CFD Letters

Journal homepage:
https://semarakilmu.com.my/journals/index.php/CFD_Letters/index
ISSN: 2180-1363

Flow and Heat Transfer Analysis on Reiner-Philippoff Fluid Flow over a Stretching Sheet in the Presence of First and Second Order Velocity Slip and Temperature Jump Effects

Noor Amalina Nisa Ariffin[1,*], Iskandar Waini[2], Abdul Rahman Mohd Kasim[3], Mohamad Hidayad Ahmad Kamal[4], Mohd Rijal Ilias[5], Seripah Awang Kechil[5]

[1] Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA, Cawangan Pahang, Kampus Jengka, 26400 Bandar Tun Abdul Razak, Jengka, Pahang, Malaysia
[2] Fakulti Teknologi Kejuruteraan Mekanikal dan Pembuatan, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
[3] Centre for Mathematical Sciences, College of Computing and Applied Sciences, Universiti Malaysia Pahang, Kuantan, Pahang, Malaysia
[4] Department of Mathematical Sciences, Faculty of Science, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor Bahru, Johor Darul Takzim, Malaysia
[5] Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia

ARTICLE INFO

Article history:
Received 11 August 2022
Received in revised form 27 September 2022
Accepted 27 November 2022
Available online 12 January 2023

Keywords:
Reiner-Philippoff fluid; stretching sheet; heat transfer; velocity slip; temperature jump; non-newtonian

ABSTRACT

Most of the fluid used in industrial application (i.e. Oils and gas industry, food manufacturing, lubrication and biomedical) do not conform to the Newtonian postulate. In contrast to the Newtonian fluid, the viscosity of the fluid can change when under force to either more liquid or more solid and dependent on shear rate history. This behaviour of fluids is commonly known as non-Newtonian fluid. The non-Newtonian fluid is so widespread in nature and technology resulting in very high interest of investigating among scientist. The Reiner-Philippoff fluid is one of the types of non-Newtonian fluid models that exhibiting the dilatant, pseudoplastic and Newtonian behaviors. Hence, this study is devoted to analyze the flow and heat transfer of Reiner-Philippoff fluid with the presence of first and second order velocity slip together with the temperature jump effects over a stretching sheet. Partial differential equations of continuity, momentum and energy equations were transformed into the similarity equations. The obtained equations were then solved via bvp4c function in MATLAB software. For the validation purpose, the present model and its numerical solution were compared with previous established solutions under limiting case where the present model is condensed to be identical with the reported model and turn to be in very strong agreement. The consequences of pertinent parameters on fluid's characteristics are analyzed in details through the plotted graphic visuals and tabular form.

1. Introduction

* *Corresponding author.*
E-mail address: amalinanisa@uitm.edu.my

https://doi.org/10.37934/cfdl.15.1.88102

Liquid, gas and even plasma can be under the same categories that is fluid where it defined as a substance that has no fixed shape and yields easily to external pressure. In understanding the movement of the fluid motion, fluid mechanics provide a platform in getting the knowledge on the mechanical movement of the fluid itself. The thin fluid flow closes to the boundary surface classified as boundary layer flow where this flow is affected by the characteristic hold by the boundary. The fluid itself can be divided into two which is Newtonian fluid that obey Newton law of viscosity and non-Newtonian fluid that did not obey the law. In boundary layer flow, some researchers have mathematically formulated the modelling of some fluid where one of the models known as Reiner-Philippoff fluid model that did not consider much by the researcher even though it hold a huge in engineering application. Some study on Reiner-Philippoff fluid shown an interesting characteristic of this fluid either on the flow characteristic or the heat transfer characteristic.

Characteristic of the fluid flow at the boundary can be affected in many ways either comes from the fluid itself, the external factor such as heat applied on the fluid system or the characteristic of the boundary. One of the effects that caused at the boundary is the stretching sheet where this effect has been consider by most of the researchers in boundary layer field [1]–[9]. For the case of non-Newtonian fluid, Rahimi *et al.* [10] provide an approximate solution of Eyring-Powell non-Newtonian fluid boundary layer flow over a stretching sheet using collocation method combined with a special technique. With the same type of fluid, Javed *et al.* [11] solve the mathematical formulation using Keller box method of incompressible flow of an Eyring-Powell non-Newtonian fluid over a stretching surface. As for the non-Newtonian Reiner–Philippoff fluid model, Ahmad *et al.* [12] perform a study in obtaining the similarity solution of Reiner–Philippoff fluid boundary layer problem over a nonlinearly stretching sheet with variable thickness. Some researcher even extending this problem by induce nanofluid properties into the fluid system as studied by Ullah *et al* [13] that focussed on the thin film of Reiner-Philippoff fluid in the changeable heat transmission and radiation over a time-dependent stretching sheet.

Besides effect on stretching sheet, there is another condition that taken into consideration by some researcher in conducting their study that is slip velocity. Aziz [14] perform a numerical study on the velocity slip flow and thermal boundary layer over a flat plate with a constant heat flux boundary condition. Mukhopadhyay and Gorla [15] on the other hand present an analysis of boundary layer flow and heat transfer towards a porous exponential stretching sheet together with velocity and thermal slips are considered instead of no-slip conditions at the boundary. By considering stretching sheet on the boundary layer flow with velocity slip effect, Mukhopadhyay [16] perform an analysis on the viscous incompressible boundary layer flow towards the nonlinear porous stretching sheet. Besides stretching sheet was consider together with slip velocity effect, Ibrahim and Shankar [17] extend the study by considering dispersion of nanoparticles, magnetic field and thermal radiation effect over a permeable stretching sheet. Khader and Megahed [18] on the other perform a numerical analysis over an impermeable nonlinear stretching sheet with a power law surface velocity, slip velocity and variable thickness. Another study was also conducted by Khader and Megahed [19] where the system of equation was solved using Chebyshev spectral method compared to finite different approaches was induced earlier.

Another influence that can affect the characteristic of the fluid system is caused by varies of heat supplied such as temperature jump. Sajadifar *et al.* [20] perform a numerical analysis on carboxymethyl cellulose aluminum oxide nanofluid through a microtube with different nanoparticles volume fraction on the slip velocity and temperature jump boundary conditions. The study was then extended by Goodarzi *et al.* [21] with almost the same fluid system considered earlier by focussing more on the analysis of different slip coefficient in optimizing the qualities of the microtube surface. Das *et al.* [22] on the other hand perform an analysis on copper-water boundary layer flow with hydromagnetic convective over a permeable stretching sheet, surface slip and temperature jump due to solar radiation. By using homotopy analysis method, Guo *et al.* [23] conduct an analysis on the flow and heat transfer of nanofluid in the flow over a stretching sheet with variable thickness, velocity slip and temperature jump. Theoretical study that combining velocity slip and stretching sheet with temperature jump effect was conducted by Zheng *et al.* [24] that study on flow and heat transfer of stagnation point nanofluid flow with thermal radiation, velocity slip, temperature jump over a stretching sheet in a porous medium. The study with the same effect was also considered by Shen *et al.* [25] that consider bioconvection heat transfer of a nanofluid over a stretching sheet with velocity slip and temperature jump that containing gyrotactic microorganisms that caused the convection. The same effect also has been considered in Zhu et al. [26] and Fang and Aziz [27].

