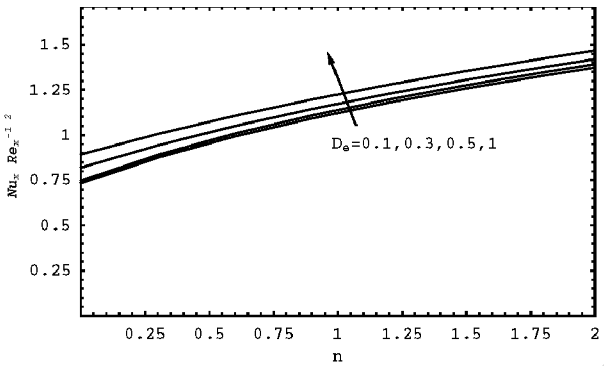

Fig. 3. Local Nusselt number as a function of n for various values of D_e with $Pr = 3$, $Sc = 2.5$ and $\gamma = 0.1$

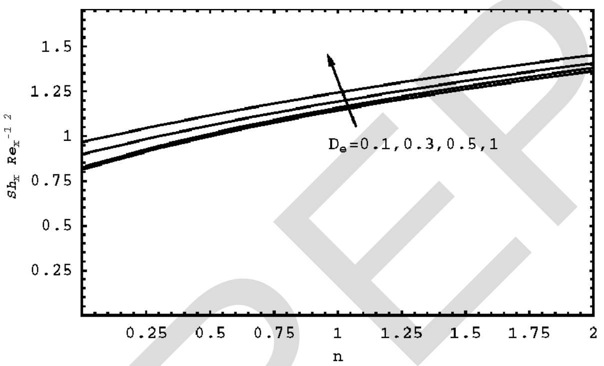

Fig. 4. Local Sherwood number as a function of n for various values of D_e with $Pr = 3$, $Sc = 2.5$ and $\gamma = 0.1$

The local Nusselt number and the local Sherwood number are plotted in Figs. 5 and 6 for various values of n and γ . In Fig. 5, the local Nusselt number is plotted against the exponent parameter n and the heat generation(absorption) parameter keeping all other parameters fixed.

It is observed that the local Nusselt number increases with an increase of n for a fixed value of γ and decreases with an increase of for a fixed values of n . Physically, the presence of heat generation will increase the fluid temperature near the surface and thus decreasing the heat transfer at the plate, while as the absolute value of the heat absorption increases the local Nusselt number increases.

The variation of the local Sherwood number with γ for various values of n when all other parameters fixed are shown in Fig. 6. It is displayed that the local Sherwood number increases with increasing n for a fixed value of γ . For a fixed n there is no effects for the generation/absorption parameter γ on the local Sherwood number. This is because from mathematical point in view Eqs. (8) and (9) are uncoupled.

Finally Fig. 7 shows the influence of the exponent parameter n on the local Sherwood number.

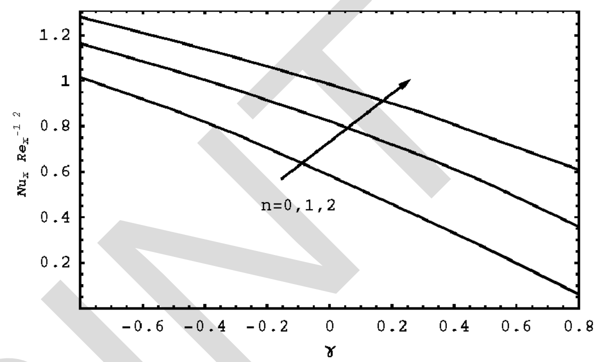

Fig. 5. Local Nusselt number as a function of γ for various values of n with $Pr = 3$, $Sc = 2.5$ and $D_e = 0.2$

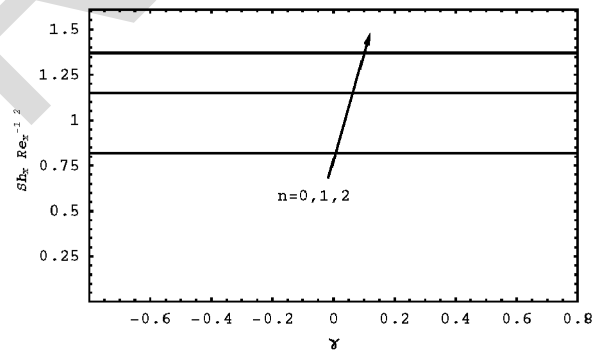

Fig. 6. Local Sherwood number as a function of γ for various values of n with $Pr = 3$, $Sc = 2.5$ and $D_e = 0.2$

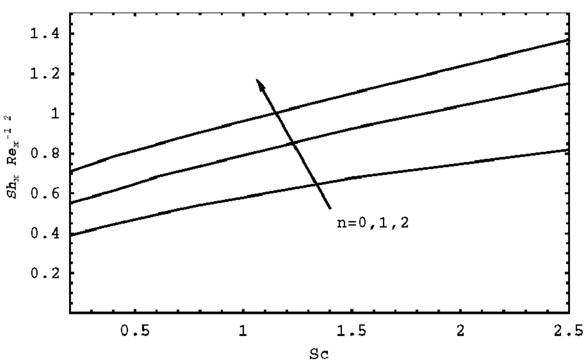

Fig. 7. Local Sherwood number as a function of Sc for various values of n with $Pr = 3$, $\gamma = 0.1$ and $D_e = 0.2$

It is observed that the local Sherwood number increases as either the exponent parameter n or Schmidt number Sc is increased keeping all other parameters fixed.

V. Conclusion

In this study, we have presented the effects due to heat generation/absorption on stagnation point heat and mass transfer of a Maxwell fluid with variable wall heat and mass flux. The numerical results indicated that the local skin-friction coefficient, the local Nusselt number and the local Sherwood number decrease with the increase of the Deborah number.

Also, it was found that the heat generation parameter has the effect of depressing the local Nusselt number while the absolute value of the heat absorption parameter has the effect of enhancing it. Moreover, it was noted that both the local Nusselt number and the local Sherwood number increase as the exponent parameter increases. Furthermore, it was found that an increase in the Schmidt number leads to an increase in the local Sherwood number.

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