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Research Article

Mixed Convection Boundary Layers with Prescribed Temperature in the Unsteady Stagnation Point Flow toward a Stretching Vertical Sheet

Nik Mohd Asri Nik Long,[1,2] Lee Feng Koo,[2,3] Tze Jin Wong,[2,3] and Melini Suali[1]

[1] *Department of Mathematics, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia*
[2] *Institute for Mathematical Research, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia*
[3] *Department of Basic Science and Engineering, Faculty of Agriculture and Food Sciences, Universiti Putra Malaysia, Sarawak Campus, 97008 Bintulu, Sarawak, Malaysia*

Correspondence should be addressed to Lee Feng Koo; kooleefeng@yahoo.com

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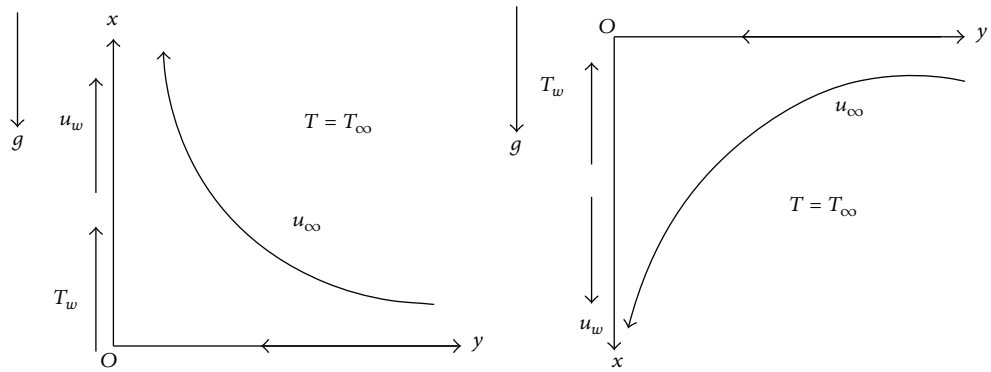
Mixed convection boundary layer caused by time-dependent velocity and the surface temperature in the two-dimensional unsteady stagnation point flow of an in-compressible viscous fluid over a stretching vertical sheet is studied. The transformed nonlinear boundary layer equations are solved numerically using the shooting technique in cooperation with Runge-Kutta-Fehlberg (RKF) method. Different step sizes are used ranging from 0.0001 to 1. Numerical results for the skin friction coefficient and local Nusselt number are presented for both assisting and opposing flows. It is found that the dual solutions exist for the opposing flow, whereas the solution is unique for the assisting flow. Important features of the flow characteristics are displayed graphically. Comparison with the existing results for the steady case show an excellent agreement.

1. Introduction

Stagnation point flow, describing the fluid motion near the stagnation region of a solid surface, exists in both cases of fixed or moving body in a fluid. Flow in incompressible viscous fluid on stretching sheet plays an important role in engineering applications such as extrusion of polymers, continuous casting, cooling of metallic plates, glass fiber production, hot rolling, paper production, wire drawing, and aerodynamic extrusion of plastic sheets [1–6]. Sakiadis [7] studied the boundary layer flow problem on a continuously moving surface with constant velocity. Crane [8] obtained the exact analytical solution for the two-dimensional stretching surface in a quiescent fluid. The effects of a variable surface temperature and linear surface stretching were examined by Grubka and Bobba [9]. Similar problem to that of Grubka and Bobba [9] for the case of power-law surface velocity and three different thermal boundary conditions were considered by Ali [10] and extended to the stretching surface subject to suction or injection [11]. Meanwhile, Ingham [12] investigated the existence of the dual solutions of the boundary layer equations of a continuously moving vertical plate with temperature inversely proportional to the distance up to the plate. Wang [13, 14] studied the behavior of liquid film on an unsteady stretching surface where the similarity transformation was employed to transform the governing partial differential equations to a nonlinear ordinary differential equation with an unsteadiness parameter. The boundary layer flow due to a stretching surface in vertical direction in steady, viscous, and incompressible fluid whereby the buoyancy forces are taken into consideration was discussed by Daskalakis [15], Lin and Chen [16], Ali and Al-Yousef [17], Chamkha [18], and Ishak et al. [19]. Vajravelu [20] studied the flow and heat transfer characteristics in a viscous fluid over a nonlinearly stretching sheet. Elbashbeshy and Bazid [21, 22] analyzed the heat transfer over an unsteady stretching surface. Tsai et al. [23] studied the nonuniform heat source or sink effect on the flow and heat transfer



(a) Assisting flow (b) Opposite flow

Figure 1: Physical model and coordinate system.

from an unsteady stretching sheet through a quiescent fluid numerically. Ishak and Nazar [24] extended Grubka and Bobba [9] and Ali's [10] work to the axisymmetric laminar boundary layer flow along a continuous stretching cylinder immersed in an incompressible viscous fluid. Patil et al. [25] obtained the numerical results for two-dimensional mixed convection flow along a vertical semi-infinite power-law stretching sheet. Bachok et al. [26] adopted the RKF method to solve the free convection boundary layer flow near a continuously moving vertical plate subject to suction and injection, whereas Bachok and Ishak [27] discussed the variations of skin friction coefficient and heat transfer rate at the surface subject to the nonlinear stretching/shrinking sheet immersed in a viscous fluid. Aziz and Hashim [28] investigated the effects of viscous dissipation on flow and heat transfer in a thin liquid film on an unsteady stretching sheet using homotopy analysis method. Chamkha and Ahmed [29] presented the effects of heat generation/absorption and chemical reaction on unsteady magnetohydrodynamics flow heat and mass transfer near a stagnation point of a three-dimensional porous body in the presence of a uniform magnetic field. Suali et al. [30] studied the behavior of unsteady stagnation point flow of an incompressible viscous fluid by considering both stretching and shrinking sheets with suction and injection. Very recently, Liu and Megahed [31] analyzed the effects of internal heat generation on the flow and heat transfer on an unsteady stretching sheet in the presence of thermal radiation and variable heat flux by means of homotopy perturbation method.

In the present paper, we investigate the behavior of the mixed convection boundary layer flow with prescribed temperature in the unsteady stagnation point flow over a stretching vertical sheet. The momentum and energy equations are solved numerically, and the characteristics of the flow are analyzed.