Based on the above discussed literature review, the study on boundary layer flow with the consideration of stretching sheet, velocity slip and temperature jump boundary condition was found significantly effecting the fluid characteristic. The literature also shown that there is still very small number of studies considering these effects on Reiner-Philippoff fluid model. Thus, for the best of knowledge, this study attempts to investigate the boundary layer flow of Reiner-Philippoff fluid flow over a stretching sheet in the presence of velocity slip and temperature jump effects. The fluid system will be modelled mathematically subjected to effect considered in this study and solved numerically. The analysis will then be conducted to study the flow characteristic and heat transfer occurs in the fluid system.

2. Mathematical Formulation

The flow of Reiner–Philippoff fluid past a stretching is considered. The flow configuration is illustrated as in Figure 1. The surface velocity is taking as $u_w(x) = ax^{1/3}$ with $a > 0$. In this investigation, the second order slip factors of the velocity and the temperature jump on the sheet are also deliberated. Here, the surface temperature T_w and the ambient temperature T_∞ are assumed as constants. Additionally, the mass flux velocity $v_w(x)$ is applied on the surface to represent the surface permeability. Likewise, the radiative heat flux is $q_r = -(4\sigma^*/3k^*)(\partial T^4/\partial y)$ with k^* and σ^* signifies the mean absorption and the Stefan-Boltzmann constants and given that $T^4 \cong 4T_\infty^3 T - 3T_\infty^4$ [28]. The governing equations for the present model can be written as [29]–[31]

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

$$\frac{\partial u}{\partial y} = \frac{\tau}{\mu_\infty + \dfrac{\mu_0 - \mu_\infty}{1 + \left(\dfrac{\tau}{\tau_s}\right)^2}} \tag{2}$$

$$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = \frac{1}{\rho}\frac{\partial \tau}{\partial y} \tag{3}$$

$$u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} = \left(\frac{k}{\rho C_p} + \frac{16\sigma^* T_\infty^3}{3(\rho C_p)k^*}\right)\frac{\partial^2 T}{\partial y^2} \tag{4}$$

The Eq. (1) to (4) are subjected to the following boundary conditions in Eq. (5) where the first and second order slip velocity and temperature jump are addressed.

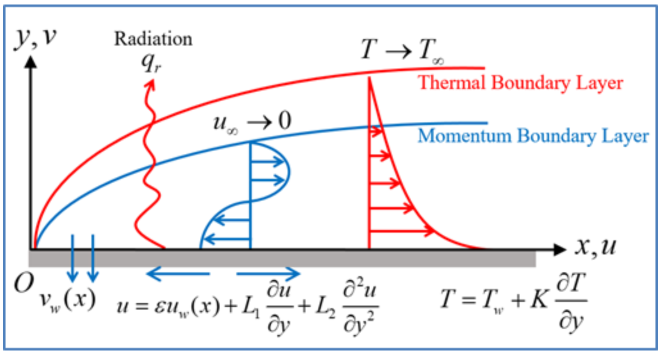

Fig. 1. Schematic configuration of flow

$$u = \varepsilon u_w(x) + L_1 \frac{\partial u}{\partial y} + L_2 \frac{\partial^2 u}{\partial y^2},\ v = v_w(x),\ T = T_w + K\frac{\partial T}{\partial y} \text{ at } y = 0;$$
$$u \to 0,\ T \to T_\infty \text{ as } \eta \to \infty \tag{5}$$

The term ρ is the fluid density, ρC_p is the heat capacity, k is the thermal conductivity, T is the temperature, L_1 and L_2 are the first-order and the second-order velocity slip factors, respectively, K is the thermal slip factor, and (u, v) be the velocity components in the (x, y) direction. Besides, τ is the shear stress with the reference shear stress τ_s, the limiting dynamic viscosity μ_∞, and the zero-shear dynamic viscosity μ_0. The present model can be present three type of sheet where at $\varepsilon = 0$ denotes the static sheet, $\varepsilon > 0$ for stretching sheet and $\varepsilon < 0$ for shrinking sheet. In this paper the concentration will be focus on the stretching sheet only.

The similarity solutions are only existed by employing the similarity transformation as follows [30], [31]:

$$\psi = \sqrt{a\nu}\, x^{2/3} f(\eta),\ \tau = \rho\sqrt{a^3\nu}\, g(\eta),\ \theta(\eta) = \frac{T - T_\infty}{T_w - T_\infty},\ \eta = \frac{y}{x^{1/3}}\sqrt{\frac{a}{\nu}} \tag{6}$$

where the stream function ψ is defined by $u = \partial\psi/\partial y$ and $v = -\partial\psi/\partial x$. Using Eq. (6), the following term will be obtained.

$$u = a x^{1/3} f'(\eta),\ \ v = -\sqrt{a\nu}\, x^{-1/3}\left(\frac{2}{3} f(\eta) - \frac{1}{3}\eta f'(\eta)\right) \tag{7}$$

By setting $\eta = 0$, the wall mass flux velocity becomes:

$$v_w(x) = -\frac{2}{3}\sqrt{a\nu}\, x^{-1/3} S \tag{8}$$

where $f(0) = S$ signify the constant mass flux parameter with $S < 0$ and $S > 0$ are for injection and suction, respectively, while $S = 0$ denote the impermeable surface, and $\nu = \mu_\infty/\rho$ is the fluid kinematic viscosity. After applying Eq. (6) and (7), the complexity of Eq. (1) to (4) are reduced to the following similarity equations

$$g' + \frac{2}{3} ff'' - \frac{1}{3} f'^2 = 0 \tag{9}$$

$$g = f''\left(\frac{\lambda\gamma^2 + g^2}{\gamma^2 + g^2}\right) \tag{10}$$

$$\frac{1}{\Pr}\left(1 + \frac{4}{3}R\right)\theta'' + \frac{2}{3} f\theta' = 0 \tag{11}$$

subjected to:

$$\begin{aligned} &f(0) = S,\ f'(0) = \varepsilon + A_1 f''(0) + A_2 f'''(0),\ \theta(0) = 1 + B\theta'(0); \\ &f'(\eta) \to 0,\ \theta(\eta) \to 0 \ \text{ as } \ \eta \to \infty \end{aligned} \tag{12}$$

with the Reiner–Philippoff fluid parameter λ, the Bingham number γ, the Prandtl number $\Pr$, the thermal radiation parameter R, the thermal slip parameter B, the first-order and the second-order velocity slip parameters denoted by and A_2, respectively, and they are defined by:

$$\lambda = \frac{\mu_0}{\mu_\infty},\ \gamma = \frac{\tau_s}{\rho\sqrt{a^3\nu}},\ \Pr = \frac{\mu C_p}{k},\ R = \frac{4\sigma^* T_\infty^3}{kk^*},\ B = K\sqrt{\frac{a}{\nu}},\ A_1 = L_1\sqrt{\frac{a}{\nu}},\ A_2 = \frac{aL_2}{\nu} \tag{13}$$

Note that, $\lambda = 1$ is for the Newtonian fluid case, while $\lambda < 1$ and $\lambda > 1$ represent the shear thickening (dilatant) fluid and the shear-thinning (pseudoplastic) fluid cases.

