Penerbit Akademia Baru

CFD Letters

Journal homepage: www.akademiabaru.com/cfdl.html
ISSN: 2180-1363

The Boundary Layer Flow, Heat and Mass Transfer beyond an Exponentially Stretching/Shrinking Inclined Sheet

Open Access

Hazirah binti Mohd Azmi[1], Siti Suzilliana Putri Mohamed Isa[1,2,*], Norihan Md. Arifin[1,3]

1 Laboratory of Computational Sciences and Mathematical Physics, Institute for Mathematical Research, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor Darul Ehsan, Malaysia
2 Centre of Foundation Studies for Agricultural Science, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor Darul Ehsan, Malaysia
3 Department of Mathematics, Faculty of Science, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor Darul Ehsan, Malaysia

ARTICLE INFO

Article history:
Received 21 June 2020
Received in revised form 20 August 2020
Accepted 25 August 2020
Available online 31 August 2020

Keywords:
Inclined sheet; stretching; shrinking

ABSTRACT

The characteristics of heat and mass transmission, together with the features of fluid flow where the fluid is bounded by a stretching/shrinking sheet are influenced by the rotation angle of the sheet. In addition, the comparison between two conditions of stretching/shrinking sheet, known as: 1. normal position of sheet (zero rotation), 2. when it is inclined, contribute significant applications in science and technology, especially in experimental and theoretical research. According to this fact, this paper examines the impact of stretching and shrinking parameters acting on the inclined sheet, which contribute to the changes on the flow, heat and mass transfer in a Newtonian fluid. The variations of velocity, temperature and concentration of Newtonian fluid also being observed. The momentum, energy and concentration equations are acting as the controlling equations and written as partial differential equations (PDE). Subsequently, these equations were transformed into the ordinary differential equations (ODE) by using the similarity transformation. Finally, the ODE is solved numerically by bvp4c program in Matlab software. Dual numerical solutions are obtained in this paper, and presented in the figure form. The features of flow pattern, heat and mass transfer are described in details, together with the profiles of velocity, temperature and concentration of the related fluid. As a result, it is found that rate of skin friction coefficient, local Nusselt number, and local Sherwood number are reduced with the addition of inclination angle. On the other hand, velocity profile and the local Nusselt number are enhanced due to the impact of stretching rate at the inclined sheet.

1. Introduction

The fluid flow over an inclined plane has significant contributions on gas turbines, extrusion of plastic sheets from a die, MHD (magnetohydrodynamic) power generators, the boundary layer from a liquid film condensation process and polymer industries [1]. Therefore, the numerical reports on this engineering field have been published recently. An analysis of steady MHD two-dimensional

* *Corresponding author.*
E-mail address: ctsuzilliana@upm.edu.my (Siti Suzilliana Putri Mohamed Isa)

https://doi.org/10.37934/cfdl.12.8.98107

boundary layer flow of a viscous fluid towards an exponentially stretching inclined porous sheet in the presence of thermal radiation, Soret and Dufour effects with suction/blowing is presented by Sravanthi [2]. The MHD boundary layer flow of Casson fluid over an inclined stretching surface was investigated by Bala Anki Reddy [3]. On the other hand, mixed convection Eyring-Powell nanofluid flow over an inclined surface is studied by Khan *et al.,* [4]. Unsteady mixed convection flow of Casson fluid past an inclined stretching sheet in the presence of nanoparticles is investigated by Rawi *et al.,* [5]. The multiple numerical solutions of a non-Newtonian Carreau fluid flow over an inclined shrinking surface have been obtained by Khan *et al.,* [6]. The latest findings published in the field of linear inclined stretching/shrinking sheet in micropolar fluid were reported by Lund *et al.,* [7] by adding the convective boundary condition impact.

In the cases of stretching and shrinking sheet with zero inclination angle, there is a high possibility of achieving multiple numerical solutions. The occurrence of multiple solutions in the related cases have been done by some researchers [8-14], and their work focused on the exponential function of stretching/shrinking sheet velocity. Meanwhile, dual numerical solutions in linear inclined stretching/shrinking sheet have been obtained by Lund *et al.,* [7]. Thus, to verify the excepted solution stability analysis is used, and the rest is decided as unstable. This investigation can be operated by using the bvp4c program from Matlab software and processed numerically for dual solutions. The solution with the initial decay of disturbance labeled as a stable solution (first solution). Besides, an unstable solution, which is mentioned as the second solution, owns the initial growth of disturbance. As a conclusion, a stable numerical solution is reliable and really occurs in an actual fluid state [14]. The application of stability analysis in the related cases (zero inclined stretching/shrinking sheet) has been done by some researchers [11, 15-17]. Meanwhile, Lund *et al.,* [7] have successfully selected the stable solution in their model micropolar fluid.

