Egypt. J. Chem. **Vol. 67** No. 3 pp 273 - 282 (2024)

Egyptian Journal of Chemistry

http://ejchem.journals.ekb.eg/

Both micro-structural slips and conductivity variation properties of magneto nanoflow of micropolar fluid

Mohamed Y. Abou-zeid[a*] and Mohamed G. Ibrahim[b]

[a] Department of Mathematics, Faculty of Education, Ain Shams University, Heliopolis, Cairo, 11757, Egypt.

[b] Department of Basic and Applied Science, Faculty of Engineering, IAEMS, 11311, Cairo, Egypt.

* Corresponding author ‘s E-mail address: mastermath2003@gmail.com

Abstract

Electrical and thermal conductivity plays a paramount role in food industries' heat operation processes. Hence, this analysis sheds light on the variation of conductivity properties in MHD boundary layer flow with micropolar nanofluid. Micro-structural slips and Arrhenius impacts are also taken into consideration. Reliable suitable similarity transformations of the resulting fluid equation system are applied, to give an ordinary differential system of equations. Rung-Kutta method with shooting technique is utilized to achieve numerical results. The technical algorithms are made via a full package of ***Mathematica 13.1.1***. Sketches/results are prepared for the velocity, microrotation velocity, temperature and nanoparticles concentration distributions against physical parameters. Results assured on the variation of conductivity properties improve the temperature distribution of fluid and then the operation system attained more energy, that beneficial in industries of food operations with the aid idea of Ohmic heaters.

*Keyword***s:** Electrical and thermal conductivity in variable case; Slip velocity in a multiple case; Micropolar fluid; Mathematica package ver. 13.

1. Introduction

Nowadays, in many industrial processes the electrical conductivity plays the most important rule, which considered phenomenon that happens in some materials once cooled to temperatures in lower degree. In ***1911*** [**1**] Onnes offers the first look at the meaning of electrical conductivity and obtain the definite resistance of metals at small temperatures. In the latest view, scholars, and examiners premeditated the electrical conductivity bases to its numerous claims: In electrical processes such magnetic resonance imaging devices, digital electrical circuits, particle accelerators, in medicine processes, like magnetic resonance**.** Inflows, Obalalu *et al* [**2**] announced a recommendation for the electrical conductivity variable case influence of Casson fluid in presence of nanoparticle. They alleged that electrical conductivity has a converse relation with fluid concentration. Otherwise, Qasim *et al* [**3**] suggest a new mechanism of nanoparticle theory on the peristaltic pumping. Electrical conductivity has a dominant relation to fluid concentration and temperature. An original theoretical method to the relationship among electrical conductivity and fluid concentration. The literature on the line of conductivity properties and their relation to fluid concentration is in Refs. [**4 − 8**].

The flows with slip conditions are considered a substantial concern of microsystems in applications like micro-valves, pumps with small sizes, and nozzles. The boundary layer flow with slip conditions in the case of multiple case was constructed by Dawar *et al* [**9**]. Authors show that microstructural slip parameter is the cause growing in velocity distribution more than in the case of a non-microstructural slip. Velocity slip and thermal radiation effects on the unsteady flow with stretching sheet problem are numerically solved by Mabood and Shateyi [**10**]. The author state that the slip parameter is the cause in enhancing the fluid velocity at the center of the layer and diminish the velocity at the edge of layer. Mahmoud and Waheed [**11**] scrutinized the influence of the magnetic field on micropolar fluid with boundary layer flow. Afzal and Aziz **[12]** addressed

*Corresponding author should be addressed: mastermath2003@gmail.com (Mohamed Y. Abou-zeid). Receive Date: 10 August 2023 Revise Date: 08 September 2023 Accept Date: 17 September 2023

DOI: 10.21608/EJCHEM.2023.228497.8407

the effect of MHD slip and non-constant conductivity properties on the flow of nanofluid in the flow with presence of nanoparticles**.** In addition, many researches are studied the important/ substantial applications of fluid in different types(**see Refs.** [**13 − 20**]).

The results of such fluid problems need a high technical algorithm to cure the high nonlinear terms that appear in MHD fluid of the boundary flow, So, we select a semi-analytical method which named by algorithms of the shooting method joint with the iteration of Rung-Kutta-Fehlberg method. ***Generally***, the shooting algorithm is measured as an extremely helpful method that is secondhand to solve the problems of boundary value by reducing it to 1st problem. The algorithm of the shooting algorithms is anticipated initially by Merle 1988 [**21**], who finds the solution of nonlinear Dirac equations. The shooting technique is discretized for solving flow studies with transpiration influence by Hasanuzzaman *et al* **[22]**. Lanjwani *et al* [**23**] studied the Casson fluid flow using the shooting method. Many authors and detectives use the numerical and semi-analytical algorithms to get the solutions of boundary layer problems with variable conditions, see Refs. [**24 − 40**].

In the above investigations, all researchs are in the line of boundary layer flow problems with constant conductivity properties. This is not sufficient to visualize all their applications in food industries. The existing paper presents a new theoretical suggestion for the mechanisms of conductivity properties (Thermal and electrical) varying with the fluid concentration. This suggestion helps to provide the behavior of non-constant electrical and thermal conductivity in many industries' processes. Sketches are extracted for all possible distributions of velocities and fluid temperature and concentration. This study can serve as a model which may support in comprehension the mechanics of physiological flows. Physically, our model corresponds to transport of the gastric juice in the small intestine.

2 Formulation of the problem

The flow of a micropolar nanofluid on a surface with multiple slips and stretches. Non-constant electrical and thermal conductivity is premeditated. $\breve{u}_s = a\breve{x}$ is supposed the stretching velocity and a is the rate of stretch. The fluid equation model is theoretically scrutinized as the following **[9]**:

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

$$\breve{u}\frac{\partial \breve{u}}{\partial \breve{x}} + \breve{v}\frac{\partial \breve{u}}{\partial \breve{y}} = \frac{\kappa}{\rho}\frac{\partial \breve{N}}{\partial \breve{y}} + \frac{(\mu+\kappa)}{\rho}\frac{\partial^2 \breve{u}}{\partial \breve{y}^2} - \frac{\sigma(\breve{C})B_0^2\breve{u}}{\rho} + g\{\beta_c(\breve{C} - \breve{C}_\infty) + \beta_{\breve{T}}(\breve{T} - \breve{T}_\infty)\}, \tag{2}$$

$$\breve{u}\frac{\partial \breve{N}}{\partial \breve{x}} + \breve{v}\frac{\partial \breve{N}}{\partial \breve{y}} = \frac{\Omega}{\rho_j}\frac{\partial^2 \breve{N}}{\partial \breve{y}^2} - \frac{\kappa}{\rho_j}\left(2\breve{N} + \frac{\partial \breve{u}}{\partial \breve{y}}\right), \tag{3}$$