The coefficient of the skin friction C_f and the local Nusselt number Nu_x are given as:

$$C_f = \frac{\tau_w}{\rho u_w^2}, \quad Nu_x = \frac{xq_w}{k\left(T_w - T_\infty\right)} \tag{14}$$

where:

$$\tau_w = \rho\sqrt{a^3\nu}\left(g(\eta)\right)_{y=0}, \quad q_w = -k\left(\frac{\partial T}{\partial y}\right)_{y=0} + (q_r)_{y=0} \tag{15}$$

Here, τ_w denotes the value of τ on $y = 0$ and q_w is the surface heat flux. Using Eq. (14) and Eq. (15), yield

$$\mathrm{Re}_x^{1/2} C_f = g(0), \quad \mathrm{Re}_x^{-1/2} Nu_x = -\left(1 + \frac{4}{3}R\right)\theta'(0) \tag{16}$$

where $\mathrm{Re}_x = u_w(x)x/\nu$ is the local Reynolds number.

3. Results and Discussions

This section provides a details discussion on the outputs from numerical computational of Eq. (9) to (11) with respected to boundary conditions in Eq. (12) utilising the bvp4c solver in MATLAB software. The procedures on the proposed method are once explained in [32], [33]. The numerical results are then presented in the tabular and graphical forms.

To ensure the computation on the present model is acceptable, the validation procedures are carried out by direct comparison between the present results with the established output for the case where the equations and its boundary conditions are identical. It is worth to mention that, the current equations can be reduced to the equations by Cortell [33], Waini *et al.* [34] and Sajid *et al.* [35] in certain conditions. The comparative's results present a very strong agreement where it can be concluded the present model and results are adequate. The details comparative analysis can be found in Table 1, Table 2 and Table 3. The computation for Table 1 and 2 are done at fixed value $\varepsilon = \lambda = \gamma = 1$ and $\mathrm{Pr} = 2$. it can be seen the values of $f''(0)$ significantly condensed and the quantity of $-\theta'(0)$ enriched for the larger value of S. physically the situation happened due to the forces built by the permeable plate. Table 2 also presenting at the presence radiation circumstance led to lessen the performance of $-\theta'(0)$. The output in Table 3 is presented to strengthen the trustworthiness of the present outputs as the value of $g(0)$ concurs very well with those reported by Sajid *et al.* [35]. It can be concluded that, the strong value of Bingham number γ and Reiner–Philippoff fluid parameter λ decelerated the value of $g(0)$.

Table 1
Values of $f''(0)$ for different S when $\varepsilon = \lambda = \gamma = 1$ and $\mathrm{Pr} = 2$

S	Cortell [33]	Waini *et al.* [34]	Present Result
−0.5	−0.518869	−0.518869	−0.518869426
0.0	−0.677647	−0.677648	−0.677647984
0.5	−0.873627	−0.873643	−0.873642862

Table 2
Values of $-\theta'(0)$ for R and S when $\varepsilon = \lambda = \gamma = 1$ and $\mathrm{Pr} = 2$

R	S	Cortell [33]	Waini *et al.* [34]	Present Result
	−0.5	0.3989462	0.399100	0.399099808
0	0.0	0.7643554	0.764357	0.764356557
	0.5	1.2307661	1.230792	1.230791767
	−0.5	0.2873762	0.287485	0.287483696
1	0.0	0.4430879	0.443323	0.443323143
	0.5	0.6322154	0.632200	0.632199696

Table 3
Values of $g(0)$ for γ and λ when $S = 0$ and $\varepsilon = 1$

γ	λ	Sajid *et al.* [35]	Present Result
0.1	0.1	−0.660273	−0.660275191
0.5	0.1	−0.380604	−0.380603982
1.0	0.1	−0.246415	−0.246414994
0.1	0.3	−0.664497	−0.664497828
0.1	0.5	−0.668484	−0.668486423
0.1	0.7	−0.672282	−0.672276683

The graphical results for physical interest $\mathrm{Re}_x^{1/2}C_f$ and $\mathrm{Re}_x^{-1/2}Nu_x$ are presented for various value of significant parameter. Figures. 2 and 3 show the impact of λ and S on the variations of $\mathrm{Re}_x^{1/2}C_f$ and $\mathrm{Re}_x^{-1/2}Nu_x$ at $\varepsilon = 1,\ \gamma = 0.1,\ A1 = 0.1,\ A2 = 0.1,\ B = 1, R = 5$ and $\mathrm{Pr} = 10$. The increases of λ shows an decreasing behaviour for $\mathrm{Re}_x^{1/2}C_f$ but increase in term of $\mathrm{Re}_x^{-1/2}Nu_x$. On the other hand, a contradict behaviour was noticed on $\mathrm{Re}_x^{1/2}C_f$ and $\mathrm{Re}_x^{-1/2}Nu_x$ for parameter S with the increases of parameter S increase the $\mathrm{Re}_x^{1/2}C_f$ but decrease in term of $\mathrm{Re}_x^{1/2}Nu_x$.

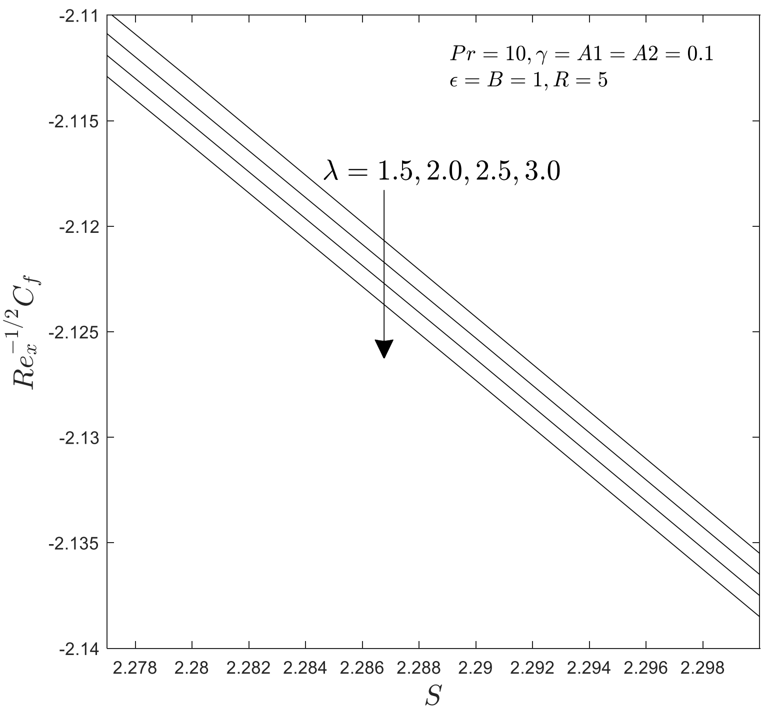

Fig. 2. $\mathrm{Re}_x^{1/2} C_f$ vs S and λ

The variation of $\mathrm{Re}_x^{1/2}C_f$ and $\mathrm{Re}_x^{-1/2}Nu_x$ for various S and $A1$ on the fixed $\varepsilon = 1,\ \gamma = 0.1,\ \lambda = 1.5,$ $A2 = 0.1,\ B = 1, R = 5$ and $\mathrm{Pr} = 10$ are captured on Figures 4 and 5. The increases of $A1$ shows an increment behaviour for $\mathrm{Re}_x^{1/2}C_f$ but decreasing in term of $\mathrm{Re}_x^{-1/2}Nu_x$. Conversely, a contradict behaviour was noticed on $\mathrm{Re}_x^{1/2}C_f$ and $\mathrm{Re}_x^{-1/2}Nu_x$ for larger in value of S. The decreasing trend for value of $\mathrm{Re}_x^{1/2}C_f$ is obviously seen at absenteeism of first order slip ($A1 = 0$) however the substantial increment was perceived in $\mathrm{Re}_x^{-1/2}Nu_x$. This behavior were acceptable since the present of $A1$ cause the flow more attached to the surface and release the energy.