Based on the previous works, dual numerical solutions on the case of exponentially inclined stretching/shrinking sheet still not being reported. Therefore, the aim of this paper is to analyze the effects of inclination angle, stretching, and shrinking parameters on steady MHD flow over an inclined exponentially stretching/shrinking sheet via Matlab bvp4c program. The governing equations, in the form of partial differential equations are transformed into ordinary differential equations (ODEs). These ODEs system, together with the related boundary conditions are solved in Matlab bvp4c program to find out the characteristics of the following: velocity, temperature and concentration profiles, skin friction coefficient, local Nusselt number, and local Sherwood number. The restrictions of our numerical study are the positive range of mixed convection parameter (assisting flow case) and positive buoyancy ratio. In addition, we also do not perform stability analysis in our study because of the page's limitation. However, our selection of a stable solution is based on the concept of uniform increment or decrement in the profiles of velocity, temperature, and concentration against boundary layer thickness [7, 11, 15-17].

2. Methodology

Consider the mathematical formulation for two-dimensional incompressible, viscous, and electrically conducting Newtonian fluid bounded by a semi-infinite inclined stretching/shrinking sheet. This sheet is inclined with an angle κ to the vertical and has an exponential variation of velocity u_w. The *x*-axis is placed along the stretching/shrinking surface, and the *y*-axis is perpendicular to it. The subscripts w and ∞ at parameters T and C represent the position at the stretching/shrinking sheet and at the point far from the sheet. The schematic diagram for this problem is presented in Figure 1. The mathematical model of this problem is governed by continuity, momentum, energy, and concentration equations. These equations are extended from the case of boundary layer

Newtonian fluid flow over a shrinking sheet, with zero inclination angle [11]. The extension compared to the previous work [11] are by adding the condition of stretching sheet, and the sheet is inclined with the respective angle. The related governing equations are presented, as below:

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

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=\nu\frac{\partial^2 u}{\partial y^2}+g\beta_T(T-T_\infty)\cos\kappa+g\beta_C(C-C_\infty)\cos\kappa \tag{2}$$

$$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=\alpha\frac{\partial^2 T}{\partial y^2}+\frac{DK_T}{C_S C_P}\frac{\partial^2 C}{\partial y^2} \tag{3}$$

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

where u and v are the components of velocity in the x and y directions, $\nu=\mu/\rho$ is the kinematic viscosity, μ denotes the viscosity, ρ is the fluid density, g is the gravitational acceleration, β_T is the coefficient of thermal expansion, β_C is the coefficient of solutal expansions, T is the temperature of the fluid, C is the concentration of the fluid, α is the thermal diffusivity, D is the solutal diffusivity of the medium, K_T is the thermal diffusion ratio, C_S is the concentration susceptibility, C_P is the specific heat at constant pressure and T_m is the mean fluid temperature.

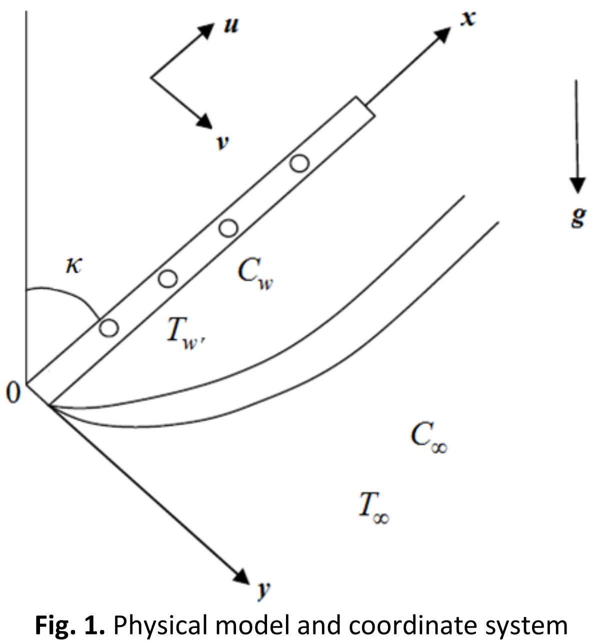


Fig. 1. Physical model and coordinate system

The appropriate boundary conditions are:

$$\begin{aligned}&= u_w(x)=\lambda U_0\exp\left({}^{x}/_{L}\right),\ \ v=v_w(x),\ \ T_w(x)=T_\infty+\ T_0\exp\left({}^{x}/_{2L}\right),\\ &C_w(x)=C_\infty+\ C_0\exp\left({}^{x}/_{2L}\right), \qquad \text{at } y=0\\ &u\to 0,\ T\to T_\infty,\ \ C\to C_\infty \qquad \text{as } y\to\infty\end{aligned} \tag{5}$$

where $\lambda>0$ is the stretching parameter, $\lambda<0$ is the shrinking parameter and the wall mass suction velocity is represented by $v_w(x)<0$. The term $\exp(x/2L)$ in temperature T_w and concentration distribution C_w are taken from previous studies [11, 18-21], so that the numerical results will satisfy the final boundary condition after substituting similarity variables.