2. Basic Equation

Consider two-dimensional incompressible viscous fluid near the unsteady stagnation point flow on a stretching vertical surface. Assume that the fluid occupies the half plane ($y > 0$) and the vertical surface located at the Cartesian coordinate (x, y) with origin O, and the x-axis is along the direction of the surface and the y-axis is normal to it. Two equal forces are impulsively applied along the x-axis of the vertical stretching sheet where $u_w(x,t)$, $T_w(x,t)$, $T_\infty(x,t)$, and $u_\infty(x,t)$ are denoted as the velocity of the stretching sheet, prescribed temperature, uniform temperature of the ambient fluid, and the free stream velocity to the boundary layer, respectively. Both assisting and opposing flows are taken into consideration, and their configuration is shown in Figure 1. Under this assumption together with the Boussinesq and boundary layer approximations, the governing equations can be written as follows:

$$\begin{gathered}\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0,\\ \frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = \frac{\partial u_\infty}{\partial t} + u_\infty\frac{\partial u_\infty}{\partial x} + \nu\frac{\partial^2 u}{\partial y^2}\\ \pm g\beta\left(T - T_\infty\right),\\ \frac{\partial T}{\partial t} + u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} = \alpha\frac{\partial^2 T}{\partial y^2},\end{gathered} \tag{1}$$

where u and v are velocity components in x and y direction, g, T, α, ν, and β are gravity acceleration, fluid temperature, thermal diffusivity, kinematic viscosity, and thermal expansion coefficient, and the sign $\pm$ corresponds to the assisting and opposing buoyant flows, respectively, subjected to the boundary conditions Nik Long et al. [32]:

$$\begin{gathered}v = 0, \quad u = u_w(x,t), \quad T = T_w \quad \text{at } y = 0;\\ u \longrightarrow u_\infty(x,t), \quad T \longrightarrow T_\infty \quad \text{as } y \longrightarrow \infty\end{gathered} \tag{2}$$

and $u_w(x,t)$, $u_\infty(x,t)$, and T_w are denoted as

$$\begin{gathered}u_w(x,t) = \frac{bx}{1-\lambda t}, \qquad u_\infty(x,t) \longrightarrow \frac{ax}{1-\lambda t},\\ T_w = T_\infty + \frac{cx}{1-\lambda t},\end{gathered} \tag{3}$$

Table 1: Value of $f''(0)$ and $-\theta'(0)$ for $b/a = 1$ and $\lambda = 1$ at various Pr.

(a)

Pr	Buoyancy assisting flow			
	$f''(0)$		$-\theta'(0)$	
	Ishak et al. [33]	Present	Ishak et al. [33]	Present
0.72	0.3645	0.3645	1.0931	1.0931
6.8	0.1804	0.1804	3.2902	−3.2896
20	0.1175	0.1175	5.6230	5.6201
40	0.0873	0.0872	7.9463	7.9383
60	0.0729	0.0728	9.7327	9.7180
80	0.0640	0.0639	11.2413	11.2187
100	0.0578	0.0577	12.5726	12.5411

(b)

Pr	Buoyancy opposing flow			
	$f''(0)$		$-\theta'(0)$	
	Ishak et al. [33]	Present	Ishak et al. [33]	Present
0.72	−0.3852	−0.3852	1.0293	1.0293
6.8	−0.1832	−0.1832	3.2466	3.2461
20	−0.1183	−0.1183	5.5923	5.5896
40	−0.0876	−0.0876	7.9227	−7.9149
60	−0.0731	−0.0730	9.7126	−9.6982
80	−0.0642	−0.0641	11.2235	11.2012
100	−0.0579	−0.0578	12.5564	12.5252

where a, b, and c are positive constants. Equation (1) describes the unsteady flow over a stretching surface.

Introduce the following similarity transformations:

$$\Psi(x,\eta(y,t)) = \left(\frac{a\nu}{1-\lambda t}\right)^{1/2} x f(\eta),$$
$$\eta(y,t) = \left(\frac{a}{\nu(1-\lambda t)}\right)^{1/2} y, \tag{4}$$
$$\theta(\eta) = \frac{T - T_\infty}{T_w - T\infty},$$

where η is similarity variable and $\Psi(x, y)$ is stream function defined as

$$u = \frac{\partial \Psi}{\partial y}, \qquad v = -\frac{\partial \Psi}{\partial x}. \tag{5}$$

Substituting (4) into (5) yields

$$u = \left(\frac{ax}{1-\lambda t}\right) f'(\eta), \qquad v = -\left(\frac{a\nu}{1-\lambda t}\right)^{1/2} f(\eta), \tag{6}$$

where the prime denotes the differentiation with respect to η. Substituting (4) into (1) leads to the following nonlinear ordinary differential equations:

$$f'''(\eta) + f(\eta) f''(\eta) - \left[f'(\eta)\right]^2 + 1 + A\left(1 - f'(\eta) - \frac{1}{2}\eta f''(\eta)\right) \pm \lambda Q^2 \theta = 0, \tag{7}$$

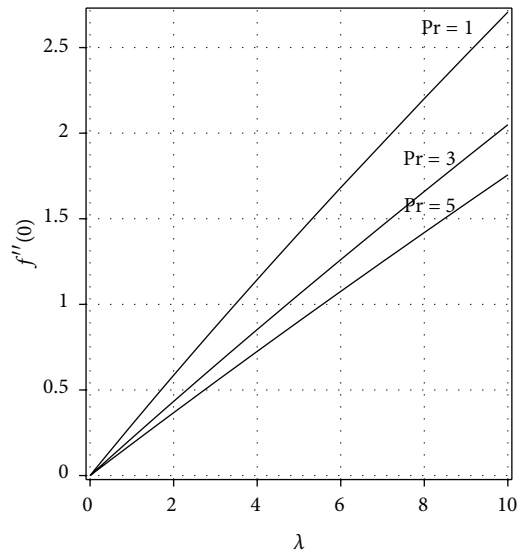
$$\frac{1}{\mathrm{Pr}}\theta''(\eta) + f(\eta)\theta'(\eta) - f'(\eta)\theta(\eta) - A\left(\theta(\eta) + \frac{1}{2}\theta'(\eta)\eta(y,t)\right) = 0 \tag{8}$$

and the boundary condition (2) becomes

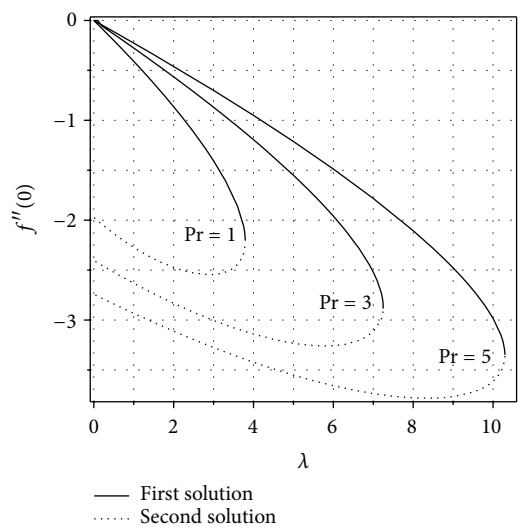
$$f(0) = 0, \qquad f'(0) = \frac{b}{a}, \qquad f'(\infty) = 1,$$
$$\theta(0) = 1, \qquad \theta(\infty) = 0, \tag{9}$$

where $Q = b/a$ is the ratio of stretching velocity parameter, $A = \lambda/a$ is the unsteadiness parameter, $\mathrm{Pr} = \nu/\alpha$ is the Prandtl number and the constant λ, $(\lambda \geq 0)$ is the buoyancy parameter defined as $\lambda = \mathrm{Gr}_x/\mathrm{Re}_x^2$, $\mathrm{Gr}_x = g\beta(T_w - T_\infty)x^3/\nu^2$ is local Grashof number, and $\mathrm{Re}_x = u_w x/\nu$ is the local Reynolds number. The buoyancy parameter, λ, can be written as

$$\lambda = \frac{g\beta(T_w - T_\infty)x}{u_w^2}. \tag{10}$$



(a) Assisting flow



(b) Opposing flow

Figure 2: Comparison of skin friction, $f''(0)$ for different Pr when $A = b/a = 1$.