The variation of $\mathrm{Re}_x^{1/2}C_f$ and $\mathrm{Re}_x^{-1/2}Nu_x$ for various S and $A1$ on the fixed $\varepsilon = 1,\ \gamma = 0.1,\ \lambda = 1.5,$ $A2 = 0.1,\ B = 1, R = 5$ and $\mathrm{Pr} = 10$ are captured on Figures 4 and 5. The increases of $A1$ shows an increment behaviour for $\mathrm{Re}_x^{1/2}C_f$ but decreasing in term of $\mathrm{Re}_x^{-1/2}Nu_x$. Conversely, a contradict behaviour was noticed on $\mathrm{Re}_x^{1/2}C_f$ and $\mathrm{Re}_x^{-1/2}Nu_x$ for larger in value of S. The decreasing trend for value of $\mathrm{Re}_x^{1/2}C_f$ is obviously seen at absenteeism of first order slip ($A1 = 0$) however the substantial

increment was perceived in $\mathrm{Re}_x^{-1/2} Nu_x$.This behavior were acceptable since the present of $A1$ cause the flow more attached to the surface and release the energy.

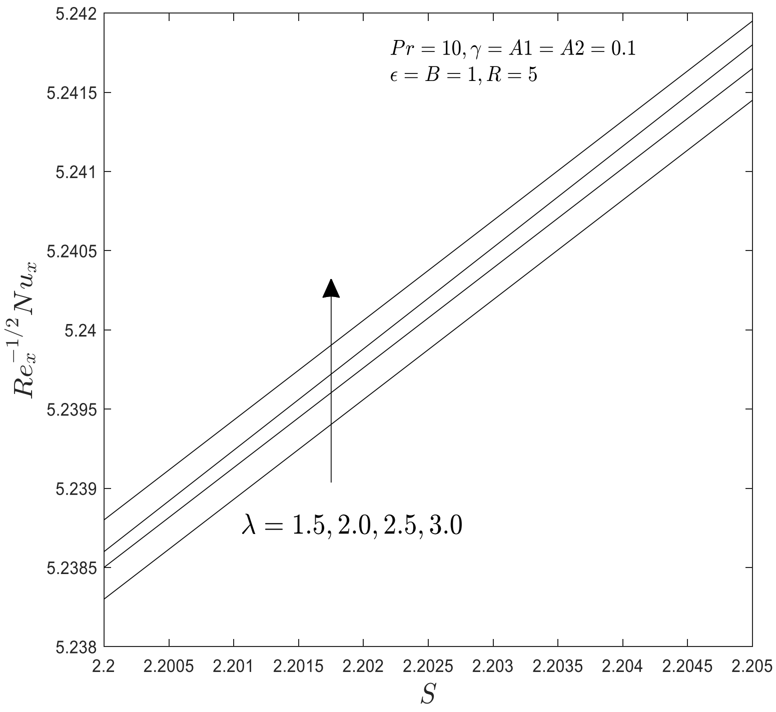

Fig. 3. $\mathrm{Re}_x^{1/2}\, Nu$ vs S and λ

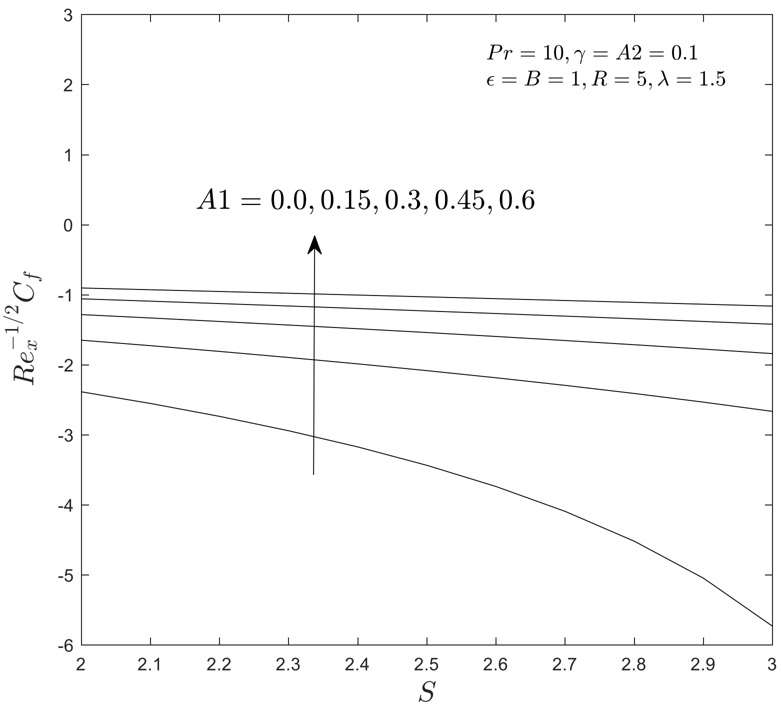

Fig. 4. $\mathrm{Re}_x^{1/2}\, C_f$ vs S and $A1$

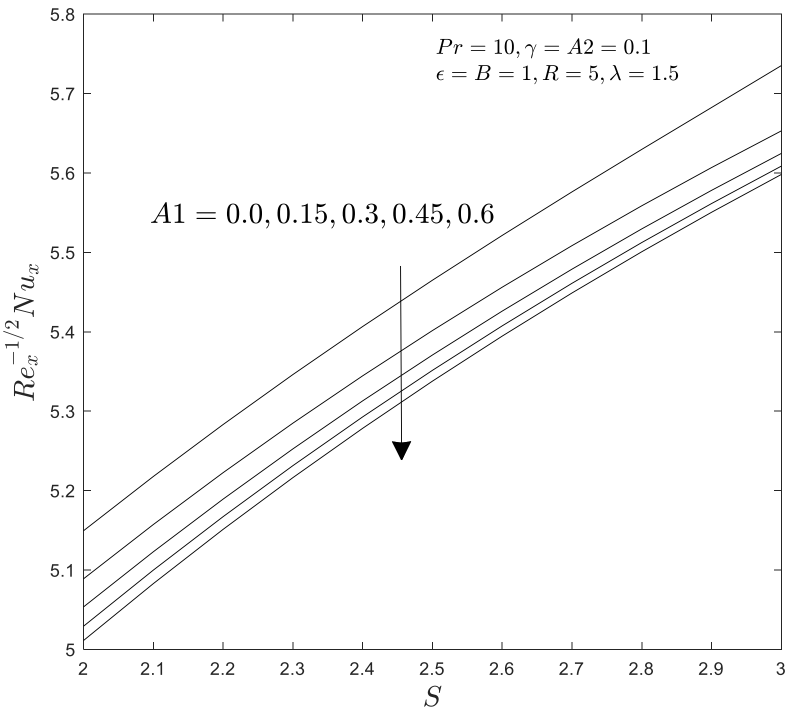

Fig. 5. $\mathrm{Re}_x^{1/2} Nu$ vs S and $A1$

The analysis on $\mathrm{Re}_x^{1/2} Nu_x$ was also conducted in Figures 6 and 7 subjected to various values of B. From the Figure 6, the increases of parameter B condense the $\mathrm{Re}_x^{1/2} Nu_x$ values significantly. It also detected the changes in value of λ did not affecting the value of $\mathrm{Re}_x^{1/2} Nu_x$ while only slightly change for the different of S.