$$\breve{u}\frac{\partial \breve{T}}{\partial \breve{x}} + \breve{v}\frac{\partial \breve{T}}{\partial \breve{y}} = \frac{1}{\rho c_p}\left(\frac{\partial}{\partial \breve{x}}k(\breve{C})\frac{\partial \breve{T}}{\partial \breve{x}} + \frac{\partial}{\partial \breve{y}}k(\breve{C})\frac{\partial \breve{T}}{\partial \breve{y}}\right) + \frac{16\sigma^*\breve{T}_\infty^3}{3\rho c_p k^*}\frac{\partial^2 \breve{T}}{\partial \breve{y}^2} + \frac{\sigma(\breve{C})B_0^2\breve{u}^2}{\rho c_p} + \breve{\tau}\left[D_B\frac{\partial \breve{T}}{\partial \breve{y}}\frac{\partial \breve{C}}{\partial \breve{y}} + \frac{D_B}{D_{\breve{T}}}\left(\frac{\partial \breve{T}}{\partial \breve{y}}\right)^2\right], \tag{4}$$

$$\breve{u}\frac{\partial \breve{C}}{\partial \breve{x}} + \breve{v}\frac{\partial \breve{C}}{\partial \breve{y}} = -K_r^2(\breve{C} - \breve{C}_\infty)\left(\frac{\breve{T}}{\breve{T}_\infty}\right)^n e^{\left(\frac{-E_a}{K_B\breve{T}}\right)} + \frac{D_{\breve{T}}}{T_\infty}\frac{\partial^2 \breve{T}}{\partial \breve{y}^2} + D_B\frac{\partial^2 \breve{C}}{\partial \breve{y}^2}. \tag{5}$$

The gradient velocity of spin is suited as:

$$\Omega = \mu\left(\frac{\alpha}{2} + 1\right)j. \tag{6}$$

The parameter α is defined as a micropolar parameter, which equal $(= \frac{\kappa}{\mu})$

The conditions of flow problem are as follows:

$$\breve{u} = \breve{u}_s + \breve{u}_{slip}, \breve{v} = 0, \breve{T} = \breve{T}_s, \breve{N} = -\breve{n}\frac{\partial \breve{u}}{\partial \breve{y}}, \breve{C} = \breve{C}_s \text{ at } \breve{y} = 0, \tag{7}$$

$$\breve{u} \to 0, \breve{N} \to 0, \breve{T} \to \infty, \breve{C} \to \infty \text{ as } \breve{y} \to \infty, \tag{8}$$

Now,

$$\breve{u}_{slip} = -\frac{2}{3}\left\{\frac{3}{8}\left[l^4 + \frac{2(1-l^2)}{k_n^2}\right]\lambda^2\frac{\partial}{\partial \breve{y}}\left(-R_0\breve{N} + \frac{\partial \breve{u}}{\partial \breve{y}}\right) - \lambda\left(\frac{1-\beta l^2}{\beta} - \frac{3}{2}\frac{1-l^2}{k_n}\right)\frac{\partial \breve{u}}{\partial \breve{y}}\right\}, \tag{9}$$

$$\breve{u}_{slip} = \frac{\partial}{\partial \breve{y}}\left(-R_0\breve{N} + \frac{\partial \breve{u}}{\partial \breve{y}}\right)B + \frac{\partial \breve{u}}{\partial \breve{y}}A, \tag{10}$$

The symbols $A, B, \breve{n}, \breve{u}, \breve{x}, \breve{y}, R_0, B_0$ represent the slip constants, the parameter of micro-rotation, the coordinates, the multiple slips, the magnetic field forte respectively, and the concentration ($\breve{C}$) of fluid, the Brownian (D_B) diffusion coefficient, the diffusion ($D_{\breve{T}}$) coefficient, gravitational (g) acceleration, mean absorption coefficient, the Stefan-Boltzmann (σ^*) constant, the Knudsen (k^*) number, the temperature, the expansion ($\beta_{\breve{C}}$) of concentration, thermal ($\beta_{\breve{T}}$) expansion, the vortex viscosity, the electrical (κ) conductivity, the density (ρ), the heat ratio, and the dynamic (μ) viscosity, respectively. The similarity transformations are defined as:

$$\breve{u} = \frac{\partial \psi}{\partial y}, \psi = \sqrt{a v x}f(\xi), \breve{v} = -\frac{\partial \psi}{\partial y}, \breve{N} = ax\sqrt{\frac{a}{v}}g(\eta),$$

$$\Theta(\eta) = \frac{\breve{T} - \breve{T}_\infty}{\breve{T}_s - \breve{T}_\infty}, \Phi(\eta) = \frac{\breve{C} - \breve{C}_\infty}{\breve{C}_s - \breve{C}_\infty}, D_1 = \frac{\breve{T}_s - \breve{T}_\infty}{x}, \eta = \sqrt{\frac{a}{v}}y, D_2 = \frac{\breve{C}_s - \breve{C}_\infty}{x}, \tag{11}$$

In the last decade, a researcher **[29]** present a new relation for conductivity parameters depending on the fluid concentration.

$$\kappa\,(\hat{C}) = \kappa_0\left[1+\beta_1\left(\frac{\hat{C}-\hat{C}_\infty}{\hat{C}_s-\hat{C}_\infty}\right)\right], \quad (12)$$

Here, the mean thermal (κ_0) conductivity of the suspension, the relation for the dependence $\beta_1 = \frac{1}{\kappa_0}\frac{\partial\kappa}{\partial\hat{T}}$ of the thermal conductivity on the concentration of the nanoparticles, in addition, $0 < \beta_1 < 1$, $\beta_1 = 0$ at the conductivity constant case. The conductivity properties in the conductivity case are known as:

$$\sigma(\hat{C}) = \sigma_0\left[1+\beta_2\left(\frac{\hat{C}-\hat{C}_\infty}{\hat{C}_s-\hat{C}_\infty}\right)+\cdots+O(\alpha)\right], \quad (13)$$

As the high order of α leads to minimum values of $\sigma(\hat{C})$ so, we neglect the higher order of conductivity as:

$$\sigma(\hat{C}) = \sigma_0\left[1+\beta_2\left(\frac{\hat{C}-\hat{C}_\infty}{\hat{C}_s-\hat{C}_\infty}\right)\right], \quad (14)$$

Using Eq. (9) - (14), the Eqs. (2)– (5) are condensed as:

$$\gamma_2\varphi+(\alpha+1)f'''-f'^2-\alpha g'+ff''+\gamma_1\theta-M\,(1+\beta_1\,\theta)\,f'=0, \quad (15)$$

$$\left(\frac{\alpha}{2}+1\right)g''+fg'-gf'-\alpha(f''+2g)=0, \quad (16)$$

$$\frac{(1+R)}{P_r}\,\theta''+(\beta_2\theta'\varphi'+(1+\beta_2\varphi)\theta")+E_cMf'^2+Nb\,\theta'\phi'+Nt\,\theta'^2-\theta f'+f\theta'+M\,(1+\beta_1\,\theta)\,E_c\,f'^2=0, \quad (17)$$

$$\varphi''-S_c\,f'\varphi+S_c\,f\varphi'+\frac{N_t}{N_b}\theta''-P_r\,\sigma(1+\delta\,\theta)^n e^{\left(\frac{-E}{1+\delta\,\theta}\right)}\varphi=0. \quad (18)$$

