THERMAL FLOW OF MICROPOLAR GOLD-BLOOD NANOFLUID FLOWING THROUGH A PERMEABLE CHANNEL WITH IMPACT OF GYAROTACTIC MICROORGANISMS

by

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Presently, *the scientists across the world are carrying out the theoretical as well as the experimental examinations for describing the importance of nanofluid in the heat transfer phenomena. Such fluids can be obtained by suspending nanoparticles in base fluid. Experimentally, it has proved that the thermal characteristics of nanofluid are much better and appealing as compared to traditional fluid. The current work investigates the heat transfer for flow of blood that comprises of micropolar gold nanoparticles. A microorganism creation also affects the concentration of nanoparticles inside the channel. Suitable transformation has used to change the mathematical model to dimensionless form and then have solved by employing the homotopy analysis method. In this investigation it has revealed that, fluid's motion decays with growth in Reynolds, Darcy numbers and volumetric fraction. Thermal characteristics support by augmentation in volumetric fraction, while oppose by Prandtl number. Density of microorganism weakens by growth in Peclet and bioconvection Lewis numbers.*

Key words: *heat transfer, micropolar nanoparticles, gyrotactic microorganisms, porous channel, thermal radiation, homotopy analysis method*

Introduction

The limitations in improving the transfer of heat in engineering systems for instance, cooling of electronic and solar systems is essentially due to the slower thermal conductivity in traditional fluids like oil, ethylene glycol and water*, etc.* Choi [1] was the first gentleman who has introduced the concept of nanofluid by mixing the nanosized particles in a pure fluid. Afterwards, various researchers have conducted plenty of investigations for fluid-flowing through channels with main focus upon the augmentation of heat transfer characteristics by suspending different kinds of nanoparticles in different base fluids. Sheikholeslami and Ganji [2] have discussed the thermal flow characteristics for Cu-H_2O nanofluid-flow amid two parallel plates. Later the authors [3] have used the nanoparticles of alumina and copper-oxide in a pure fluid to further improve the thermal flow characteristics of conventional fluid. This time, the authors have employed the Brownian motion upon flow system and have evaluated the thermal and viscous forces by employing Koo-Kleinstreuer-Li correlation. Rashid *et al.* [4] have inspected the squeezing nanofluid-flow in a channel by suspending the gold nanoparticles in water. Different shapes of nanoparticles have used in this investigation. Shah *et al.* [5] have extended the work of Sirivinas *et al.* [6] by introducing micropolar gold blood nanofluid to flow system in a channel.

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The fundamental requirement to model the fluid that comprises of micro-rotational components has introduced the theory of micropolar fluid. The idea of micopolar fluid have introduced first by Eringen [7]. Afterwards, this term became an area of dynamic exploration in the field of research. This class of fluid could describe the fluid's characteristics at micro scale. In these fluids the spinning motion is described by micro-rotational vectors. Srinivasacharya *et al.* [8] have investigated the time-dependent micropolar fluid-flow amid two permeable and parallel plates. In this study, the injection flow at the top surface and periodic suction at the bottom plate has been considered by the authors. Fakour *et al.* [9] have inspected the thermal flow of micropolar fluid-flowing through a channel. Abbas *et al.* [10] have revealed thermal characteristics for micropolar nanofluid-flow between two plats using slip conditions. Baharifard *et al.* [11] studied the mass and heat transfers for MHD micropolar fluid-flow past a stirring surface with injection and suction behavior in the surface.

Recently, the exploration for laminar flow and transmission of heat through porous channels has appealed many researchers due its industrial and biological applications. These applications include the biological fluid transportation through contracting or expanding vessels, underground resources of water, and the synchronous pulsation of permeable diaphragms, *etc.* Many investigations have been conducted for heat and mass transfer between porous plates using various flow conditions. Terrill [12] has explored the thermal transmission for 2-D incompressible laminar fluid-flow amid two porous plates. It has concluded in this inspected that; the heat transfer rate has increased by suction and has declined by injection. Bharali and Borkakati [13] have investigated the MHD fluid-flow in a channel influenced by Hall current. In this study, magnetic effects has practiced to the flow system both in parallel and perpendicular directions and has highlighted that, by removing the impact of the Hall current the flow has remained unchanged even by changing the direction of applied magnetic field. Hassan [14] has analyzed the production of irreversibility for MHD fluid-flowing in a permeable channel. Islam *et al.* [15] have examined the micropolar fluid-flow amid two plates by considering different flow conditions upon flow system. The authors have used the nanoparticles of graphene oxide and copper in water as base fluid and have established that the expansion in volumetric fractions has reduced the flow characteristics and has grown up the thermal characteristics. Delhi Babu and Gunesh [16] have discussed mathematically the model for steady MHD fluid-flow amid two porous plates with revolving flow.