The solution of (7) subject to the boundary conditions (9) is given by

$$f(\eta) = \eta, \tag{11}$$

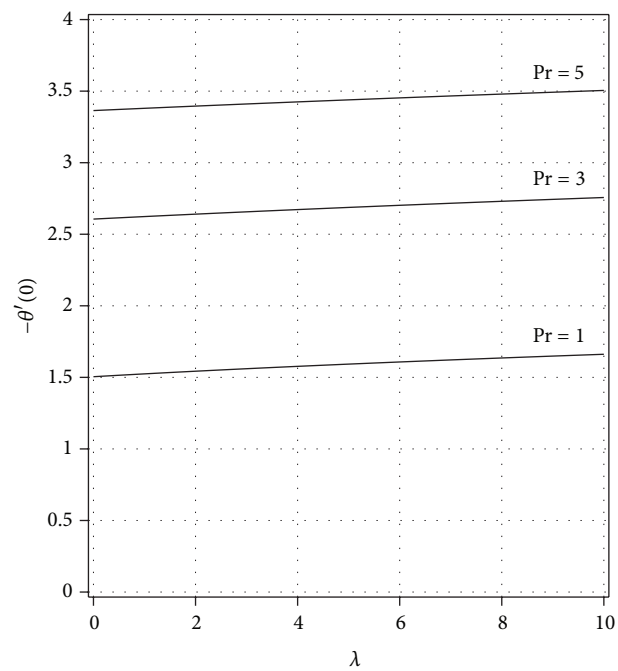
where $\lambda = 0$ and $b/a = 1$.

The quantities of physical interest are the skin friction coefficient, C_f, and the Local Nusselt number, Nu_x, which are defined by

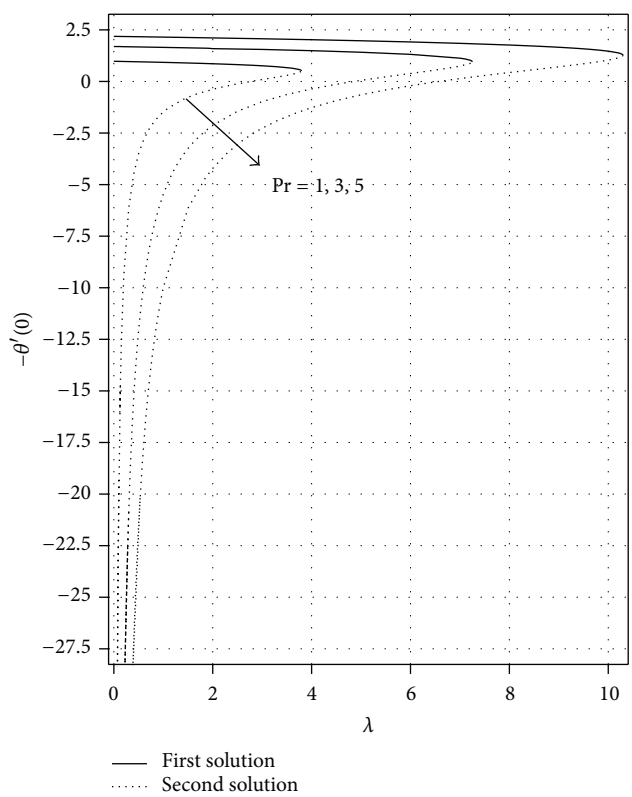
$$C_f = \frac{\tau_w}{\rho u_w^2}, \qquad \mathrm{Nu}_x = \frac{x q_w}{k(T_w - T_\infty)}, \tag{12}$$

where ρ is the fluid density. The wall shear stress, τ_w, and the heat flux, q_w, are defined as

$$\tau_w = \mu\left(\frac{\partial u}{\partial y}\right)_{y=0}, \qquad q_w = -k\left(\frac{\partial T}{\partial y}\right)_{y=0}, \tag{13}$$



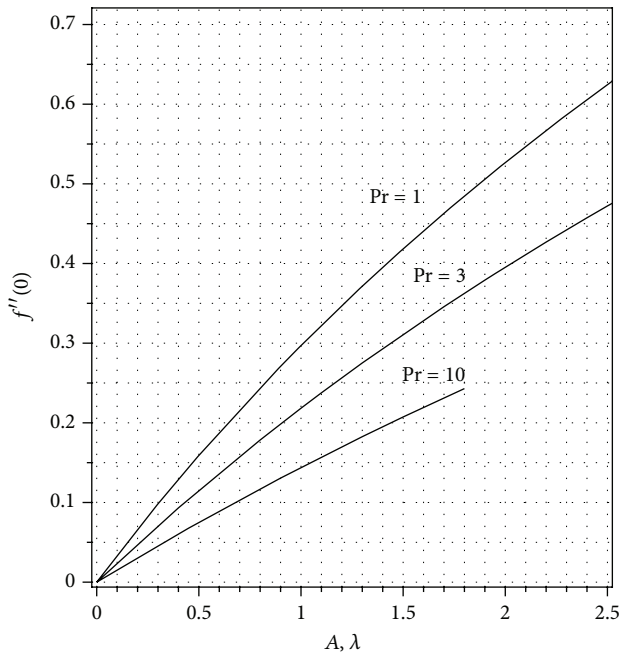
(a) Assisting flow



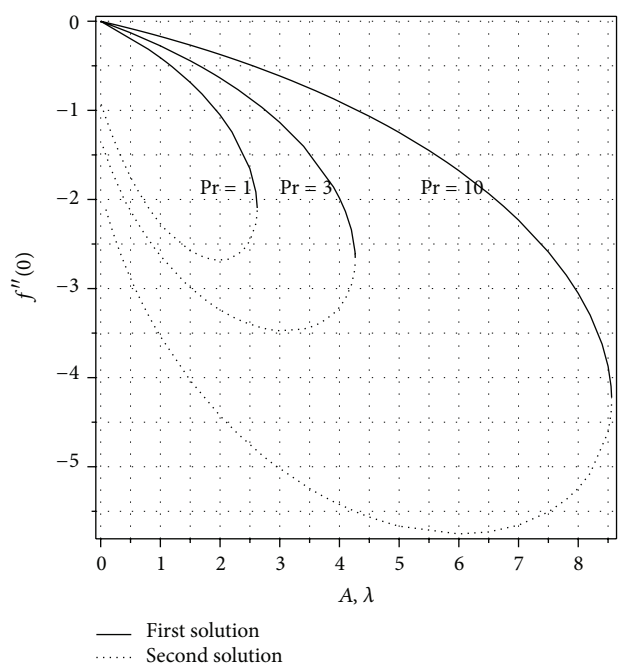
(b) Opposing flow

Figure 3: Comparison of local Nusselt number, $-\theta'(0)$ for different Pr when $A = b/a = 1$.