The similarity of boundary conditions

$$f'\,(0)=1+\gamma f''(0)+\delta_1 f'''(0)+R_0\,g'(0),\ f(0)=0,\ g(0)=-mf'',$$

$$\theta(0)=1,\ \phi(0)=1, \quad (19)$$

$$\theta(\infty)=0,\ \phi(\infty)=0,\ f'(\infty)=0,\ g(\infty)=0. \quad (20)$$

Where, the magnetic ($M=\frac{\sigma_0 B_0^2}{\rho a}$) field, the thermal ($R=\frac{16\,\sigma^*\check{T}_\infty^3}{3\rho c_p k^*}$) radiation parameter, the Soret ($S_c=\frac{\nu}{D_B}$) Parameter, the thermophoresis ($N_t=\frac{\tau D_{\check{T}}(\check{T}_s-\check{T}_\infty)}{\check{T}_\infty\nu}$) parameter, the Prandtl ($P_r=\frac{\mu c_p}{k}$) parameter, the Brownian motion ($N_b=\frac{\tau D_B(\check{C}_s-\check{C}_\infty)}{\check{T}_\infty\nu}$) parameter, the Eckert ($E_c=\frac{\check{u}_s^2}{c_p(\check{T}_s-\check{T}_\infty)}$) number, the thermal Grashof ($\gamma_1=\frac{\beta_{\check{T}}D_1 g}{a^2}$) number, the mass Grashof ($\gamma_2=\frac{\beta_{\check{C}}D_2 g}{a^2}$) number, the chemical ($\sigma=\frac{k_r^2}{a}$) reaction parameter, and the activation ($E=\frac{E_a}{K_B\check{T}}$) parameter.

3 Adaptive solutions using Shooting

The solution of a system (15-18) with related conditions (19-20) using Rung-Kutta method with the adaptive shooting method is through this section. 1st order of solution for equations is attained via 1st iteration, and then the shooting algorithm is used to 2st, 3st, etc…. If we suppose,

$$f=y_1, f'=y_2, f''=y_3, g=y_4, g'=y_5, \theta=y_6, \theta'=y_7, \varphi=y_8 \text{ and } \varphi'=y_9,$$

Then the recurrence relations for fluid distributions are as:

$$y_3'=\frac{M(1+\beta_1 y_8)f'[\eta]-\gamma_1 y_6-\gamma_2 y_8+y_2{}^2+\alpha y_5-y_1 y_3}{(1+\alpha)}, \quad (21)$$

$$y_5'=\frac{y_4 y_2-y_1 y_5+\alpha(2y_1+y_3)}{(1+\frac{\alpha}{2})}, \quad (22)$$

$$y_7'=-\frac{(1+R)(\beta_2 y_7 y_9)}{Pr}+\mathrm{Pr}\frac{y_6 y_2-\mathrm{ec}M(1+\beta_1 y_8)y_2{}^2-y_1 y_7-\mathrm{Nt}y_7{}^2-\mathrm{Nb}y_7 y_9}{(1+\beta_2 y_8)}, \quad (23)$$

$$y_9'=-e^{-\frac{e_a}{1+\xi y_6}}\mathrm{pr}\sigma(1+\xi y_6)y_8+y_1 y_9+\frac{\mathrm{Nt}y_7'}{\mathrm{Nb}}, \quad (24)$$

Subject to conditions

$$y_2(0)=1+\gamma y_3(0)+\delta_1 y_3'(0)+R_0\,y_5(0),\ y_1(0)=0,\ y_4(0)=-my_3,$$

$$y_6(0)=1,\ y_8(0)=1 (25)$$

$$y_6(\infty)=0,\ y_8(\infty)=0,\ y_2(\infty)=0,\ y_4(\infty)=0. \quad (26)$$

Therefore, The process is repeated iteratively many times until convergence is occurred, i.e., until the absolute values of the difference between every two successive approximations of the missing conditions is less than (in our problem $\varepsilon$is taken =10^-7, and these algorithms of the shooting method are used with aid of ***Mathematica 13.1.1.***to get the results offered in the next section.

4 Results and discussions

In this section, we sketch of velocity $f'(\eta)$, microrotation velocity $g(\eta)$, temperature $\theta(\eta)$, and nanoparticles concentration $\varphi(\eta)$ profiles. All graphs are offered against pertinent physical parameters of interest for four different values. The following values are used as standard values of the problem parameters: $\mathrm{Pr} = 1, \mathrm{Nb} = 0.2, M = 0.5, \gamma = 0.1, \alpha = 1, \gamma_2 = 0.6, \xi = 0.2, \beta_1 = 0.2, \beta_2 = 0.2, \sigma = 0.2, E_a = 1, \gamma_1 = 0.5, \; R = 1, \; Nt = 0.3, \mathrm{ec} = 0.15, \delta = 0.01, b = 0.1, m = 0.1.$

Mass Grashof number is a non-dimensional parameter and is used in the correlation of mass transfer due to the attractive force between particles induced mixed convection at a solid surface immersed in a fluid. The effects of mass Grashof number γ_2 and the magnetic field parameter M on the velocity $f'(\eta)$ are shown in **Figs. (1)** and **(2)**, respectively, and it is shown from these figures that the velocity increases by increasing γ_2, while it decreases as M increases. Also, for small values of γ_2 and large values of M, the velocity decreases with η, with a relationship that seems like a parabola. The physical expectation and previous definition of mass Grashof number are consistent with the result in Fig. (1). The following the result in figure **(2)**; the force exerted on a charged particle entire a liquid which is moving with a specific velocity through an electric field and magnetic field is called Lorentz force. This entire electromagnetic force on this liquid always prevents the flow. Fig**. (3)** shows the variation of the velocity $f'(\eta)$with η for various values of first order slip condition parameter γ. It is clear from Fig.**(3)**, that the velocity decreases as γ increases in the interval $\eta \in [0, 1.78]$; otherwise, it decreases by increasing γ. Therefore, the behavior of $f'(\eta)$ in the interval $\eta \in [1.78, \infty)$ is opposite to its behavior in the interval $\eta \in [0, 1.78]$. The effects of other parameters are similar to those obtained in Figs. **(1)** and **(2)**.

Eq. **(16)** evaluates how the microrotation velocity distribution $g(\eta)$ variations with the dimensionless coordinate η. The effects of the microrotation parameter α and m on the microrotation velocity distribution $g(\eta)$ are illustrated in figures **(4)** and **(5)**, respectively. It is obviously that the microrotation velocity distribution increases as both α and m increase, but in case of m, it seems like a parabola with upper and down vortices for m < 0.3, and m > 0.3. moreover, the microrotation velocity has a positive sign, and for major values of α and little values of m, it becomes larger with η till a finite value of η, after this maximum value it goes lower. The influence of thermal Grashof number γ_1 on the microrotation velocity distribution $g(\eta)$ is shown in Fig. **(6)**. It is observed that the microrotation velocity diminutions as $\gamma_1$in the range of η, namely, $\eta \in [0, 1.41]$; otherwise there is an enhancement in the value of $g(\eta)$ as γ_1 increases. So, the manner of $g(\eta)$ in the interval $\eta \in [1.41, \infty)$, is opposite to its manner in the interval $\eta \in [0, 1.41]$, and in the first interval, a maximum value of $g(\eta)$ occurs at η =0.58.

The temperature distribution θ is elucidated for various values of the parameter of thermal radiation R and the parameter of microrotation α, is elucidated in Figs. **(7)** and **(8)**, respectively. It is notted from figures **(7)** and **(8)**, respectively, that the temperature becomes larger with the increase of R, while it goes lower as α increases. Furthermore, It is observed that for major values of R and little values of , the relation between θ and η is a straigt line, and all curves intersect at $\eta = 0$.