Since nanoparticles are not self-driven and start motion only when it is affected by thermophoresis and Brownian motion. Even in the augmentation of mass and heat transformation the high concentration of nanoparticles can affect the stability of this phenomenon. A combination of biotechnological mechanisms with nanofluids that is established by motile microorganisms can provide better results in such physical phenomenon. Gyrotactic microorganisms are actually self-driven and can gather in the closed vicinity of the top layer of fluid-flow that causes the upper surface of the fluid to be denser. The dispersal of gyrotactic microorganism in nanofluid is normally enhanced the heat transfer characteristics of fluid. Algehyne *et al*. [17] was the first gentleman who has floated the idea about the configurations in thicker culture of free spinning organisms. Anusha *et al.* [18] have examined the squeezing liquid-flow using gyrotactic microorganism amid of two opposite and parallel plates. Shahid *et al.* [19] studied the influence of magnetized Reynolds number upon motile microorganisms between circular plates filled with nanoparticles. Ahmad *et al.* [20] have inspected the nanofluid-flow influenced by microorganism through a porous plate. It has noticed in this investigation that, the heat and mass transfer rates have been augmented by considering the impact of gyrotactic microorganism. More comprehensive investigations have been conducted by [21, 22].

Form the mentioned literature and similar related studies, the authors have noticed that, large number of articles have been published to describe the flow of nanoparticles by using different geometrical shapes. However, comparatively less attention has been paid to micropolar fluid with gold-blood nanoparticles flowing through channel. Moreover, to the best of author's knowledge, no investigation so far has performed for micropolar gold-blood nanoparticles flowing through porous channel with the effects of gyrotactic microorganisms. For augmenting the heat transfer characteristics in current investigation, the thermal radiations have also applied to the flow system. Homotropy analysis method (HAM) [23, 24] has used to find the solution of modeled equations.

Problem formulation

Take a steady 2-D incompressible laminar flow of micropolar nanofluid amid two permeable plates. The base fluid is taken as blood with gold nanoparticles hanged in in it. The influence of thermal radiation exists in the channel with static or moving walls. Moreover, the fluid-flow is also influenced by the presence of gyrotactic microorganism. The geometrical view with conditions at the boundaries is presented in fig. 1. The fluid is flowing in $\hat{x}$-direction while $\hat{y}$-axis is normal to the channel's walls. The walls of the channel apart by a distance H, L is the axial length while, W is the width of the channel walls. The suction and injection of flow at the walls of the channel is fixed and unvarying. Moreover, the body forces such as gravity, Coriolis, centrifugal force and magnetic effects are ignored. At the walls the axial velocities are assumed to be linear with mathematical description:

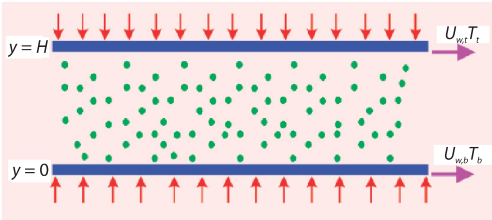

Figure 1. Geometrical view of the flow problem

$$u_{w,t} = u_t\left(\frac{\hat{x}}{H}\right),\quad u_{w,\mathrm{b}} = u_b\left(\frac{\hat{x}}{H}\right)$$

By using the suppositions, the problem can be described mathematically [6, 25-28]:

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

$$\frac{\rho_{\mathrm{nf}}}{\varepsilon}\left(\hat{u}\frac{\partial \hat{u}}{\partial \hat{x}} + \hat{v}\frac{\partial \hat{u}}{\partial \hat{y}}\right) = -\frac{\partial \hat{p}}{\partial \hat{x}} + \left(\mu_{\mathrm{nf}} + \hat{k}\right)\left(\frac{\partial^2 \hat{u}}{\partial \hat{x}^2} + \frac{\partial^2 \hat{u}}{\partial \hat{y}^2}\right) + \hat{k}\frac{\partial N}{\partial \hat{y}} - \frac{\mu_{nf}}{k_1}\hat{u} \tag{2}$$

$$\frac{\rho_{\mathrm{nf}}}{\varepsilon}\left(\hat{u}\frac{\partial \hat{v}}{\partial \hat{x}} + \hat{v}\frac{\partial \hat{v}}{\partial \hat{y}}\right) = -\frac{\partial \hat{p}}{\partial \hat{y}} + \left(\mu_{\mathrm{nf}} + \hat{k}\right)\left(\frac{\partial^2 \hat{v}}{\partial \hat{x}^2} + \frac{\partial^2 \hat{v}}{\partial \hat{y}^2}\right) - \hat{k}\frac{\partial N}{\partial \hat{x}} - \frac{\mu_{nf}}{k_1}\hat{v} \tag{3}$$