where μ and k are the dynamic viscosity and the thermal conductivity, respectively. The relation between μ and ρ is

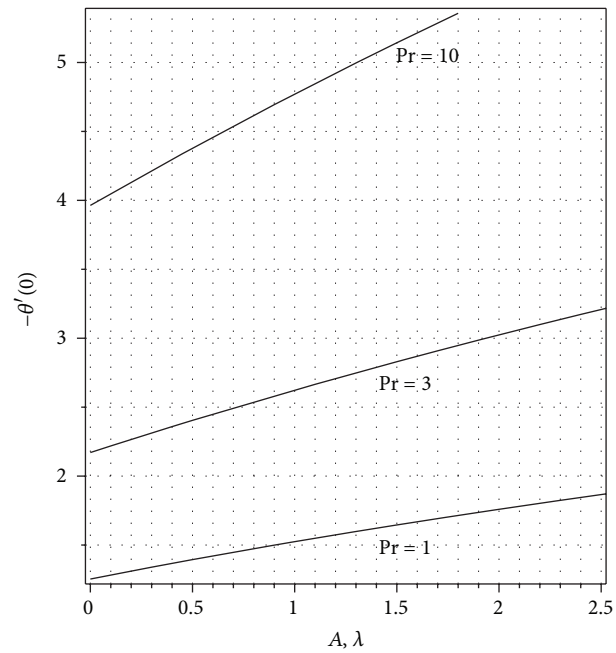


(a) Assisting flow

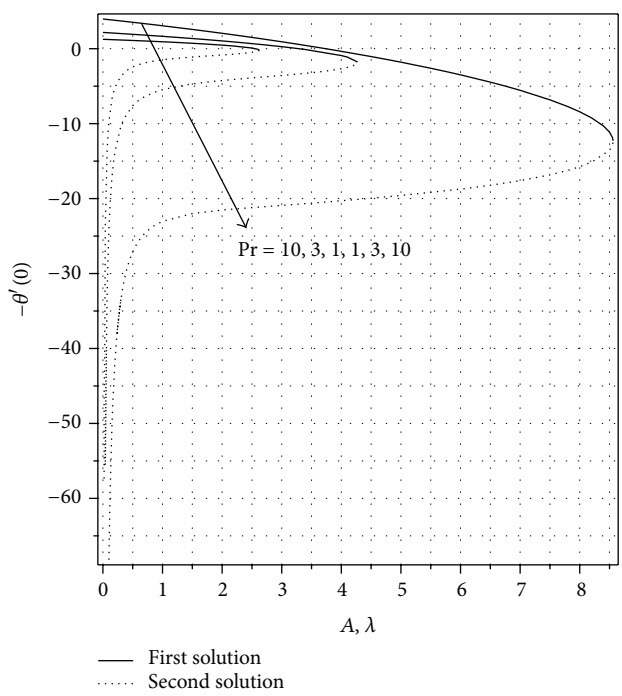


(b) Opposing flow

Figure 4: Comparison of skin friction, $f''(0)$ for different Pr when $A = \lambda$.



(a) Assisting flow



(b) Opposing flow

Figure 5: Comparison of local Nusselt number, $-\theta'(0)$ for different Pr when $A = \lambda$.

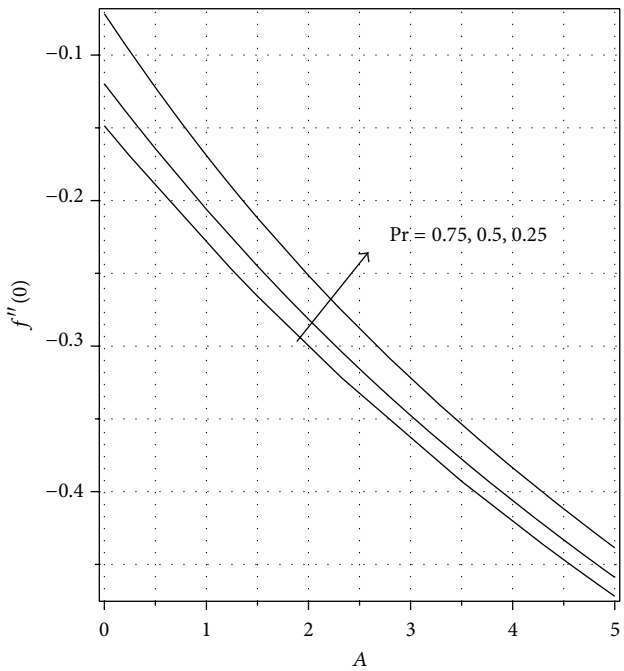
defined as $\nu = \mu/\rho$. Using the similarity variables (4), we obtain

$$\frac{1}{2}C_f \mathrm{Re}_x^{1/2} = f''(0), \qquad \mathrm{Nu}_x \mathrm{Re}_x^{1/2} = -\theta'(0) \tag{14}$$

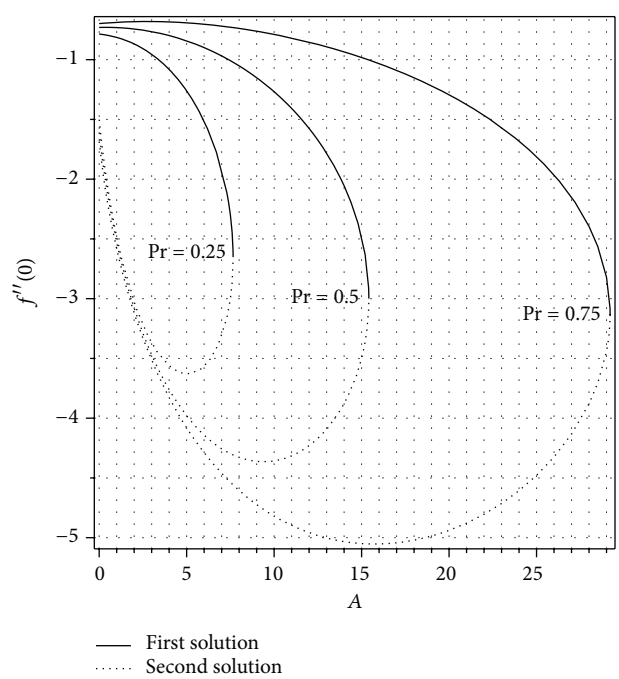
which represent the skin friction coefficient and heat transfer rate at the surface, respectively.