The influence of the thermophoresis parameter Nt and Brownian motion parameter Nb on the nanoparticles concentration φ are given in figures **(9)** and **(10)**, respectively. Therefore, in these figures, equation (18) is evaluated versus the non-dimensional coordinate η. It is also noted from these figures that the nanoparticles concentration φ increases with the increase of Nt, whereas it decreases as Nb increases. It is also noted that the nanoparticles concentration for different values of Nt becomes larger with increasing η and reaches a maximum value (at a finite value of η: $\eta = \eta_0$) after which it decreases. The following clarifies the thermophoresis effect on nanoparticles concentration, namely, the result in Fig **(9)**. Thermophoresis or thermo-migration is an original sin that occurs in a blend of transported particles, where the different particle types display different echoes to the nanoparticles concentration gradient force. So, the thermophoresis parameter causes an increament of the nanoparticles concentration. Fig. **(11)** shows the variation of the concentration of nanoparticles φ with η for several values of the parameter of thermal radiation R. It is seen from Fig.**(11)**, that the nanoparticles concentration decreases with the increase of R, in the interval $\eta \in [0, 2.9]$; otherwise, itincreases by increasing R. So, the manner of φ in the interval $\eta \in [2.9, \infty)$ is counteractive to its manner in the interval $\eta \in [0, 2.9]$. The other figures have the effect, so they are excluded here to save space. A dual role phenomena has obtained in figure **(12)** by increase the values of β_2 against the values of concentration distribution.

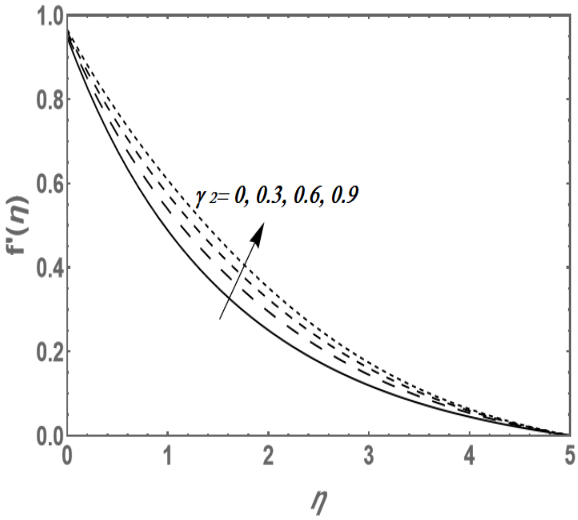

Fig. 1: Velocity ($f'(\eta)$) distribution versus γ_2.

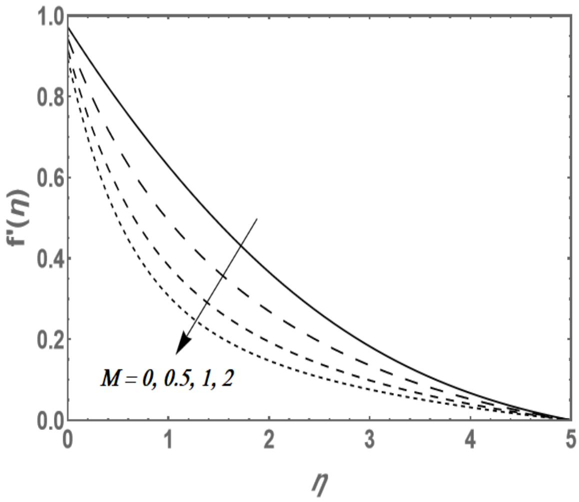

Fig. 2: Velocity ($f'(\eta)$) distribution versus M.

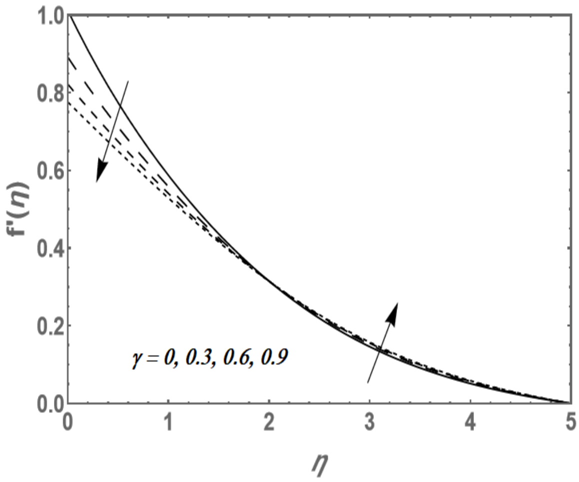

Fig. 3: Velocity ($f'(\eta)$) distribution versus γ.

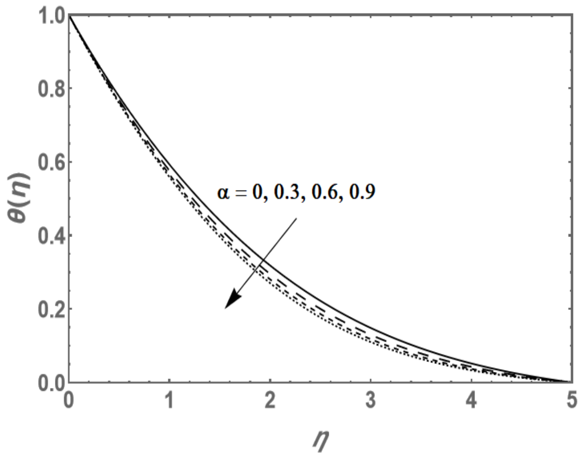

Fig. 4: Microrotation ($g(\eta)$) distribution versus α.

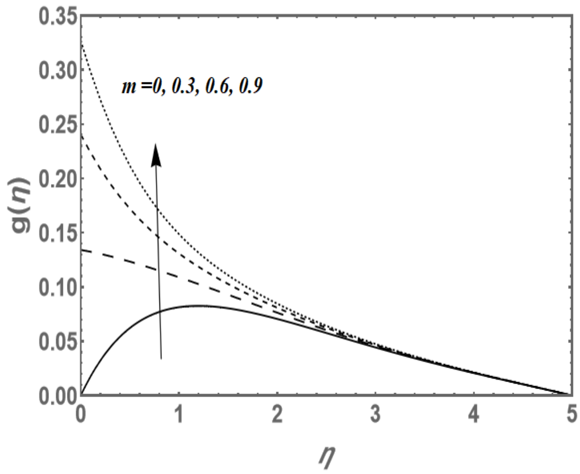

Fig. 5: Microrotation ($g(\eta)$) distribution versus m.

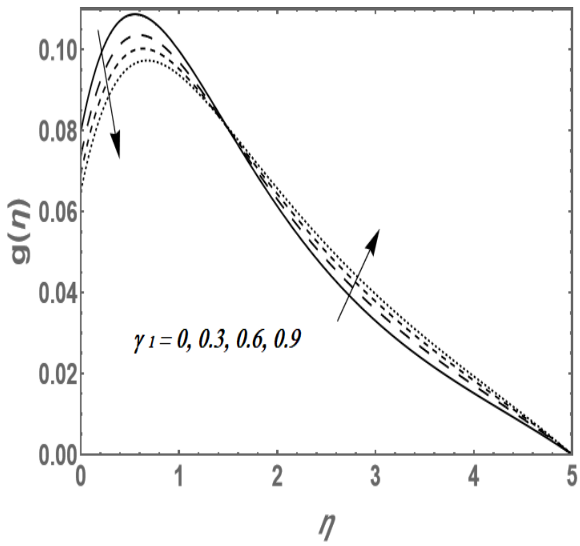

Fig. 6: Microrotation ($g(\eta)$) distribution versus γ_1.