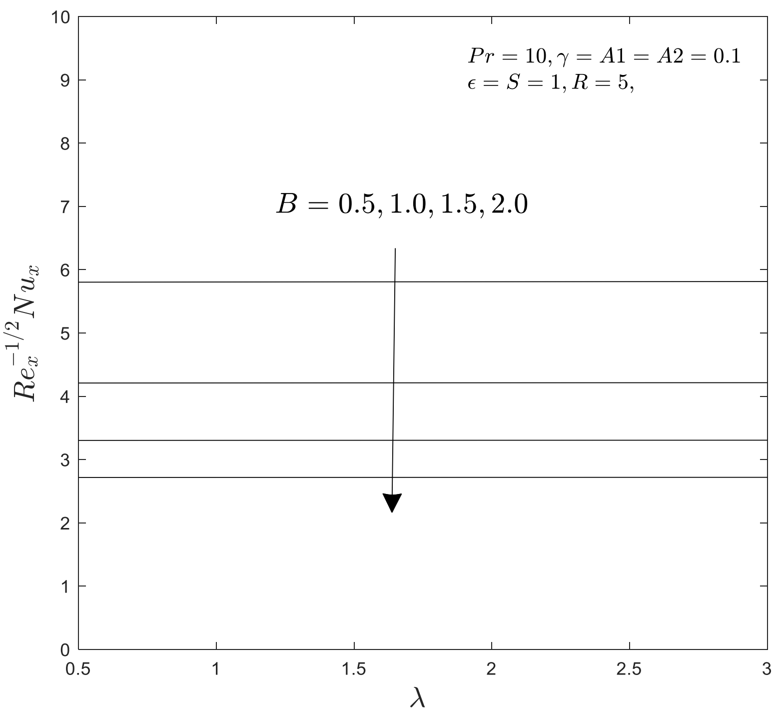

Fig. 6. $\mathrm{Re}_x^{1/2} C_f$ vs S and B

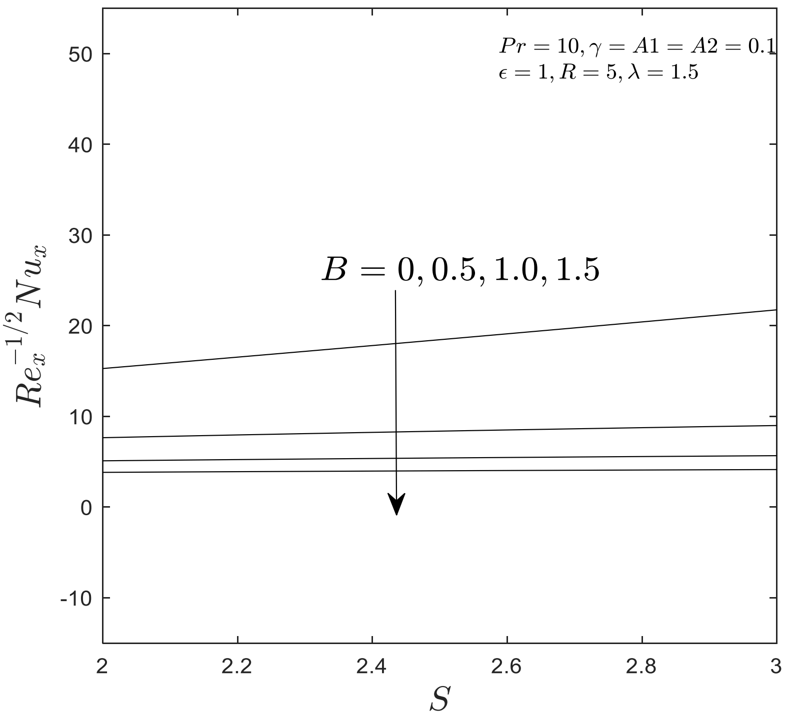

Fig. 7. $\mathrm{Re}_x^{1/2} Nu$ vs S and B

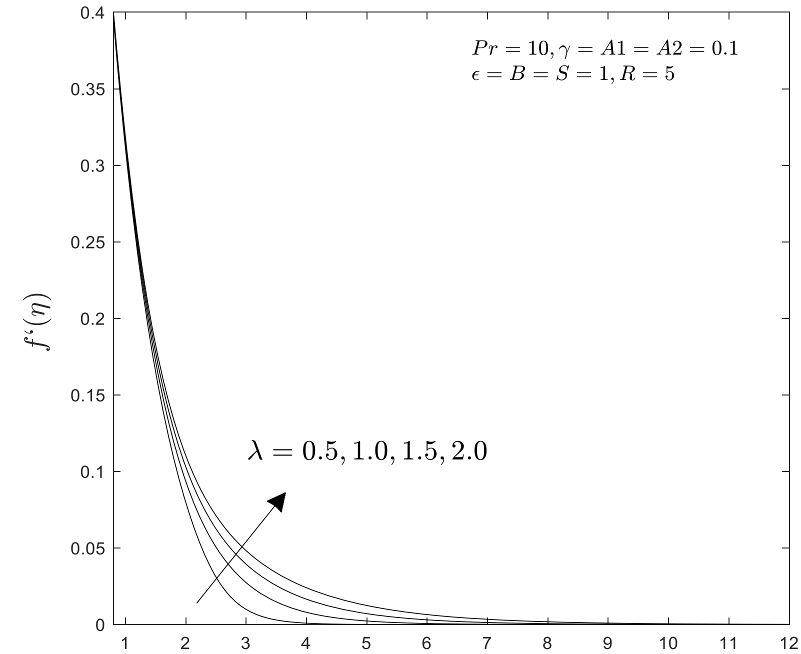

Fig. 8. $f'(\eta)$ vs η and λ

Figures 8 and 9 presented the distribution of velocity and temperature of various values λ and B respectively. For the growing quantity of λ, the velocity of the fluid shows increasing trend but contradict for the growing of B for temperature distribution. Distributions of velocity and temperature profile for first slip and second slip velocity are demonstrated in Figures 10 - 13 respectively. Near the sheet, the increasing in the first order slip reducing the velocity of fluid but boosting at far from the plate. The temperature of the fluid showing increasing trend for the increment in first order slip quantities. However, the contradict behavior has been shown in velocity and temperature for the increasing of second order slip quantities. Further, it is clearly noticed all the distributions were fully fulfilled the boundary condition at far from the plate. It is also signifying the present model is correct.