Introducing new similarity variables:

$$\theta(\eta) = \frac{T-T_\infty}{T_w-T_\infty},\ \phi(\eta) = \frac{C-C_\infty}{C_w-C_\infty}, \quad \eta = y\left(\frac{U_0}{2\nu L}\right)^{1/2} \exp\left({}^{x}/_{2L}\right),$$
$$u = U_0 \exp\left({}^{x}/_{L}\right) f'(\eta), \tag{6}$$
$$v = -\left(\frac{\nu U_0}{2L}\right)^{1/2} \exp\left({}^{x}/_{2L}\right) [f(\eta) + \eta f'(\eta)]$$

where prime indicates the differentiation with respect to η.

Substituting Eq. (6) into Eqs. (2–5), the new ordinary differential equations and boundary conditions are obtained as below:

$$f''' + ff'' - 2(f')^2 + 2Ri\left[exp\left(\frac{-3X}{2}\right)\right](\theta + N\phi)\cos\kappa = 0 \tag{7}$$

$$\frac{1}{Pr}\theta'' + f\theta' - f'\theta + Db\phi'' = 0 \tag{8}$$

$$\frac{1}{Sc}\phi'' + f\phi' - f'\phi + Sr\theta'' = 0 \tag{9}$$

$$f'(\eta) = \lambda,\quad f(\eta) = S,\quad \theta(\eta) = 1,\quad \phi(\eta) = 1 \qquad \text{at} \quad \eta = 0$$
$$f'(\eta) \to 0,\quad \theta(\eta) \to 0,\quad \phi(\eta) \to 0 \qquad \text{as} \quad \eta \to \infty \tag{10}$$

The parameters involved in this problem are listed in Table 1. On the other hand, the physical parameters of skin friction coefficient C_f, local Nusselt number Nu_x and local Sherwood number Sh_x are presented as follow:

$$C_f = \left(\frac{\mu}{\rho U_0^2}\right)\left(\frac{\partial u}{\partial y}\right), \quad Nu_x = \left(\frac{L}{T_w-T_\infty}\right)\left(-\frac{\partial T}{\partial y}\right)_{y=0}, \quad Sh_x = \left(\frac{L}{C_w-C_\infty}\right)\left(-\frac{\partial C}{\partial y}\right)_{y=0} \tag{11}$$

Substituting Eq. (6) into Eq. (11), then we get

$$C_f\sqrt{2Re_x}exp\left(\frac{-3X}{2}\right) = f''(0), \quad Nu_x\sqrt{2/Re_x}exp\left(\frac{-X}{2}\right) = -\theta'(0),$$
$$Sh_x\sqrt{2/Re_x}exp\left(\frac{-X}{2}\right) = -\phi'(0) \tag{12}$$

The final stage of the methodology is by performing the numerical calculation on the system of ordinary differential equations Eqs. (7-9) together with the boundary conditions as shown in Eq. (10) using MatLab bvp4c program. This program is used to obtain the graphical representation of velocity, temperature, and concentration profiles. These graphs are plotted due to the variation of boundary layer thickness η. Moreover, the numerical values of the skin friction coefficient C_f, local Nusselt number Nu_x and local Sherwood number Sh_x are obtained and presented in the form of graphs.

Table 1
The governing parameters

No.	Parameters	Mathematical Formulation
1.	Mixed convection parameter	$Ri = Gr/Re^2$ Where $Ri > 0$ indicates the case of aiding flow.
2.	Thermal Grashof number	$Gr = g\beta_T(T_0 - T_\infty)L^3/v^2$
3.	Reynolds number	$Re = U_0L/v$
4.	Dimensionless coordinate along the plate parameter	$X = x/L$, where L is the length of the stretching/shrinking sheet
5.	Buoyancy ratio	$N = \beta_C(C_0 - C_\infty)/\beta_T(T_0 - T_\infty)$
6.	Prandtl number	$Pr = v/\alpha$
7.	Schmidt number	$Sc = v/D$
8.	Soret number	$Sr = [DK_T(T_0 - T_\infty)]/[T_m v(C_0 - C_\infty)]$
9.	Dufour number	$Db = [DK_T(C_0 - C_\infty)]/[C_S C_P v(T_0 - T_\infty)]$
10.	Suction parameter	$S = \left(v_w(x)/\exp\left({}^{x}/_{2L}\right) \times \sqrt{2L/vU_0}\right) > 0$