3. Result and Discussion

The transformed nonlinear ordinary differential equations (7) subject to the boundary condition (9) are solved numerically using RKF method with shooting technique. The numerical results are given to carry out a parametric study showing the influence of the nondimensional parameters;

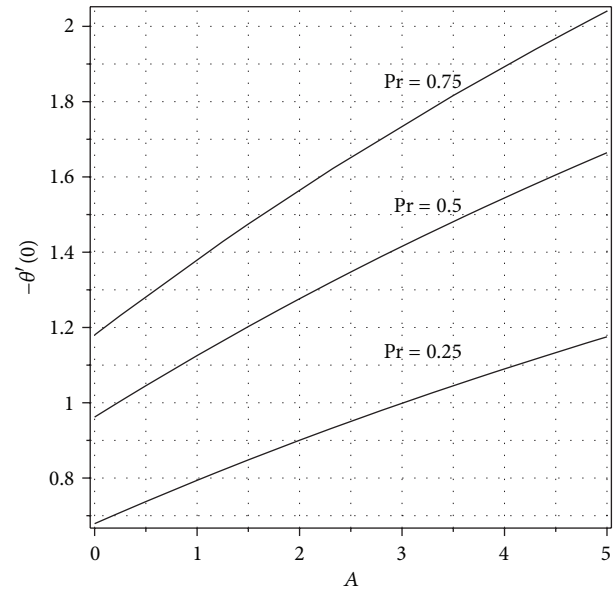


(a) Assisting Flow

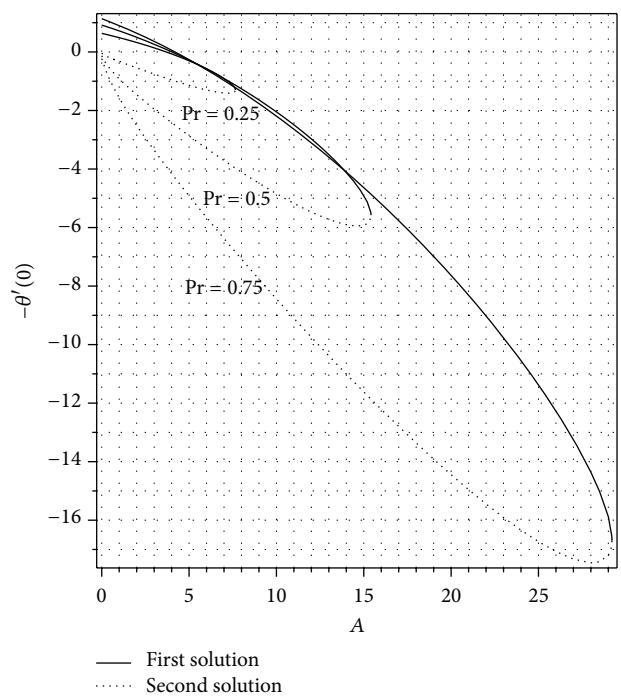


(b) Opposing Flow

Figure 6: Comparison of skin friction, $f''(0)$ for different Pr when $\lambda = 0.5$ and $f'(0) = 1.25$.



(a) Assisting flow

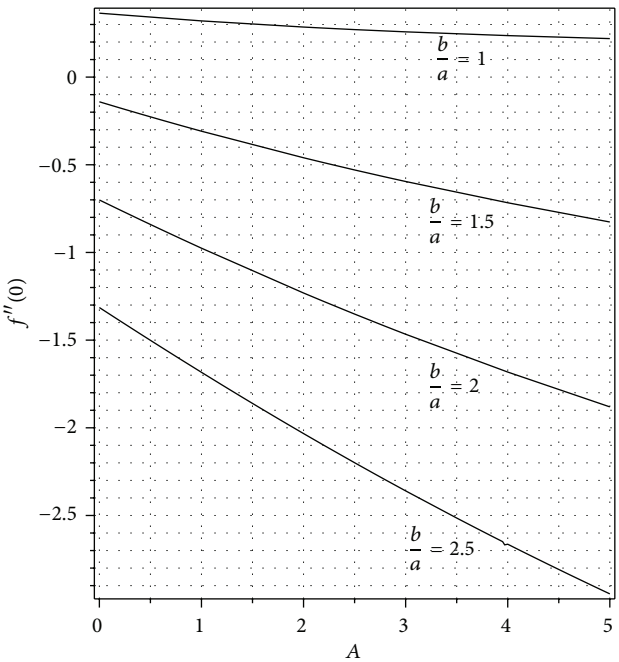


(b) Opposing flow

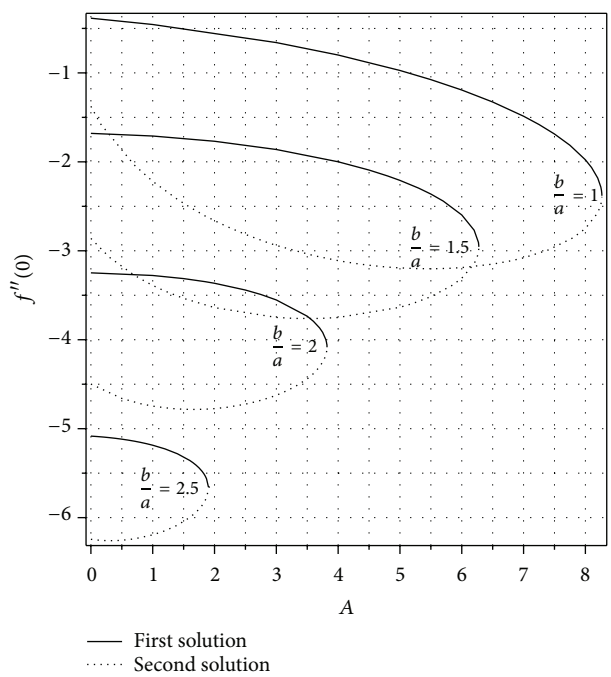
Figure 7: Comparison of local Nusselt number, $-\theta'(0)$ for different Pr when $\lambda = 0.5$ and $-\theta(0) = 1.25$.

that is, unsteadiness parameter, A, Prandtl number, Pr, and buoyancy parameter, λ. For the validation of the numerical results, the case of $A = 0$ (steady flow) is considered and compared with those of Ishak et al. [33]. The quantitative comparison is tabulated in Table 1, and it is found to be in excellent agreement.