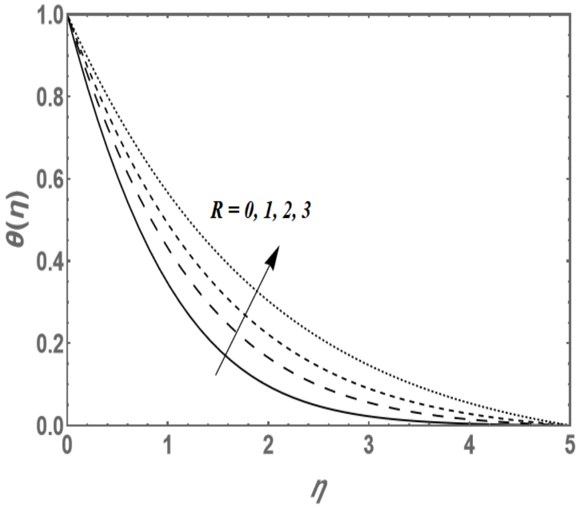

Fig. 7: Temperature ($\theta(\eta)$) distribution versus R.

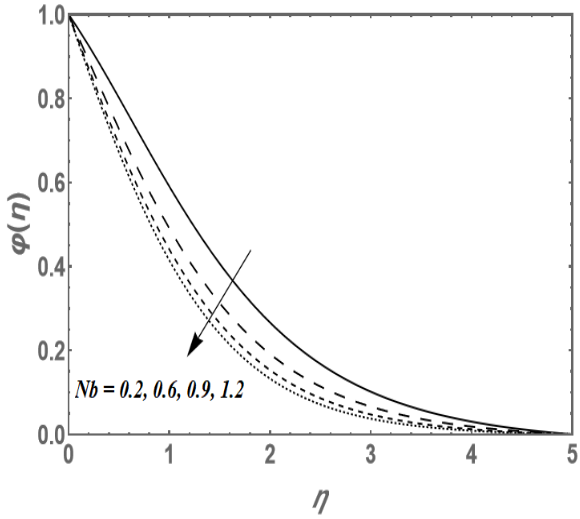

Fig. 10: Concentration($\varphi(\eta)$)distribution versus N_b.

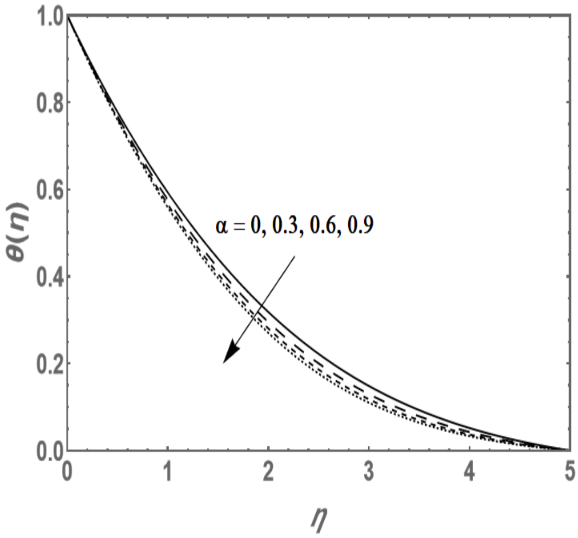

Fig. 8: Temperature ($\theta(\eta)$) distribution versus α.

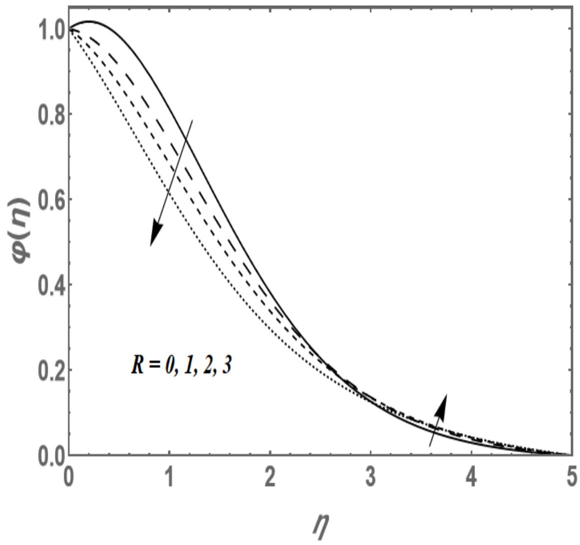

Fig. 11: Concentration $\varphi(\eta)$ distribution versus R.

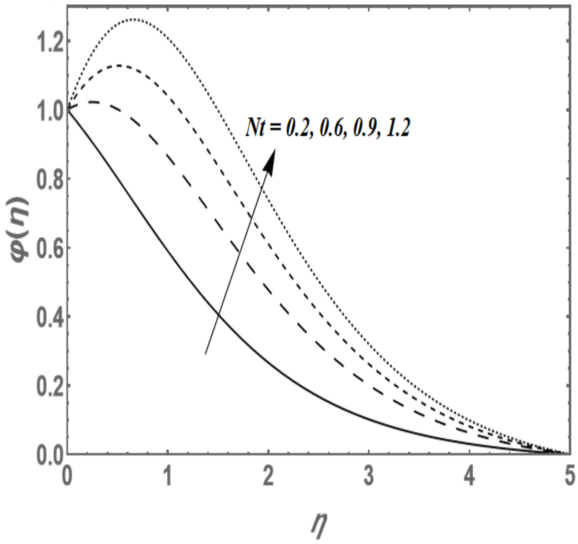

Fig. 9: Temperature ($\varphi(\eta)$) distribution versus *M*

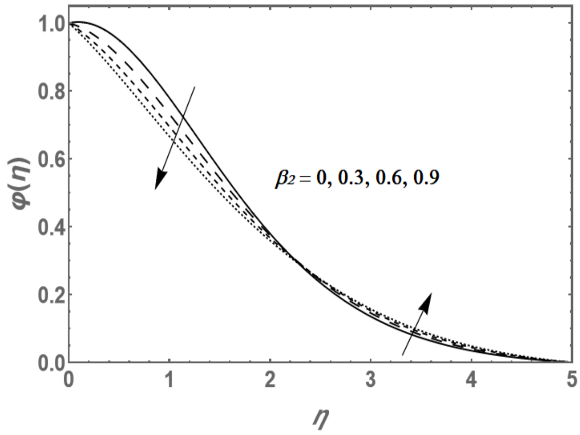

Fig. 12: Concentration$\varphi(\eta)$distribution versus β_2.