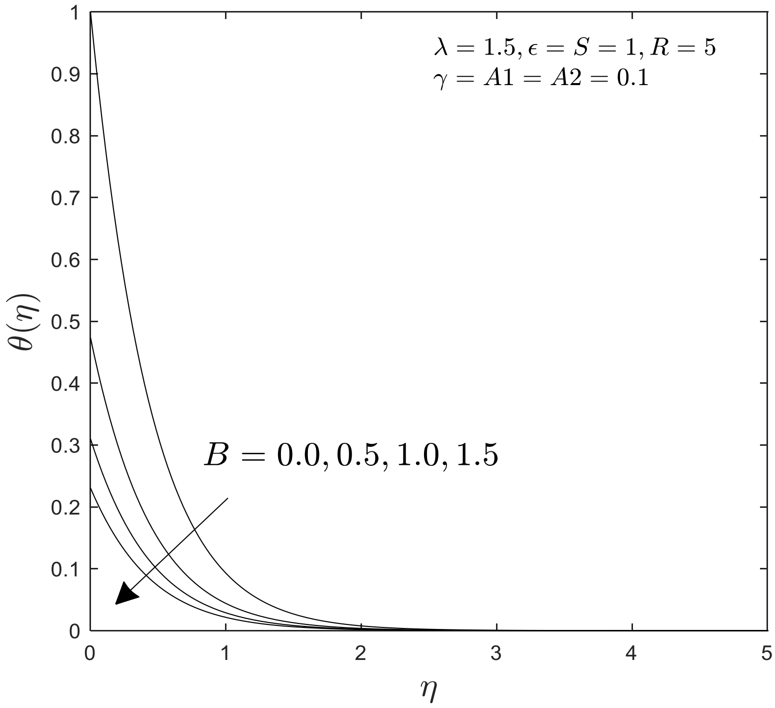

Fig. 9. $\theta(\eta)$ vs η and B

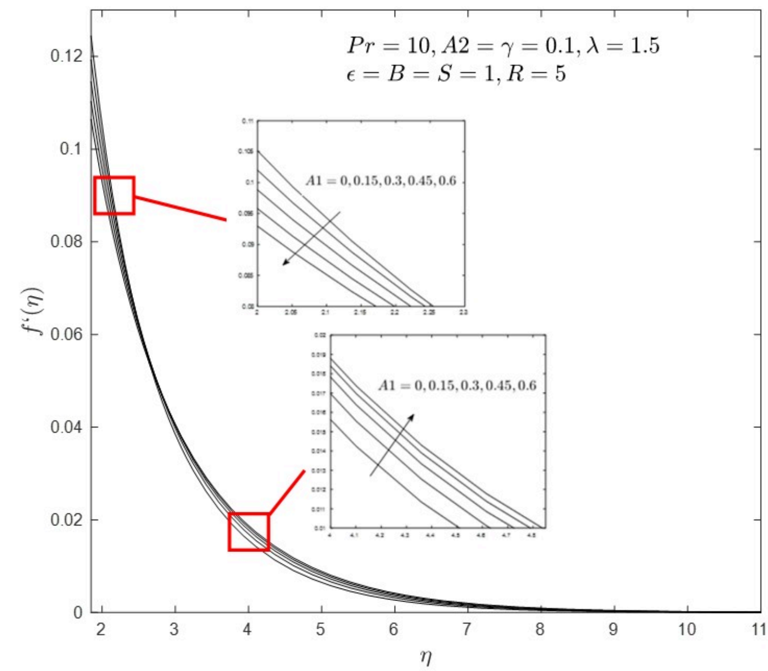

Fig. 10. $f'(\eta)$ vs η and $A1$

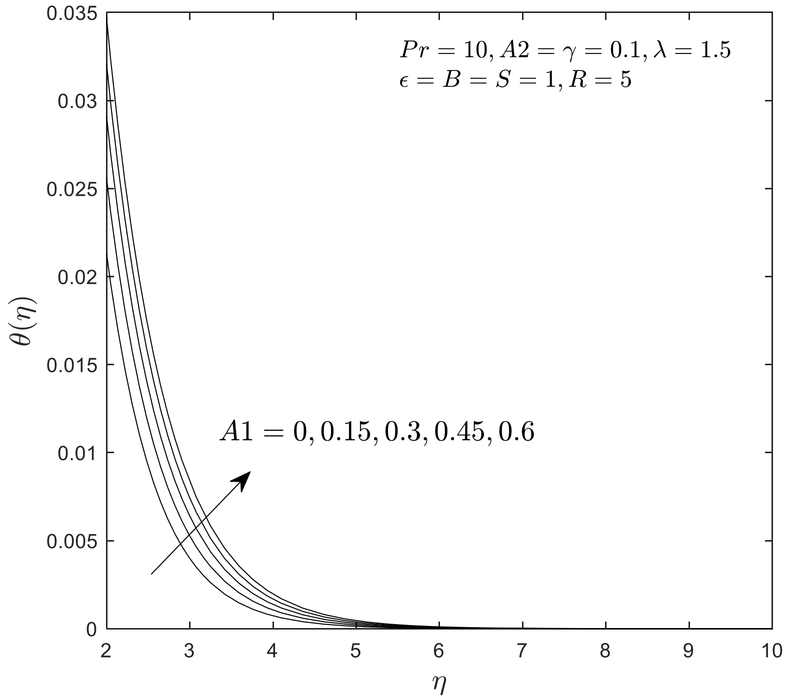

Fig. 11. $\theta(\eta)$ vs η and $A1$

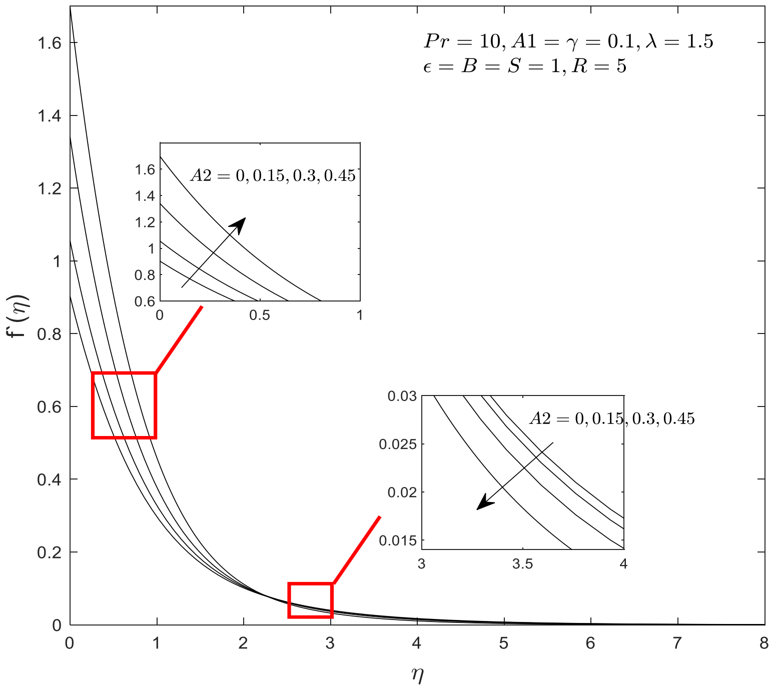

Fig. 12. $f'(\eta)$ vs η and $A2$

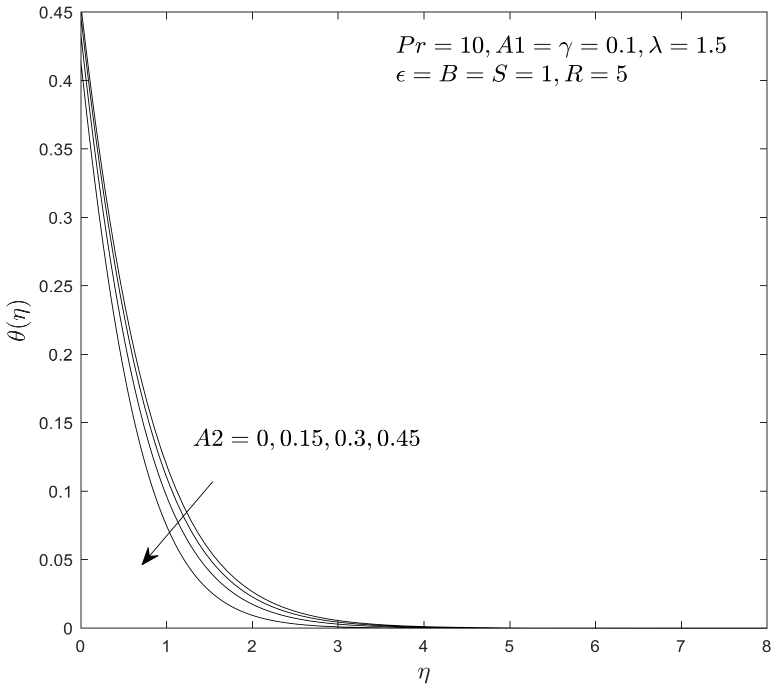

Fig. 13. $\theta(\eta)$ vs η and $A2$

4. Conclusions

This paper presented the numerical results of Reiner–Philippoff fluid flow over a stretching sheet. The flow is taking the consideration of thermal radiation together with first and second order slip velocities and also thermal slip condition. The value of suction parameter is one of the significant factors of variation skin friction and heat transfer. The present of velocity slip improve the skin friction but lagging the heat transfer coefficient. The temperature jump or temperature slip give the same impact as velocity slip to the heat transfer coefficient.

Acknowledgement
The authors would like to acknowledge Universiti Teknologi MARA (UiTM) Cawangan Pahang for financial support through MyRA research grant (600-RMC/GPM LPHD 5/3 (138/2021)). A deep appreciation also goes to Universiti Malaysia Pahang (UMP) and Universiti Teknikal Melaka (UTeM) for guidance and support.

References
[1] Waini, Iskandar, Najiyah Safwa Khashi'ie, Abdul Rahman Mohd Kasim, Nurul Amira Zainal, Anuar Ishak, and Ioan Pop. "Radiative Heat Transfer of Reiner–Philippoff Fluid Flow Past a Nonlinearly Shrinking Sheet: Dual Solutions and Stability Analysis." *Chinese Journal of Physics* 77, no. August 2021 (2022): 45–56. https://doi.org/10.1016/j.cjph.2021.11.037.
[2] Khashi'ie, Najiyah Safwa, Iskandar Waini, Abdul Rahman Mohd Kasim, Nurul Amira Zainal, Anuar Ishak, and Ioan Pop. "Magnetohydrodynamic and Viscous Dissipation Effects on Radiative Heat Transfer of Non-Newtonian Fluid Flow Past a Nonlinearly Shrinking Sheet: Reiner–Philippoff Model." *Alexandria Engineering Journal* 61, no. 10 (2022): 7605–7617. https://doi.org/10.1016/j.aej.2022.01.014.
[3] Waini, Iskandar, Najiyah Safwa Khashi'ie, Abdul Rahman Mohd Kasim, Nurul Amira Zainal, Anuar Ishak, and Ioan Pop. "Nonlinear Radiative Heat Transfer of Magnetohydrodynamic Non-Newtonian Fluid Flow Past a Shrinking Sheet: Reiner–Philippoff Model." *Waves in Random and Complex Media*, 2022, 1–22. https://doi.org/10.1080/17455030.2022.2038815

[4] Waini, Iskandar, Abdul Rahman Mohd Kasim, Najiyah Safwa Khashi'ie, Nurul Amira Zainal, Anuar Ishak, and Ioan Pop. "Insight into Stability Analysis on Modified Magnetic Field of Radiative Non-Newtonian Reiner–Philippoff Fluid Model." *Journal of Applied and Computational Mechanics* 8, no. 2 (2022): 745–53. https://doi.org/10.22055/jacm.2022.38820.3287.
[5] Dzulkifli, Nor Fadhilah, Norfifah Bachok, Nor Azizah Yacob, Ioan Pop, Norihan Arifin, and Haliza Rosali. "Stability Solution of Unsteady Stagnation-Point Flow and Heat Transfer over a Stretching/Shrinking Sheet in Nanofluid with Slip Velocity Effect." *CFD Letters* 14, no. 1 (2022): 66–86. https://doi.org/10.37934/cfdl.14.1.6686.
[6] Prathi Vijaya Kumar, Cheela Sunitha, Giulio Lorenzini, and Shaik Mohammed Ibrahim. "A Study of Thermally Radiant Williamson Nanofluid Over an Exponentially Elongating Sheet with Chemical Reaction Via Homotopy Analysis Method." *CFD Letters* 14, no. 5 (2022): 68–86. https://doi.org/10.37934/cfdl.14.5.6886.
[7] Nurul Amira Zainal, Kohilavani Naganthran, and Roslinda Nazar. "Unsteady MHD Rear Stagnation-Point Flow of a Hybrid Nanofluid with Heat Generation/Absorption Effect." *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences* 87, no. 1 (2021): 41–51. https://doi.org/10.37934/arfmts.87.1.4151.
[8] Japili, Nirwana, Haliza Rosali, and Norfifah Bachok. "Slip Effect on Stagnation Point Flow and Heat Transfer Over a Shrinking/Stretching Sheet in A Porous Medium with Suction/Injection." *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences* 90, no. 2 (2022): 73–89. https://doi.org/10.37934/arfmts.90.2.7389.