Figures 2 and 3 present the variations of skin friction coefficient, $f''(0)$, and local Nusselt number, $-\theta'(0)$, with respect to buoyancy parameter, λ, for different values of Pr, and $A = 1$. For $A = \lambda$, the variations are displayed in Figures 4 and 5. It is observed that for the assisting flow, an increase in λ would increase, $f''(0)$ and $-\theta'(0)$ for all cases (Figures 2 to 5), while an increase in Pr would decrease $f''(0)$ (Figures 2 and 4) and increase $-\theta'(0)$ (Figures 3 and 5). For the opposing

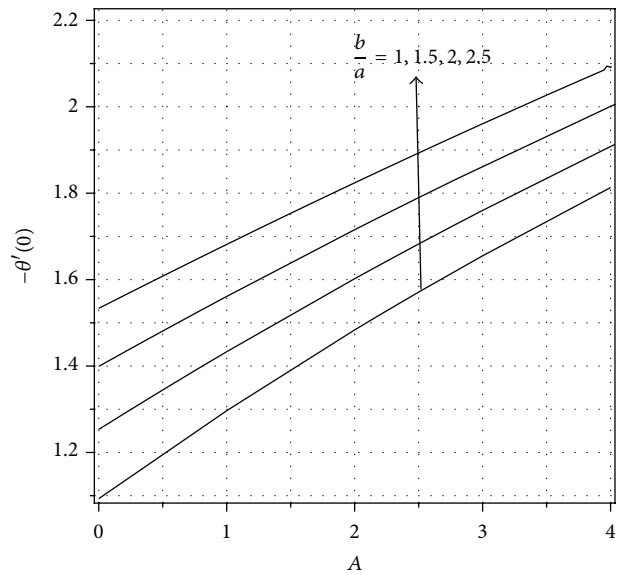


(a) Assisting flow

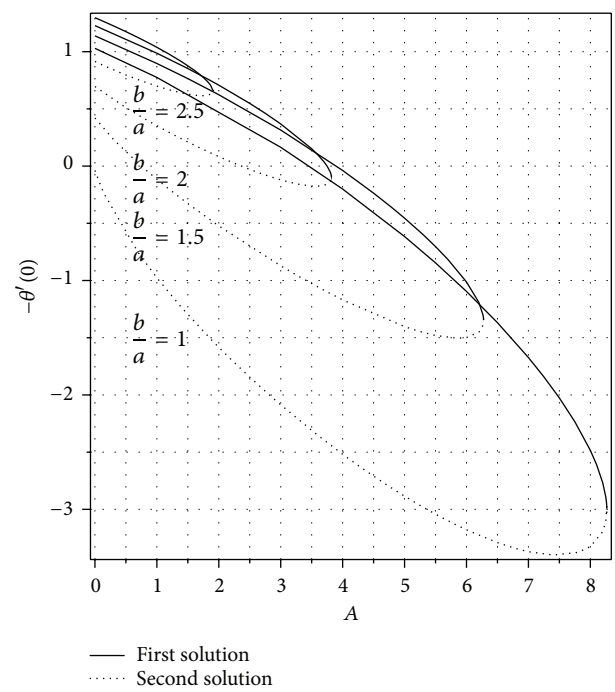


(b) Opposing flow

Figure 8: Comparison of Skin friction, $f''(0)$ for different b/a when Pr = 0.72 and $\lambda = 1$.



(a) Assisting flow

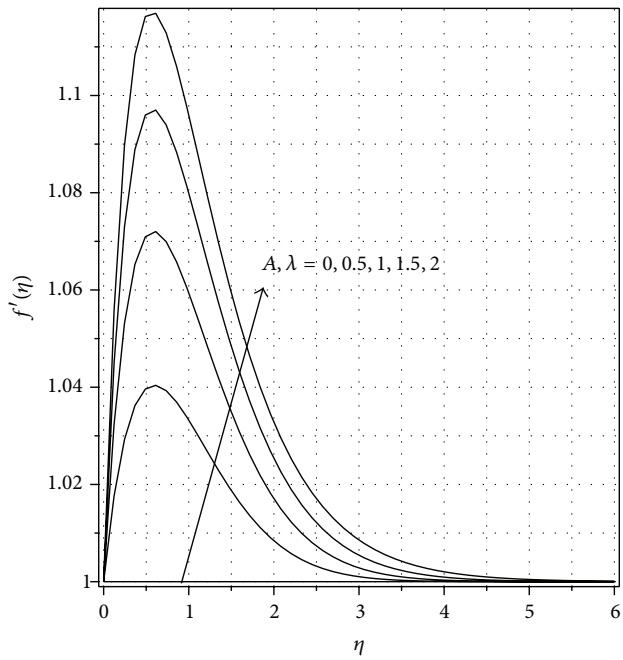


(b) Opposing flow

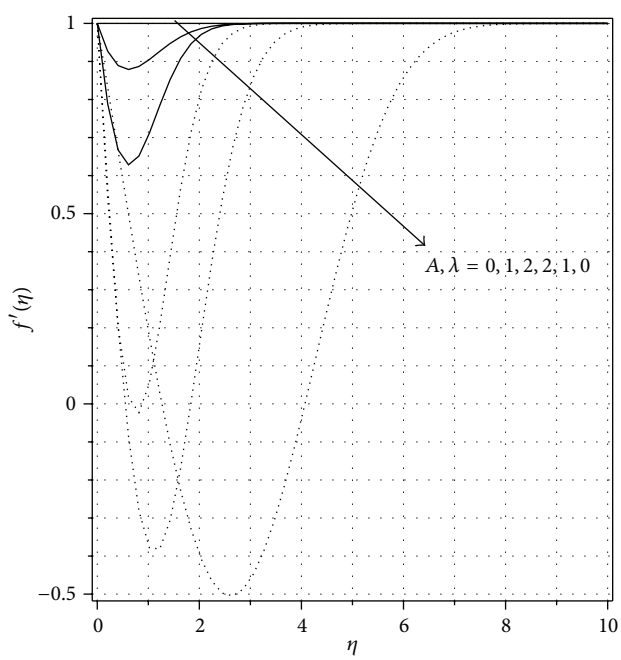
Figure 9: Comparison of local Nusselt number, $-\theta'(0)$ for different b/a when Pr = 0.72 and $\lambda = 1$.

flow, as λ and Pr increase the $f''(0)$ decreases and $-\theta'(0)$ increases for the first solution, but opposite behavior can be seen for the second solution. It is also noted that for the opposing flow, the dual solutions exist for $\lambda < \lambda_c$ and no solutions for $\lambda > \lambda_c$. For $\lambda = \lambda_c$, there exist a unique solution; the boundary layer separation occurs.