5 Conclusion

This analysis scrutinizes a new theoretical suggestion for a mechanism of electrical and thermal conductivity on the boundary layer flow of miro polar fluid with a stretching sheet. Multiple/ microstructural slips, radiation, and nanoparticle are also studied. The fluid model is designated arithmetically by a system of ODEs. A computer program use the ***Mathematica 13.1.1*** is prepared with a shooting method to obtain the results/sketches. Investigations of these effects together are very useful due to their important vital applications in various scientific fields, especially in medicine and medical industries, such as endoscopes, respirators, and diverse medical implementations, as nanoparticles can be utilized in the remedy of cancer tumors. Moreover, this study investigates the influence of an endoscope on the unsteady incompressible flow which plays a very important role in medical diagnosis due to its wild clinical applications in determining the reasons behind many diseases in the human organs. For example, the motion of gastric juice when an endoscope is inserted through a small intestine. In addition, it is expected that the current effort will help a vehicle for considerate additional multifaceted difficulties in industry, engineering **[41-74]**. The main/essential notes are itemized as follows:

- The fluid temperature gets better at the higher values of thermophoresis (N_t) number in the case of ($\beta_1, \beta_2 = 0.3$).
- Mass Grashof (γ_2) number and Magnetic (M) parameter have a dual role phenomenon on the fluid-particle concentration.
- Thermophoresis (N_t) number has a clear/ non-wobbling behavior on the fluid temperature and concentration.
- γ has two contradicting effects on the fluid velocity distribution.
- Micro rotation distribution has a stable behavior in absence of micro polar fluid.
- Results indicate that the concentration-dependent electrical and thermal conductivity gets the fluid particle distributions better.

Data availability statements

The authors states that all the files are provided in the paper no hidden file is required however if journal required any further data from us we will provide and the the corresponding author is responsible to provide to the journal.

References

1- T. Sakai, G. Adachi and J. Shiokawa, Electrical conductivity of Ln VO 3 compounds, 11, (1976) 1295-1300.

2- A. M. Obalalu, O. A. Ajala, A. Abdulraheem and A. O. Akindele, The influence of variable electrical conductivity on non-Darcian Casson nanofluid flow with first and second-order slip conditions, Partial Differential Equations in Applied Mathematics, 4 (2021) 100084.

3- M. Qasim, Z. Ali, A. Wakif and Z. Boulahia, Numerical Simulation of MHD Peristaltic Flow with Variable Electrical Conductivity and Joule Dissipation Using Generalized Differential Quadrature Method, Commun. Theor. Phys., 71 (2019) 509–518.

4- P. G. Kumar, D. Sakthivadivel, N. Thangapandian, M.Salman, A. K. Thakur, R. Sathyamurthy and S. C. Kim, Effects of ultasonication and surfactant on the thermal and electrical conductivity of water – Solar glycol mixture based Al_2O_3 nanofluids for solar-thermal applications, Sustainable Energy Technologies and Assessments, 47 (2021) 101371.

5- T.P. Iglesias and J. C. R. Reis, on the definition of excess electrical conductivity, Journal of Molecular Liquids 344 (2021) 117764.

6- A. Shimojuku, T. Yoshino, D. Yamazaki, T. Okudaira, Electrical conductivity of fluid-bearing quartzite under lower crustal conditions, Physics of the Earth and Planetary Interiors, 8 (2012) 198–199.

7- M. Glassl, M. Hilt and W. Zimmermann, Convection in nanofluids with a particle-concentration-dependent thermal conductivity, Phys. Rev., E, 83 (2011) 046315.

8- S. P. Janga and S. U. S. Choi, Role of Brownian motion in the enhanced thermal conductivity of nanofluids, Applied Physics Letters, 84 (2004) 4316-4318.

9- A. Dawar, Z. Shah, A. Tassaddiq, S. Islam and P. Kumam, Joule heating in magnetohydrodynamic micropolar boundary layer flow past a stretching sheet with chemical reaction and microstructural slip, Case Studies in Thermal Engineering, 25 (2021) 100870.

10- F. Mabood and S. Shateyi, Multiple Slip Effects on MHD Unsteady Flow Heat and Mass Transfer Impinging on Permeable Stretching Sheet with Radiation, Modelling and Simulation in Engineering, Volume 2019, Article ID 3052790.

11- M. Mahmoud and S. Waheed, Effects of slip and heat generation/absorption on MHD mixed convection flow of micropolar fluid over a heated stretching surface, Math. Probl Eng., vol. 2010, ID 579162.

12- K. Afzal and A. Aziz, Transport and heat transfer of time-dependent MHD slip flow of nanofluids in solar collectors with variable thermal conductivity and thermal radiation, Results in Physics, 6 (2016) 1-8.

13- M. G. Ibrahim and M. Abouzeid, Influence of variable velocity slip condition and activation energy on MHD peristaltic flow of Prandtl nanofluid through a non-uniform channel, Scientific Reports, 12(1), 2022, 18747.

14- M. G. Ibrahim, Computational calculations for temperature and concentration-dependent density