3. Results

The impact of inclination angle κ, stretching parameter $\lambda > 0$, and shrinking parameter $\lambda < 0$ in the profiles of velocity $f'(\eta)$, temperature $\theta(\eta)$ and concentration $\phi(\eta)$ together with the variation of skin friction coefficient C_f, local Nusselt number Nu_x and local Sherwood number Sh_x are illustrated in Figures 2 – 7. In the present study, the following values are fixed for the entire MatLab program unless otherwise mentioned: $\kappa = 45°$, $S = 2.8$, $Sc = 1$, $Pr = 1$, $Ri = 0.2$, $N = 0.5$, $X = 0.1$, $Sr = 2$ and $Db = 0.1$. The thickness of boundary layer $\eta = 8$ is constantly used for numerical computations. The validation of our numerical results obtained from MatLab is performed, by comparing our results with previous investigators [11, 18, 22-23] on the values of wall-temperature gradient $-\theta'(0)$. Magyari and Keller [22] and Mukhopadhyay [23] are the well-known researchers, who reported the case of the boundary layer flow and heat transfer towards a porous exponential stretching sheet. The comparison is made by reducing our Matlab bvp4c program to the case of zero inclined sheet ($\kappa = 0$), as shown in Table 2. As a conclusion, the present values of $-\theta'(0)$ are in good agreement among all results. Therefore, a good comparison proves that our bvp4c program is applicable for subsequent findings.

Table 2
Comparison on the values of wall-temperature gradient $-\theta'(0)$ for λ = 1 and κ = S = Ri = Sc = Sr = Db = N = X = 0

Pr	Isa *et al.,* [11]	Srinivasacharya and RamReddy [17]	Magyari and Keller [21]	Mukhopadhyay [22]	Present
1.0	-0.95478	-0.95478	-0.95478	0.9547	-0.95478
3.0	-1.86907	-1.86908	-1.86908	1.8691	-1.86907
5.0	-2.50013	-2.50015	-2.50014	2.5001	-2.50013
10.0	- 3.66037	-3.66043	-3.66038	3.6603	- 3.66037

Dual numerical solutions are obtained in this paper, where the first and second solutions are drawn by solid and dashed lines, respectively. However, only one solution is linearly stable and physically realizable. A stable solution has a pattern without or with the minimal existence of minimum and maximum peak. This pattern has occurred because it fully satisfies the boundary conditions in Eq. (10). Therefore, the stable solution is labelled as the first solution in Matlab program. Besides, another solution is labelled as the second solution, and it is unstable.

Figures 2-4 show the variation of velocity, temperature, and concentration profiles, respectively when the sheet is inclined by $45°$. These profiles are depicted for $\lambda = -0.5,\ 0.1\ and\ 0.7$. The first solution of velocity profile in Figure 2 shows the uniform decrement of instantaneous velocity due to the distance from the stretching sheet η, until the velocity reaches constant zero value. On the other hand, the instantaneous velocity for $\lambda < 0$ (shrinking case) presents an enhancement pattern until it reaches a zero rate. Therefore, it is proved that the zero velocity at the point far from the stretching/shrinking sheet indicates that there is no fluid movement at this point. Moreover, the instantaneous velocity of the first solution is ascended due to the increasing λ. This is due to the fact that the higher stretching sheet parameter causes the fluid tends to move with the same direction of the sheet and causes the fluid velocity to increase. Meanwhile, the fluid velocity at the point close to the sheet is reduced when the sheet is shrieked. The pattern of fluid velocity distribution, which impacted by the shrinking parameter, was proved by previous investigators [23-25]. The fluid movement of the second solution is assumed to have an opposite direction until it reaches maximum velocity, which denoted by the occurrence of a minimum peak in Figure 2. Then, the fluid of the second solution changes its direction and slowing down until the velocity is zero. As a result, the magnitude of velocity profiles for the second solution increases at the region close to the sheet, and then it decreases far from the sheet. Figure 3 shows the continuous decrement of the instantaneous temperature of the first solution for various fluid thickness η. However, the series of positive peaks are observed for temperature profile second solution. Hence, the second solution records a maximum temperature at a certain point measured from the stretching/shrinking sheet. The values of the fluid temperature for the first solution show that the temperature is the highest for the case of the shrinking sheet, whereas the temperature profile owned by the second solution becomes highest for the stretching case. Figure 4 displays the maximum peak at a small η for the concentration profile first solution. In addition, maximum and minimum peaks (for shrinking and stretching cases, respectively) are observed in the concentration profile second solution. The effect of λ is to minimize concentration rate of the first solution. Furthermore, the significant decrement of concentration rate can be seen at the point near to the sheet, for second solution graphs.