The effects of unsteadiness parameter, A and Pr, on $f''(0)$ and $-\theta'(0)$ for fix $\lambda = 0.5$ and $b/a = 1.25$ are shown in Figures 6 and 7. For the assisting flow, as A and Pr increase, the $f''(0)$ decreases and $-\theta'(0)$ increases. While for the opposing flow, as A increases the $f''(0)$ and $-\theta'(0)$ decrease for the first solution, and for the second solution, $f''(0)$ and $-\theta'(0)$ decrease until they archive their minimum values, $f''_{\min}(0)$ and $-\theta'_{\min}(0)$ and then they increase until $A = A_c$. For $A > A_c$, there exist no solution. An increase in Pr would increase

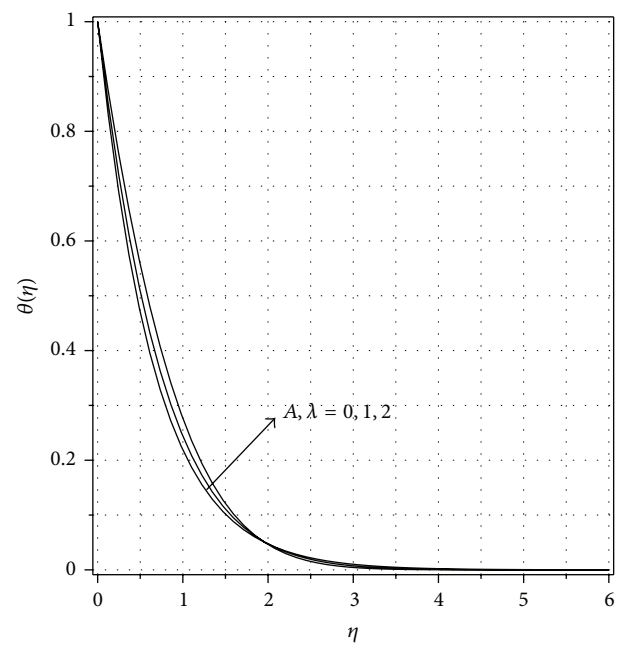


(a) Assisting flow

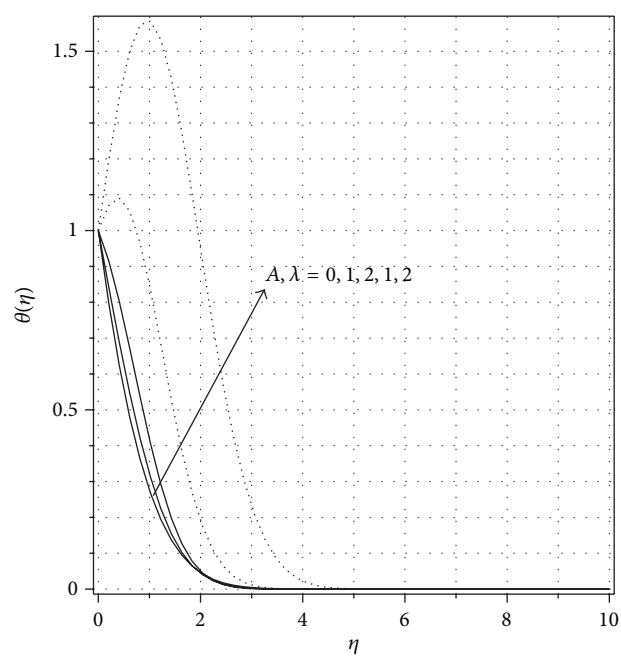


(b) Opposing flow

Figure 10: Velocity profile, $f'(\eta)$ for different $A = \lambda$ when Pr = 0.72 and $b/a = 1$.



(a) Assisting flow



(b) Opposing flow

Figure 11: Temperature profile, $f'(\eta)$ for different $A = \lambda$ when Pr = 0.72 and $b/a = 1$.

$f''(0)$ but only give little effect on $-\theta'(0)$ for the first solution, and $f''(0)$ and $-\theta'(0)$ decrease for the second solution.

Figures 8 and 9 exhibit the variations of the skin friction coefficient, $f''(0)$ and local Nusselt number, $-\theta'(0)$ for some value of b/a. As A and b/a increase, the $f''(0)$ decreases and $-\theta'(0)$ increases for the assisting flow. While for the opposing flow as A increases $f''(0)$ and $-\theta'(0)$ decreases for the first solution and $f''(0)$ increases and $-\theta'(0)$ decreases for the second solution. For the increasing values of b/a, $f''(0)$ decreases and $-\theta'(0)$ increases for both first and second solutions.

The velocity and temperature profile for different values of A and λ when Pr = 0.72 and $b/a = 1$ are displayed in Figures 10 and 11. The existance of the dual solutions for the opposing flow are clearly displayed. It is seen that for the assisting flow, the velocity profile increases to its maximum value, $f'_{\max}(\eta)$,

then decreases monotonically to a constant value. For the opposing flow, the velocity profile shows the opposite trend. The temperature profile decreases monotonically with η and becomes zero outside the boundary layer which satisfies the condition at infinity, $\theta(\infty) = 0$. These properties support the validation of the present results. It is also noticed that an increase in values of A and λ will increase the heat transfer rate at the surface. For the second solution, the temperature profile increases to attain its maximum value $\theta_{\max}(\eta)$, then decreases gradually to a constant.

4. Conclusion

In this study, the numerical solutions for both assisting and opposing flows of the mixed convection boundary layer caused by time-dependent velocity and surface temperature in two-dimensional unsteady stagnation point flow over a stretching vertical sheet are obtained. The similar transformation is advocated to reduce the governing partial differential equations into nonlinear ordinary differential equations which are solved numerically using RKF method via the shooting technique. Comparison with the existing results showed the excellent agreement. Dual solutions are found to exist for the opposing flow whereas the solution is unique for the assisting flow. The boundary layer separation occurs at $\lambda = \lambda_c$ for the opposing flow. The effect of buoyancy parameter, λ, the unsteadiness parameter, A, and Prandtl number, Pr, of the fluid has been displayed graphically and discussed in details.

Acknowledgment

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References

[1] E. M. A. Elbashbeshy, "Heat transfer over a stretching surface with variable surface heat flux," *Journal of Physics D*, vol. 31, no. 16, pp. 1951–1954, 1998.

[2] T. Fang, C. F. F. Lee, and J. Zhang, "The boundary layers of an unsteady incompressible stagnation-point flow with mass transfer," *International Journal of Non-Linear Mechanics*, vol. 46, no. 7, pp. 942–948, 2011.

[3] T. G. Fang, J. Zhang, and S. S. Yao, "Viscous flow over an unsteady shrinking sheet with mass transfer," *Chinese Physics Letters*, vol. 26, no. 1, Article ID 014703, 4 pages, 2009.