effects on creeping motion of Carreau fluid: biological applications, Waves in Random and Complex Media, 32, 2022, 2122631.
15- M. G. Ibrahim, N. A. Fawzy, Arrhenius energy effect on the rotating flow of Casson nanofluid with convective conditions and velocity slip effects: Semi-numerical calculations, Heat Transfer, 52 (2023) 687-706.
16- M. G. Ibrahim, Adaptive Computations to Pressure Profile for Creeping Flow of a Non-Newtonian Fluid With Fluid Nonconstant Density Effects, J. Heat Transfer, 144(10) 2022, 103601.
17- M. G. Ibrahim, Concentration-dependent electrical and thermal conductivity effects on magnetoHydrodynamic Prandtl nanofluid in a divergent–convergent channel: Drug system applications, Proc IMechE Part E: J Process Mechanical Engineering, 2022, ID: 0749.
18- M. G. Ibrahim, Adaptive simulations to pressure distribution for creeping motion of Carreau nanofluid with variable fluid density effects: Physiological applications, Thermal Science and Engineering Progress, 32 (1) 2022, 101337.
19- M. G. Ibrahim, Numerical simulation for non-constant parameters effects on blood flow of Carreau–Yasuda nanofluid flooded in gyrotactic microorganisms: DTM-Pade application, Archive of Applied Mechanics, 92 (2022) 1643–1654.
20- M. G. Ibrahim, Concentration-dependent viscosity effect on magnet nano peristaltic flow of Powell-Eyring fluid in a divergent-convergent channel, International Communications in Heat and Mass Transfer, 134, 2022, 105987.
21- F. Merle, Existence of stationary states for nonlinear Dirac equations, Journal of Differential Equations, 74 (1988), 50–68.
22- M. D. Hasanuzzaman, M. D. A. Kabir and M. D. T. Ahmed, Transpiration effect on unsteady natural convection boundary layer flow around a vertical slender body, Results in Engineering, 12 (2021) 100293.
23- W. Hasona, Nawal H. Almalki, Abdelhafeez A. El-Shekhipy and M. G. Ibrahim, Combined Effects of Variable Thermal Conductivity and Electrical Conductivity on Peristaltic Flow of Pseudoplastic Nanofluid in an Inclined Non-Uniform Asymmetric Channel: Applications to Solar Collectors, Journal of Thermal Science and Engineering Applications, 12 (2) (2020) 021018.
24- A. Ismael, N. T. M. Eldabe, M. Abouzeid, S. Elshabouri, Entropy generation and nanoparticles Cu O effects on MHD peristaltic transport of micropolar non-Newtonian fluid with velocity and temperature slip conditions, Egyptian Journal of Chemistry, 65 (2022) 715-722.
25- M. G. Ibrahim, Numerical simulation to the activation energy study on blood flow of seminal nanofluid with mixed convection effects, Computer Methods in Biomechanics and Biomedical Engineering, 26 (3) 2023, 2063018.
26- M. G. Ibrahim, N. Abdallah, and M. Abouzeid, Activation energy and chemical reaction effects on MHD Bingham nanofluid flow through a non-Darcy porous media, Egyptian Journal of Chemistry, 65 (2022) 137 – 144.
27- M. G. Ibrahim and Hanaa A. Asfour, The effect of computational processing of temperature- and concentration-dependent parameters on non-Newtonian fluid MHD: Applications of numerical methods, Heat Transfer, 51, 2022, 2977-2994.
28- N.T.M Eldabe, M.Y. Abou-zeid, A. Abosaliem, A. Alana, and N. Hegazy, Thermal diffusion and diffusion thermo Effects on magnetohydrodynamics transport of non-Newtonian nanofluid through a porous media between two wavy co-axial tubes, IEEE Transactions on Plasma Science, 50 (2021), 1282-1290.
29- M. E. Ouaf, M. Abouzeid, and Y. M. Younis, Entropy generation and chemical reaction effects on MHD non-Newtonian nanofluid flow in a sinusoidal channel, International Journal of Applied Electromagnetics and Mechanics 69(1) (2022) 1-21.
30- M. G. Ibrahim, W.M. Hasona and A.A. ElShekhipy, Concentration-dependent viscosity and thermal radiation effects on MHD peristaltic motion of Synovial Nanofluid: Applications to rheumatoid arthritis treatment, Computer Methods and Programs in Biomedicine 170 (2019) 39–52.
31- Nabil T. M. Eldabe, R. Rizkalla, M. Abouzeid, V. Ayad, Effect of induced magnetic field on non-Newtonian nanofluid Al2O3 motion through boundary layer with gyrotactic microorganisms, Thermal Science 26 (2021) 189-189.
32- N.T.M Eldabe, M.Y. Abou-zeid, M. E. Ouaf, D. R. Mostapha, and Y. M. Mohamed., Cattaneo-Christov heat flux effect on MHD peristaltic transport of Bingham Al_2O_3 nanofluid through a non-Darcy porous medium, Int. J. Appl. Electromag. Mech. 68 (2022), 59-84.
33- W. M. Hasona, N. H. Almalki, A. A. ElShekhipy, M. G. Ibrahim, Thermal radiation and variable electrical conductivity effects on MHD peristaltic motion of Carreau nanofluids: Radiotherapy and thermotherapy of oncology treatment, Heat Transfer—Asian Res., 48 (2019) 938-956.
34- W. Hasona, N. Al-Malki, A. A. El-Shekhipy, and M. G. Ibrahim, Combined Effects of Thermal Radiation and Magnetohydro-dynamic on Peristaltic Flow of Nanofluids: Applications to Radiotherapy and Thermotherapy of Cancer, Current NanoScience, 16(1), (2020) 121-134.
35- N. T. M. Eldabe, G. M. Moatimid, M. Abou-zeid, A. A. Elshekhipy and N. F. Abdallah, Semi-analytical treatment of Hall current effect on peristaltic flow of Jeffery nanofluid, Int. J. Appl. Electromag. Mech., 7 (2021), 47-66.
36- N. T. Eldabe, M. Y. Abou-zeid, M. A. Mohamed and M. Maged, Peristaltic flow of Herschel Bulkley nanofluid through a non-Darcy porous medium with heat transfer under slip condition, Int. J. Appl. Electromag. Mech., 66 (2021), 649-668.

37- N.T.M Eldabe, M.Y. Abou-zeid, S.M. Elshabouri, T.N. Salama, A.M. Ismael, Ohmic and viscous dissipation effects on micropolar non-Newtonian nanofluid Al2O3 flow through a non-Darcy porous media, Int. J. Appl. Electromagn., 68 209–221 (2022).

38- N. T. M. Eldabe, M. Y. Abou-zeid, A. Abosaliem, A. Alana and N. Hegazy, Homotopy perturbation approach for Ohmic dissipation and mixed convection effects on non-Newtonian nanofluid flow between two co-axial tubes with peristalsis, Int. J. Appl. Electromag. Mech. 67 (2021), 153-163.

39- A.M. Ismael, N.T.M. Eldabe, M.Y. Abou-zeid and S.M Elshabouri, Thermal micropolar and couple stresses effects on peristaltic flow of biviscosity nanofluid through a porous medium. Scientific Reports 12 (2022), 16180.

40- N. T. M. Eldabe, M. Abouzeid, H. A. Shawky, MHD Peristaltic Transport of Bingham Blood Fluid with Heat and Mass Transfer Through a Non-Uniform Channel. Journal of Advanced Research in Fluid Mechanics and Thermal Sciences, 77(2) (2020) 145–159.

41- N.T. M. Eldabe, R. R. Rizkalla, M. Abouzeid, V. M. Ayad, Thermal diffusion and diffusion thermo effects of Eyring-Powell nanofluid flow with gyrotactic microorganisms through the boundary layer, Heat Transfer-Asian Research 49(5), (2019).

42- M. Abouzeid, M. E. Ouaf, Hall currents effect on squeezing flow of non-Newtonian nanofluid through a porous medium between two parallel plates, Case Studies in Thermal Engineering 28(5) (2021) 101362.

43- N. T. Eldabe, G. M. Moatimid, M. Y. Abouzeid, A. A. ElShekhipy and N. F. Abdallah, A semianalytical technique for MHD peristalsis of pseudoplastic nanofluid with temperature-dependent viscosity: Application in drug delivery system, Heat Transfer-Asian Research 49 (2020), 424– 440.

44- N. T. M. Eldabe, G. M. Moatimid, M. Abou-zeid, A. A. Elshekhipy and N. F. Abdallah, Instantaneous thermal-diffusion and diffusion-thermo effects on Carreau nanofluid flow over a stretching porous sheet, Journal of Advanced Research in Fluid Mechanics and Thermal Sciences 72 (2020) 142-157.

45- N. T. Eldabe, S. Elshabouri, H. Elarabawy, M. Y. Abouzeid, and A. J. Abuiyada, Wall properties and Joule heating effects on MHD peristaltic transport of Bingham non-Newtonian nanofluid. Int. J. of Appl. Electromagn. Mech. 69 (2022), 87–106.

46- H. M. Mansour and M. Y. Abou-zeid, Heat and mass transfer effect on non-Newtonian fluid flow in a non-uniform vertical tube with peristalsis, Journal of Advanced Research in Fluid Mechanics and Thermal Sciences, 61(1)(2019), 44-62,

47- M.Y. Abouzeid, Chemical reaction and non-Darcian effects on MHD generalized Newtonian nanofluid motion, Egyptian Journal of Chemistry, 65(12) (2022), 647-655.

48- Eldabe, N. T., and Abouzeid, M. Y. & Ali, H. A., Effect of heat and mass transfer on Casson fluid flow between two co-axial tubes with peristalsis, J. Adv. Res. Fluid Mech. Therm. Sci. 76, 54–75 (2020).