The graphical representation of the skin friction coefficient against the stretching/shrinking parameter is displayed in Figure 5, for different values of inclination angle $\kappa = 45°, 60° \text{ and } 75°$. It is found that skin friction coefficient of the first solution decreases when the sheet tends to stretch and the sheet inclines with a higher angle. Figure 6 shows the variation of the local Nusselt number for both solutions. Local Nusselt number of the first solution is reduced due to the implementation of the inclination angle between vertical direction and stretching/shrinking sheet. However, the local Nusselt number tends to increase when the sheet is stretched. On the other hand, local Nusselt number of the second solution records the highest value for the largest inclination angle $\kappa = 75°$. The effect of κ *and* λ on local Sherwood number is viewed in Figure 7. For the first solution, the effect of the shrinking parameter is to increase the values of local Sherwood number, and the stretching parameter plays a big role in reducing them. Meanwhile, the values of local Sherwood number owned by the first solution is reduced due to the increment of κ. Figure 7 also shows that the local Sherwood number of the second solution is at the lowest rate, for the largest inclination angle. The main observation from Figures 5 until 7 is the existence of dual solutions for all the values of λ from -1 until 1.

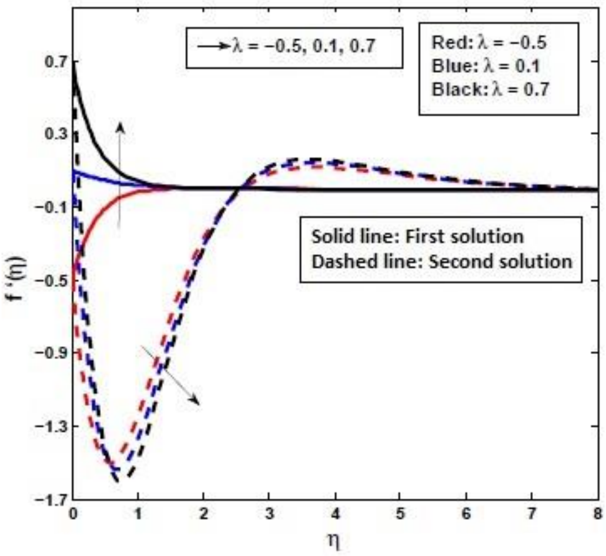


Fig. 2. Velocity profile for various λ

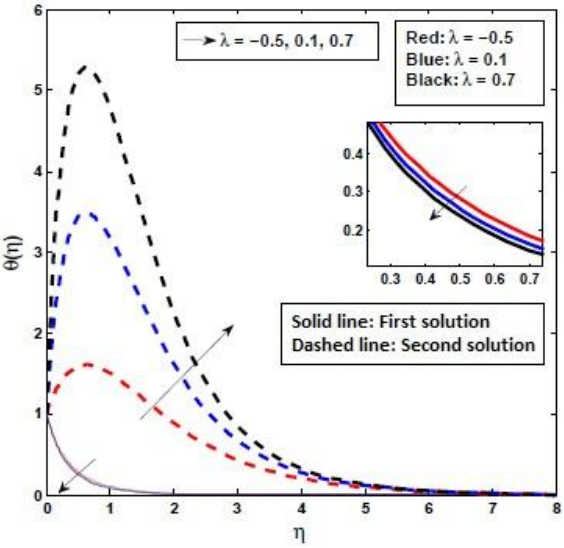


Fig. 3. Temperature profile for various λ

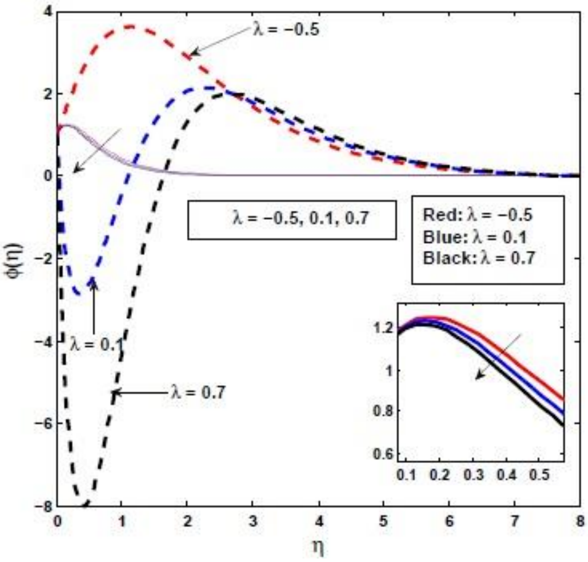


Fig. 4. Concentration profile for various λ

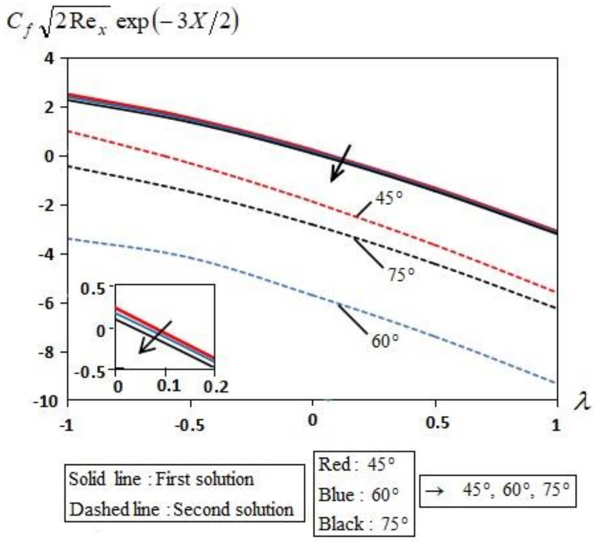
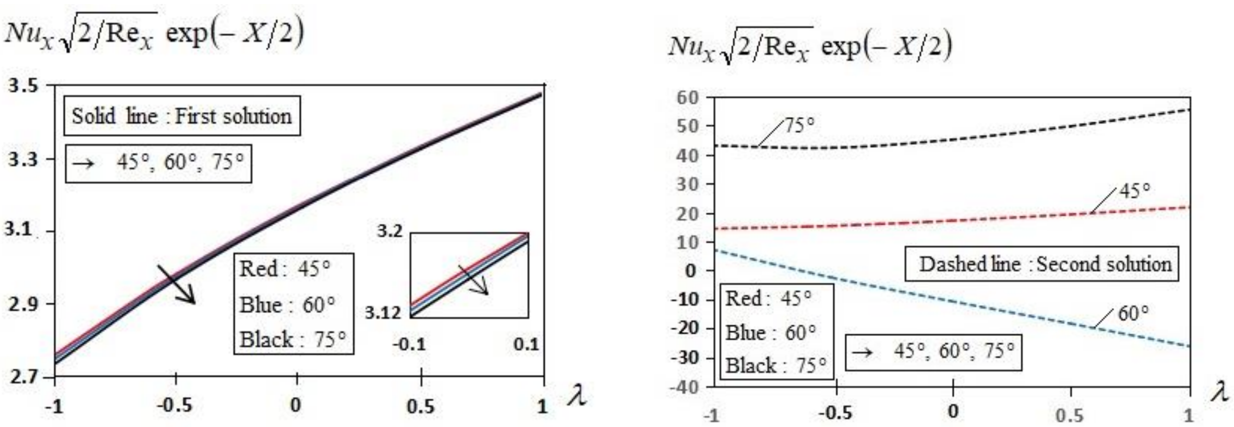


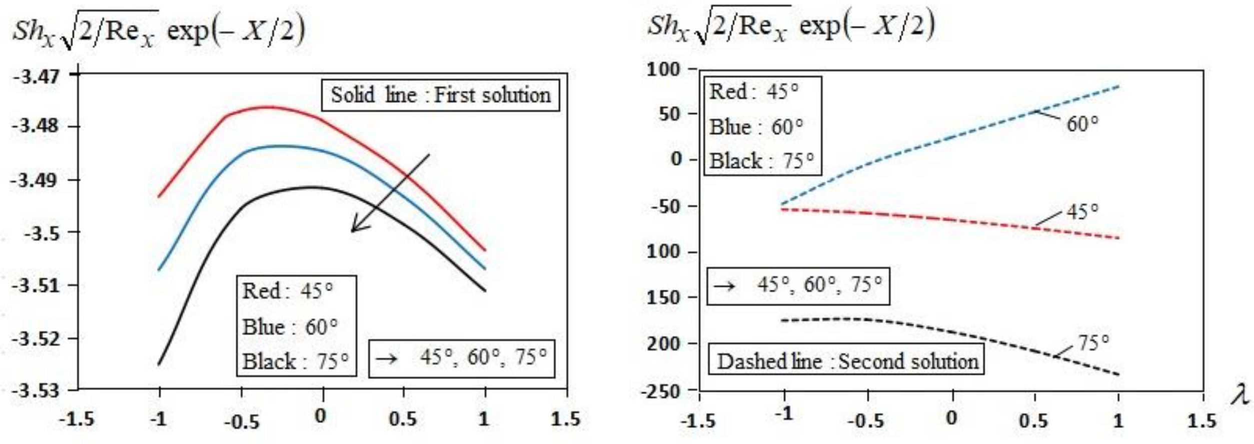
Fig. 5. Skin friction coefficient for various various λ and κ



(a) (b)

Fig. 6. Local Nusselt number for: a) first solution and b) second solution, together with the various λ and κ

CFD Letters
Volume 12, Issue 8 (2020) 98-107



(a) (b)