[9] Kho, Yap Bing, Rahimah Jusoh, Mohd Zuki Salleh, Muhammad Khairul Anuar Mohamed, Zulkhibri Ismail, and Rohana Abdul Hamid. "Inclusion of Viscous Dissipation on the Boundary Layer Flow of Cu-TiO2 Hybrid Nanofluid over Stretching/Shrinking Sheet." *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences* 88, no. 2 (2021): 64–79. https://doi.org/10.37934/arfmts.88.2.6479.
[10] Rahimi, J., D. D. Ganji, M. Khaki, and Kh Hosseinzadeh. "Solution of the Boundary Layer Flow of an Eyring-Powell Non-Newtonian Fluid over a Linear Stretching Sheet by Collocation Method." *Alexandria Engineering Journal* 56, no. 4 (2017): 621–27. https://doi.org/10.1016/j.aej.2016.11.006.
[11] Javed, Tariq, Nasir Ali, Zaheer Abbas, and Muhammad Sajid. "Flow of an Eyring-Powell Non-Newtonian Fluid over a Stretching Sheet." *Chemical Engineering Communications* 200, no. 3 (2013): 327–36. https://doi.org/10.1080/00986445.2012.703151
[12] Ahmad, A., M. Qasim, and S. Ahmed. "Flow of Reiner–Philippoff Fluid over a Stretching Sheet with Variable Thickness." *Journal of the Brazilian Society of Mechanical Sciences and Engineering* 39, no. 11 (2017): 4469–73. https://doi.org/10.1007/s40430-017-0840-7.
[13] Ullah, Asad, Ebraheem O. Alzahrani, Zahir Shah, Muhammad Ayaz, and Saeed Islam. "Nanofluids Thin Film Flow of Reiner-Philippoff Fluid over an Unstable Stretching Surface with Brownian Motion and Thermophoresis Effects." *Coatings* 9, no. 1 (2019). https://doi.org/10.3390/coatings9010021.
[14] Aziz, Abdul. "Hydrodynamic and Thermal Slip Flow Boundary Layers over a Flat Plate with Constant Heat Flux Boundary Condition." *Communications in Nonlinear Science and Numerical Simulation* 15, no. 3 (2010): 573–80. https://doi.org/10.1016/j.cnsns.2009.04.026.
[15] Mukhopadhyay, Swati, and Rama Subba Reddy Gorla. "Effects of Partial Slip on Boundary Layer Flow Past a Permeable Exponential Stretching Sheet in Presence of Thermal Radiation." *Heat and Mass Transfer/Waerme- Und Stoffuebertragung* 48, no. 10 (2012): 1773–81. https://doi.org/10.1007/s00231-012-1024-8.
[16] Mukhopadhyay, Swati. "Analysis of Boundary Layer Flow over a Porous Nonlinearly Stretching Sheet with Partial Slip at the Boundary." *Alexandria Engineering Journal* 52, no. 4 (2013): 563–69. https://doi.org/10.1016/j.aej.2013.07.004.
[17] Ibrahim, Wubshet, and Bandari Shankar. "MHD Boundary Layer Flow and Heat Transfer of a Nanofluid Past a Permeable Stretching Sheet with Velocity, Thermal and Solutal Slip Boundary Conditions." *Computers and Fluids* 75 (2013): 1–10. https://doi.org/10.1016/j.compfluid.2013.01.014.
[18] Khader, M. M., and Ahmed M. Megahed. "Numerical Solution for Boundary Layer Flow Due to a Nonlinearly Stretching Sheet with Variable Thickness and Slip Velocity." *European Physical Journal Plus* 128, no. 9 (2013): 1–7. https://doi.org/10.1140/epjp/i2013-13100-7.
[19] Khader, M. M., and A. M Megahed. "Boundary Layer Flow Due to a Stretching Sheet with a Variable Thickness and Slip Velocity." *Journal of Applied Mechanics and Technical Physics* 26, no. 2 (2015): 241–47. https://doi.org/10.1134/S0021894415020091.
[20] Sajadifar, Seyed Ali, Arash Karimipour, and Davood Toghraie. "Fluid Flow and Heat Transfer of Non-Newtonian Nanofluid in a Microtube Considering Slip Velocity and Temperature Jump Boundary Conditions." *European Journal of Mechanics, B/Fluids* 61 (2017): 25–32. https://doi.org/10.1016/j.euromechflu.2016.09.014.
[21] Goodarzi, Marjan, Saeed Javid, Ali Sajadifar, Mehdi Nojoomizadeh, Seyed Hossein Motaharipour, Quang Vu Bach, and Arash Karimipour. "Slip Velocity and Temperature Jump of a Non-Newtonian Nanofluid, Aqueous Solution of Carboxy-Methyl Cellulose/Aluminum Oxide Nanoparticles, through a Microtube." *International Journal of Numerical Methods for Heat and Fluid Flow* 29, no. 5 (2019): 1606–28. https://doi.org/10.1108/HFF-05-2018-0192.