[4] A. Ishak, R. Nazar, and I. Pop, "Steady and unsteady boundary layers due to a stretching vertical sheet in a porous medium using darcy-brinkman equation model," *International Journal of Applied Mechanics and Engineering*, vol. 11, no. 3, pp. 623–637, 2006.

[5] A. Ishak, R. Nazar, and L. Pop, "Heat transfer over an unsteady stretching surface with prescribed heat flux," *Canadian Journal of Physics*, vol. 86, no. 6, pp. 853–855, 2008.

[6] Y. Y. Lok, A. Ishak, and I. Pop, "MHD stagnation-point flow towards a shrinking sheet," *International Journal of Numerical Methods for Heat and Fluid Flow*, vol. 21, no. 1, pp. 61–72, 2011.

[7] B. C. Sakiadis, "Boundary layer behavior on continuous solid surfaces," *The American Institute of Chemical Engineers Jounal*, vol. 7, pp. 221–225, 1961.

[8] L. J. Crane, "Flow past a stretching plate," *Zeitschrift für Angewandte Mathematik und Physik ZAMP*, vol. 21, no. 4, pp. 645–647, 1970.

[9] L. J. Grubka and K. M. Bobba, "Heat transfer characteristics of a continuous, stretching surface with variable temperature," *Journal of Heat Transfer*, vol. 107, no. 1, pp. 248–250, 1985.

[10] M. E. Ali, "Heat transfer characteristics of a continuous stretching surface," *Warme-Und Stoffubertragung*, vol. 29, no. 4, pp. 227–234, 1994.

[11] M. E. Ali, "On thermal boundary layer on a power-law stretched surface with suction or injection," *International Journal of Heat and Fluid Flow*, vol. 16, no. 4, pp. 280–290, 1995.

[12] D. B. Ingham, "Singular and non-unique solutions of the boundary-layer equations for the flow due to free convection near a continuously moving vertical plate," *ZAMP Zeitschrift für Angewandte Mathematik und Physik ZAMP*, vol. 37, no. 4, pp. 559–572, 1986.

[13] C. Wang, "Liquid film on an unsteady stretching sheet," *Quarterly of Applied Mathematics*, vol. 48, pp. 601–610, 1990.

[14] C. Wang, "Analytic solutions for a liquid film on an unsteady stretching surface," *Heat and Mass Transfer*, vol. 42, no. 8, pp. 759–766, 2006.

[15] J. E. Daskalakis, "Free convection effects in the boundary layer along a vertically stretching at surface," *Canadian Journal of Physics*, vol. 70, no. 12, pp. 1587–1597, 1993.

[16] C. R. Lin and C. K. Chen, "Exact solution of heat transfer from a stretching surface with variable heat flux," *Heat and Mass Transfer*, vol. 33, no. 5-6, pp. 477–480, 1998.

[17] M. Ali and F. Al-Yousef, "Laminar mixed convection from a continuously moving vertical surface with suction or injection," *Heat and Mass Transfer*, vol. 33, no. 4, pp. 301–306, 1998.

[18] A. J. Chamkha, "Hydromagnetic three-dimensional free convection on a vertical stretching surface with heat generation or absorption," *International Journal of Heat and Fluid Flow*, vol. 20, no. 1, pp. 84–92, 1999.

[19] A. Ishak, R. Nazar, and I. Pop, "Mixed convection on the stagnation point flow toward a vertical, continously stretching sheet," *Journal of Heat Transfer*, vol. 129, no. 8, pp. 1087–1090, 2007.

[20] K. Vajravelu, "Viscous flow over a nonlinearly stretching sheet," *Applied Mathematics and Computation*, vol. 124, no. 3, pp. 281–288, 2001.

[21] E. M. A. Elbashbeshy and M. A. A. Bazid, "Heat transfer over an unsteady stretching surface with internal heat generation," *Applied Mathematics and Computation*, vol. 138, no. 2-3, pp. 239–245, 2003.

[22] E. M. A. Elbashbeshy and M. A. A. Bazid, "Heat transfer over an unsteady stretching surface," *Heat and Mass Transfer*, vol. 41, no. 1, pp. 1–4, 2004.

[23] R. Tsai, K. H. Huang, and J. S. Huang, "Flow and heat transfer over an unsteady stretching surface with non-uniform heat source," *International Communications in Heat and Mass Transfer*, vol. 35, no. 10, pp. 1340–1343, 2008.

[24] A. Ishak and R. Nazar, "Laminar boundary layer flow along a stretching cylinder," *European Journal of Scientific Research*, vol. 36, no. 1, pp. 22–29, 2009.

[25] P. M. Patil, S. Roy, and A. J. Chamkha, "Mixed convection flow over a vertical power-law stretching sheet," *International Journal*

of Numerical Methods for Heat and Fluid Flow, vol. 20, no. 4, pp. 445–458, 2010.

[26] N. Bachok, A. Ishak, R. Nazar, and I. Pop, "Ingham problem for free convection near a continuously moving vertical permeable plate," *IMA Journal of Applied Mathematics*, vol. 77, no. 4, pp. 578–589, 2011.

[27] N. Bachok and A. Ishak, "Similarity solutions for the stagnation-point flow and heat transfer over a nonlinearly stretching/shrinking sheet," *Sains Malaysiana*, vol. 40, no. 11, pp. 1297–1300, 2011.

[28] R. C. Aziz and I. Hashim, "Liquid film on unsteady stretching sheet with general surface temperature and viscous dissipation," *Chinese Physics Letters*, vol. 27, no. 11, Article ID 110202, 4 pages, 2010.

[29] A. J. Chamkha and S. E. Ahmed, "Similarity solution for unsteady MHD flow near a stagnation point of a three-dimensional porous body with heat and mass transfer, heat generation/absorption and chemical reaction," *Journal of Applied Fluid Mechanics*, vol. 4, no. 2, pp. 87–94, 2011.

[30] M. Suali, N. M. A. Nik Long, and N. M. Ariffin, "Unsteady stagnation point flow and heat transfer over a stretching/shrinking sheet with suction or injection," *Journal of Applied Mathematics*, vol. 2012, Article ID 781845, 12 pages, 2012.

[31] I. C. Liu and A. M. Megahed, "Homotopy perturbation method for thin film flow and heat transfer over an unsteady stretching sheet with internal heating and variable heat flux," *Journal of Applied Mathematics*, vol. 2012, Article ID 418527, 12 pages, 2012.

[32] N. M. A. Nik Long, M. Suali, A. Ishak, N. Bachok, and N. M. Arifin, "Unsteady stagnation point flow and heat transfer over a stretching/shrinking sheet," *Journal of Applied Sciences*, vol. 11, no. 20, pp. 3520–3524, 2011.

[33] A. Ishak, R. Nazar, and I. Pop, "Mixed convection boundary layers in the stagnation-point flow toward a stretching vertical sheet," *Mechanica*, vol. 41, no. 5, pp. 509–518, 2006.