Fig. 7. Local Sherwood number for: a) first solution and b) second solution, together with the various λ and κ

4. Conclusions

The mathematical model for steady assisting boundary layer flow, heat, and mass transfer in Newtonian fluid over an exponentially stretching/shrinking inclined sheet was formulated and solved by Matlab bvp4c program. Therefore, the following conclusions based on the first numerical solution are proposed:

i. The impact of the stretching parameter is to enhance the rate of velocity distribution and the local Nusselt number. Otherwise, it reduces the others: profiles of temperature and concentration, skin friction coefficient, and local Sherwood number.
ii. When the sheet tends to transform from shrinking stage to stretching stage (λ change from negative to positive values), the velocity increases. However, opposite phenomenon occurred for the temperature and concentration profiles. Meanwhile, the increment of skin friction coefficient and decrement of local Nusselt number and local Sherwood number for, are contributed by the higher rate of shrinking parameter.
iii. The effect of the inclination angle is to decrease all the rate of skin friction coefficient, local Nusselt number, and local Sherwood number.

Acknowledgement
This research was funded by a grant from Universiti Putra Malaysia (Putra Grant code: GP/2017/9589700).

References
[1] Bohra, Shweta. "Heat and mass transfer over a three-dimensional inclined non-linear stretching sheet with convective boundary conditions." *Indian Journal of Pure & Applied Physics (IJPAP)* 55, no. 12 (2017): 847-856.
[2] Sravanthi, C. S. "Homotopy analysis solution of MHD slip flow past an exponentially stretching inclined sheet with Soret-Dufour effects." *Journal of the Nigerian Mathematical Society* 35, no. 1 (2016): 208-226. https://doi.org/10.1016/j.jnnms.2016.02.004
[3] Reddy, P. Bala Anki. "Magnetohydrodynamic flow of a Casson fluid over an exponentially inclined permeable stretching surface with thermal radiation and chemical reaction." *Ain Shams Engineering Journal* 7, no. 2 (2016): 593-602. https://doi.org/10.1016/j.asej.2015.12.010
[4] Khan, Imad, Sumreen Fatima, M. Y. Malik, and T. Salahuddin. "Exponentially varying viscosity of magnetohydrodynamic mixed convection Eyring-Powell nanofluid flow over an inclined surface." *Results in physics* 8 (2018): 1194-1203.

https://doi.org/10.1016/j.rinp.2017.12.074

[5] Rawi, N. A., M. R. Ilias, Y. J. Lim, Z. M. Isa, and S. Shafie. "Unsteady mixed convection flow of Casson fluid past an inclined stretching sheet in the presence of nanoparticles." In *Journal of Physics: Conference Series; IOP Publishing: Bristol, UK*, vol. 890, p. 012048. 2017. https://doi.org/10.1088/1742-6596/890/1/012048

[6] Khan, Masood, Humara Sardar, M. Mudassar Gulzar, and Ali Saleh Alshomrani. "On multiple solutions of non-Newtonian Carreau fluid flow over an inclined shrinking sheet." *Results in physics* 8 (2018): 926-932. https://doi.org/10.1016/j.rinp.2018.01.021

[7] Lund, Liaquat Ali, Zurni Omar, Umair Khan, Ilyas Khan, Dumitru Baleanu, and Kottakkaran Sooppy Nisar. "Stability analysis and dual solutions of micropolar nanofluid over the inclined stretching/shrinking surface with convective boundary condition." *Symmetry* 12, no. 1 (2020): 74. https://doi.org/10.3390/sym12010074

[8] Isa, S. S. P. M., N. M. Arifin, R. Nazar, N. Bachok, F. M. Ali, and I. Pop. "MHD mixed convection boundary layer flow of a Casson fluid bounded by permeable shrinking sheet with exponential variation." *Scientia Iranica* 24, no. 2 (2017): 637-647. https://doi.org/10.24200/sci.2017.4048

[9] Isa, Siti Suzilliana Putri Mohamed, Norihan Md Arifin, Roslinda Nazar, Norfifah Bachok, and Fadzilah Md Ali. "The effect of convective boundary condition on MHD mixed convection boundary layer flow over an exponentially stretching vertical sheet." In *Journal of Physics: Conference Series*, vol. 949, no. 1, p. 012016. IOP Publishing, 2017. https://doi.org/10.1088/1742-6596/949/1/012016

[10] Isa, S. S. P. M., Norihan Md Arifin, and Umer Farooq. "The impact of slip conditions on magnetohydrodynamics radiating fluid beyond an exponentially extended sheet." In *Journal of Physics: Conference Series*, vol. 1039, no. 1, p. 012015. 2018. https://doi.org/10.1088/1742-6596/1039/1/012015