[22] Das, Kalidas, Pinaki Ranjan Duari, and Prabir Kumar Kundu. "Solar Radiation Effects on Cu–Water Nanofluid Flow over a Stretching Sheet with Surface Slip and Temperature Jump." *Arabian Journal for Science and Engineering* 39, no. 12 (2014): 9015–23. https://doi.org/10.1007/s13369-014-1380-4.

[23] Guo, Chengjie, Liancun Zheng, Chaoli Zhang, Xuehui Chen, and Xinxin Zhang. "Impact of Velocity Slip and Temperature Jump of Nanofluid in the Flow over a Stretching Sheet with Variable Thickness." *Zeitschrift Fur Naturforschung - Section A Journal of Physical Sciences* 71, no. 5 (2016): 413–25. https://doi.org/10.1515/zna-2015-0506.

[24] Zheng, Liancun, Chaoli Zhang, Xinxin Zhang, and Junhong Zhang. "Flow and Radiation Heat Transfer of a Nanofluid over a Stretching Sheet with Velocity Slip and Temperature Jump in Porous Medium." *Journal of the Franklin Institute* 350, no. 5 (2013): 990–1007. https://doi.org/10.1016/j.jfranklin.2013.01.022.

[25] Shen, Bingyu, Liancun Zheng, Chaoli Zhang, and Xinxin Zhang. "Bioconvection Heat Transfer of a Nanofluid over a Stretching Sheet with Velocity Slip and Temperature Jump." *Thermal Science* 21, no. 6 (2017): 2347–56. https://doi.org/10.2298/TSCI150424128S.

[26] Zhu, Jing, Dan Yang, Liancun Zheng, and Xinxin Zhang. "Effects of second order velocity slip and nanoparticles migration on flow of Buongiorno nanofluid." Applied Mathematics Letters 52 (2016): 183-191. https://doi.org/10.1016/j.aml.2015.09.003.

[27] Fang, Tiegang, and Abdul Aziz. "Viscous flow with second-order slip velocity over a stretching sheet." Zeitschrift für Naturforschung A 65, no. 12 (2010): 1087-1092. http://dx.doi.org/10.1515/zna-2010-1212.

[28] Ferdows, M., Md Jashim Uddin, and A. A. Afify. "Scaling Group Transformation for MHD Boundary Layer Free Convective Heat and Mass Transfer Flow Past a Convectively Heated Nonlinear Radiating Stretching Sheet." *International Journal of Heat and Mass Transfer* 56, no. 1–2 (2013): 181–87. https://doi.org/10.1016/j.ijheatmasstransfer.2012.09.020.

[29] Na, T.Y. "Boundary Layer Flow of Reiner-Philippoff Fluids." *International Journal of Non-Linear Mechanics* 29(6), no. 6 (1994): 871–77. https://doi.org/10.1016/0020-7462(94)90059-0.

[30] Yam, K. S., S. D. Harris, D. B. Ingham, and I. Pop. "Boundary-Layer Flow of Reiner-Philippoff Fluids Past a Stretching Wedge." *International Journal of Non-Linear Mechanics* 44, no. 10 (2009): 1056–62. https://doi.org/10.1016/j.ijnonlinmec.2009.08.006.

[31] Xiong, Pei Ying, Yu Ming Chu, M. Ijaz Khan, Sohail A. Khan, and S. Z. Abbas. "Entropy Optimized Darcy-Forchheimer Flow of Reiner-Philippoff Fluid with Chemical Reaction." *Computational and Theoretical Chemistry* 1200, no. March (2021): 113222. https://doi.org/10.1016/j.comptc.2021.113222.

[32] Shampine, L.F., I. Gladwell, and S. Thompson. *Solving ODEs with MATLAB*. Cambridge: Cambridge University Press, 2003.

[33] Cortell, Rafael. "Heat and Fluid Flow Due to Non-Linearly Stretching Surfaces." *Applied Mathematics and Computation* 217, no. 19 (2011): 7564–72. https://doi.org/10.1016/j.amc.2011.02.029.

[34] Waini, Iskandar, Anuar Ishak, and Ioan Pop. "Hybrid Nanofluid Flow and Heat Transfer over a Nonlinear Permeable Stretching/Shrinking Surface." *International Journal of Numerical Methods for Heat & Fluid Flow* 29, no. 9 (2019): 3110–27. https://doi.org/10.1108/HFF-01-2019-0057.

[35] Sajid, T., M. Sagheer, and S. Hussain. "Impact of Temperature-Dependent Heat Source/Sink and Variable Species Diffusivity on Radiative Reiner-Philippoff Fluid." *Mathematical Problems in Engineering* 2020 (2020). https://doi.org/10.1155/2020/9701860.