49- Eldabe, N. T., Abou-zeid, M. Y., El-Kalaawy, O. H., Moawad, S. M. & Ahmed, O.S., Electromagnetic steady motion of Casson fluid with heat and mass transfer through porous medium past a shrinking surface. Therm. Sci. 25, 257–265 (2021).

50- Abuiyada, A. Eldabe, N. T., Abouzeid, M. Y. Elshabouri, S. Influence of both Ohmic dissipation and activation energy on peristaltic transport of Jeffery nanofluid through a porous media, CFD Letters 15, Issue 6 (2023) 65-85.

51- Abou-zeid, M. Y., Implicit homotopy perturbation method for MHD non-Newtonian nanofluid flow with Cattaneo-Christov heat flux due to parallel rotating disks. J. Nanofluids 8(8), 1648–1653 (2019).

52- Abou-Zeid, M.Y., Shaaban, A.A., Alnour, M.Y.: Numerical treatment and global error estimation of natural convective effects on gliding motion of bacteria on a power-law nanoslime through a non-Darcy porous medium. J. Porous Media. 18, (2015)

53- Abou-zeid, M. Y., Homotopy perturbation method for couple stresses effect on MHD peristaltic flow of a non-Newtonian nanofluid. Microsyst. Technol. 24(12), 4839–4846 (2018).

54- Abuiyada, A. J., Eldabe, N. T., Abou-zeid, M. Y., & El Shaboury, S. M., Effects of Thermal Diffusion and Diffusion Thermo on a Chemically Reacting MHD Peristaltic Transport of Bingham Plastic Nanofluid. J. Adv. Res. Fluid Mech. Therm. Sci. 98(2), 24–43 (2022).

55- Eldabe, N. T., Abou-zeid M.Y. & Younis, Y. M., Magnetohydrodynamic peristaltic flow of Jeffry nanofluidwith heat transfer through a porous medium in a vertical tube. Appl. Math. Inf. Sci. 11(4), 1097–1103 (2017).

56- Mohamed M. A. & Abou-zeid, M. Y., Peristaltic flow of micropolar Casson nanofluid through a porous medium between two co-axial tubes. J. Porous Media 22(9), 1079–1093 (2019).

57- Eldabe, N. T., Hassan, M. A. & Abou-zeid, M. Y., Wall properties effect on the peristaltic motion of a coupled stress fluid with heat and mass transfer through a porous media. J. Eng. Mech. 142(3), 04015102 (2016).

58- Ouaf, M. E. & Abou-zeid, M., Electromagnetic and non-Darcian effects on a micropolar non-Newtonian fluid boundary-layer flow with heat and mass transfer. Int. J. Appl. Electromagn. Mech. 66, 693-703 (2021).

59- Abdelmoneim, M., Eldabe, N.T., Abouzeid, M.Y., Ouaf, M.E.: Both modified Darcy’s law and couple stresses effects on electro-osmotic flow of non-Newtonian nanofluid with peristalsis. Int. J. Appl. Electromagn. Mech. 72(3), 253–277 (2023).

60- Abou-zeid, M. Y., Homotopy perturbation method to gliding motion of bacteria on a layer of power-law nanoslime with heat transfer. J. Comput. Theor. Nanosci. 12, 3605–3614 (2015).

61- Ouaf, M., Abouzeid, M., Ibrahim, M.G.: Effects of both variable electrical conductivity and microstructural/multiple slips on MHD flow of micropolar nanofluid. Egypt. J. Chem. 66, 449–456 (2023).

62- O. S. Ahmed, N. T. Eldabe, M. Y. Abou-zeid, O. H. El-kalaawy and S. M. Moawad, Numerical treatment and global error estimation for thermal electro-osmosis effect on non-Newtonian nanofluid flow with time periodic variations, Sci. Rep. 13 (2023) 14788.

63- Mostafa, Y., El-Dabe, N., Abou-Zeid, M., Ouaf, M., Mostapha, D.: Peristaltic Transport of Carreau Coupled Stress Nanofluid with Cattaneo-Christov Heat Flux Model Inside a Symmetric Channel. J. Adv. Res. Fluid Mech. Therm. Sci. 98(1), 1-17 (2022)

64- Eldabe, N. T., Abouzeid, M. Y. & Ahmed, O. S. Motion of a thin film of a fourth grade nanofluid with heat transfer down a vertical cylinder: Homotopy perturbation method application. J. Adv. Res. Fluid Mech. Therm. Sci., 66(2), 101-113 (2020).

65- Shaaban, A.A., Abou-Zeid, M.Y. Effects of heat and mass transfer on MHD peristaltic flow of a non-newtonian fluid through a porous medium between two co-axial cylinders, Mathematical Problems in Engineering, 819683 (2013).

66- Eldabe, N.T., Abou-Zeid, M.Y. The wall properties effect on peristaltic transport of micropolar non-newtonian fluid with heat and mass transfer, Mathematical Problems in Engineering, 808062 (2010).

67- Eldabe, N. T., Abouzeid, M. Y. Mohamed, M. A. A., Abd-Elmoneim, M. M. Peristaltic mixed convection slip flow of a Bingham nanofluid through a non-darcy porous medium in an inclined non-uniform duct with viscous dissipation and radiation. J. Appl. Nonlinear Dyn. 12, 231-243 (2023).

68- HA. Sayed and M.Y. Abouzeid, Radially varying viscosity and entropy generation effect on the Newtonian nanofluid flow between two co-axial tubes with peristalsis. Scientific Reports 13 (2023), 11013.

69- MG. brahim and M.Y. Abouzeid, Computational simulation for MHD peristaltic transport of Jeffrey fluid with density-dependent parameters. Scientific Reports 13 (2023), 9191.

70- Mohamed, Y. M., Eldabe, N. T., Abou-zeid, M. Y., Mostapha, D. R. & ouaf, M. E., Impacts of chemical reaction and electric field with Cattaneo - Christov theories on peristaltic transport of a hyperbolic micropolar nanofluid, Egyptian Journal of Chemistry, 66 (7) (2023) 63 – 85.

71- Mohamed, Y. M., Eldabe, N. T., Abou-zeid, M. Y., Ouaf, M. E. & Mostapha, D. R., Chemical reaction and thermal radiation via Cattaneo-Christov double diffusion (ccdd) effects on squeezing non-Netonian nanofluid flow between two - parallel plates, Egyptian Journal of Chemistry, 66 (3) (2023) 209 – 231.

72- F. S. Bayones, A. M. Abd-Alla and E. N. Thabet, Magnetized dissipative Soret effect on nonlinear radiative Maxwell nanofluid flow with porosity, chemical reaction and Joule heating, Waves in Random and Complex Media, DOI: 10.1080/17455030.2021.2019352.

73- A. M. Abd-Alla, S. M. Abo-Dahab, Esraa N. Thabet and M. A. Abdelhafez, Heat and mass transfer for MHD peristaltic flow in a micropolar nanofluid: mathematical model with thermophysical features, Scientific Reports 13 (2023), 21540.

74- Abou-zeid, M. Y. Homotopy perturbation method for MHD non-Newtonian nanofluid flow through a porous medium in eccentric annuli in peristalsis. Therm. Sci. 5, 2069–2080 (2017).