[11] Isa, Siti Suzilliana Putri Mohamed, Norihan Md Arifin, and Umer Farooq. "Effect of Soret and Dufour numbers on double diffusive mixed convection boundary layer flow induced by a shrinking sheet." In *Journal of Physics: Conference Series*, vol. 1298, no. 1, p. 012024. IOP Publishing, 2019. https://doi.org/10.1088/1742-6596/1298/1/012024

[12] Vajravelu, K., G. Sarojamma, K. Sreelakshmi, and Ch Kalyani. "Dual solutions of an unsteady flow, heat and mass transfer of an electrically conducting fluid over a shrinking sheet in the presence of radiation and viscous dissipation." *International Journal of Mechanical Sciences* 130 (2017): 119-132. https://doi.org/10.1016/j.ijmecsci.2017.05.040

[13] Zaib, Aurang, Krishnendu Bhattacharyya, Md Uddin, and Sharidan Shafie. "Dual solutions of non-Newtonian Casson fluid flow and heat transfer over an exponentially permeable shrinking sheet with viscous dissipation." *Modelling and Simulation in Engineering* 2016 (2016). https://doi.org/10.1155/2016/6968371

[14] Dero, Sumera, Azizah Mohd Rohni, and Azizan Saaban. "MHD micropolar nanofluid flow over an exponentially stretching/shrinking surface: Triple solutions." *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences* 56, no. 2 (2019): 165-174.

[15] Ishak, Anuar. "Flow and heat transfer over a shrinking sheet: A stability analysis." *International Journal of Mechanical, Aerospace, Industrial and Mechatronics Engineering* 8, no. 5 (2014): 905-9.

[16] Adnan, N. S. M., and N. M. Arifin. "Stability analysis of boundary layer flow and heat transfer over a permeable exponentially shrinking sheet in the presence of thermal radiation and partial slip." In *J. Phys. Conf. Ser. Pap*, vol. 890, p. 012046. 2017. https://doi.org/10.1088/1742-6596/890/1/012046

[17] Najib, Najwa, Norfifah Bachok, Norihan Md Arifin, and Fadzilah Md Ali. "Stability analysis of stagnation-point flow in a nanofluid over a stretching/shrinking sheet with second-order slip, soret and dufour effects: A revised model." *Applied Sciences* 8, no. 4 (2018): 642. https://doi.org/10.3390/app8040642

[18] Srinivasacharya, D., and Ch RamReddy. "Soret and Dufour effects on mixed convection from an exponentially stretching surface." *International Journal of Nonlinear Science* 12, no. 1 (2011): 60-68.

[19] Sreenivasulu, P., and N. Bhaskar Reddy. "Soret and Dufour Effects on Boundary Layer Flow past an Exponential Stretching Sheet with Thermal Radiation and Viscous Dissipation." *Appl. Math.* 51 (2012): 10809-10816.

[20] Hayat, Tasawar, Taseer Muhammad, Sabir Ali Shehzad, and A. Alsaedi. "Soret and Dufour effects in three-dimensional flow over an exponentially stretching surface with porous medium, chemical reaction and heat source/sink." *International Journal of Numerical Methods for Heat & Fluid Flow* (2015). https://doi.org/10.1108/HFF-05-2014-0137

[21] Sharada, Kankanala. "MHD mixed convection flow of a Casson fluid over an exponentially stretching surface with the effects of soret, dufour, thermal radiation and chemical reaction." *World Journal of Mechanics* 5, no. 09 (2015): 165.
http://doi.org/10.4236/wjm.2015.59017
[22] Magyari, E., and B. Keller. "Heat and mass transfer in the boundary layers on an exponentially stretching continuous surface." *Journal of Physics D: Applied Physics* 32, no. 5 (1999): 577.
http://doi.org/10.1088/0022-3727/32/5/012
[23] Yasin, Mohd Hafizi Mat, Anuar Ishak, and Ioan Pop. "MHD stagnation-point flow and heat transfer with effects of viscous dissipation, Joule heating and partial velocity slip." *Scientific reports* 5 (2015): 17848.
http://doi.org/10.1038/srep17848
[24] Abbas, Z., M. Sheikh, and I. Pop. "Stagnation-point flow of a hydromagnetic viscous fluid over stretching/shrinking sheet with generalized slip condition in the presence of homogeneous–heterogeneous reactions." *Journal of the Taiwan Institute of Chemical Engineers* 55 (2015): 69-75.
http://doi.org/10.1016/j.jtice.2015.04.001
[25] Yahaya, Rusya Iryanti, Norihan Md Arifin, and Siti Suzilliana Putri Mohamed Isa. "Stability analysis on magnetohydrodynamic flow of casson fluid over a shrinking sheet with homogeneous-heterogeneous reactions." *Entropy* 20, no. 9 (2018): 652.
http://doi.org/10.3390/e20090652