$$\rho_{\mathrm{nf}}\, j\left(\hat{u}\frac{\partial N}{\partial \hat{x}} + \hat{v}\frac{\partial N}{\partial \hat{y}}\right) = -k\left(2N + \frac{\partial \hat{u}}{\partial \hat{y}} - \frac{\partial \hat{v}}{\partial \hat{x}}\right) + \gamma_{\mathrm{nf}}\left(\frac{\partial^2 N}{\partial \hat{x}^2} + \frac{\partial^2 N}{\partial \hat{y}^2}\right) \tag{4}$$

$$\hat{u}\frac{\partial T}{\partial \hat{x}} + \hat{v}\frac{\partial T}{\partial \hat{y}} = \frac{k_{\mathrm{nf}}}{\left(\rho C_p\right)_{\mathrm{nf}}}\left(\frac{\partial^2 T}{\partial \hat{x}^2} + \frac{\partial^2 T}{\partial \hat{y}^2}\right) - \frac{1}{\left(\rho C_p\right)_{\mathrm{nf}}}\frac{\partial q_r}{\partial \hat{y}} \tag{5}$$

$$\hat{u}\frac{\partial n}{\partial \hat{x}}+\hat{v}\frac{\partial n}{\partial \hat{y}}+\left(\frac{bW_c}{C_b-C_t}\right)\frac{\partial}{\partial \hat{y}}\left(n\frac{\partial C}{\partial \hat{y}}\right)=D_m\frac{\partial^2 n}{\partial \hat{y}^2} \tag{6}$$

where the flow along $\hat{x}$, $\hat{y}$-axes are, respectively denoted by the components $\hat{u}$, $\hat{v}$, $\hat{p}$ is the pressure, $\mu_{\rm nf}$, $\rho_{\rm nf}$ are dynamic viscosity and density of nanofluid, k_1 – the permeability, ε – the porosity of walls, q_r – the heat flux due to radiation, $\rho(C_p)_{\rm f}$ – the effective heat capacity, $k_{\rm nf}$ – the thermal conductivity, D_m – the diffusion coefficients for microorganism, respectively, T_b,n_b are temperature and microorganism at the bottom plate of channel, while T_t, n_t are the corresponding quantities at the top plate of channel, $\gamma_{\rm nf}$ is the spine gradient viscosity which is mathematically expressed as $\gamma_{\rm nf} = (\mu_{\rm nf}+ \hat{k}/2)j$ with j as the density of micro-inertia. Moreover, $W_{\rm c}$ is speed of microorganism cells.

The related conditions at boundaries:

$$\begin{aligned}
&u(\hat{x},\hat{y})=u_b\frac{x}{H},\ v(\hat{x},\ \hat{y})=v_b,\ T=T_b,\ n=n_b,\ N=-k\frac{\partial \hat{u}}{\partial \hat{y}}\ \text{ at }\ \hat{y}=0\\
&u(\hat{x},\hat{y})=u_t\frac{x}{H},\ v(\hat{x},\ \hat{y})=v_t,\ T=T_t,\ n=n_t,\ N=-k\frac{\partial \hat{u}}{\partial \hat{y}}\ \text{ at }\ \hat{y}=H
\end{aligned} \tag{7}$$

where the subscript notations b, t are used to represent the bottom and top plates of the channel. The velocities at bottom and top walls are, respectively denoted by v_t, v_b. It is to be noticed that these are different velocities so due to the difference in their directions various combination can arise. For instance, the combination $v_b > 0$, $v_t < 0$ leads to injection at the bottom and top walls. Similarly the combination $v_b < 0$, $v_t > 0$ confirms the suction at these walls [29]. The thermophysical characteristics of gold-nanoparticles are described [6, 30, 31]:

$$\begin{gathered}
\rho_{\rm nf}=(1-\varphi)\rho_f+\varphi\rho_s,\ \mu_{\rm nf}=\frac{\mu_f}{(1-\varphi)^{2.5}},\ \left(\rho C_p\right)_{\rm nf}=(1-\varphi)\left(\rho C_p\right)_{\rm f}+\varphi\left(\rho C_p\right)_{\rm s}\\
\frac{k_{\rm nf}}{k_{\rm f}}=\frac{k_s+2k_{\rm f}-2\varphi\left(k_{\rm f}-k_{\rm s}\right)}{k_s+2k_{\rm f}+\varphi\left(k_{\rm f}-k_{\rm s}\right)}
\end{gathered} \tag{8}$$

where $\rho_{\rm f}$, $k_{\rm f}$, $\rho(C_p)_{\rm f}$ are the notations for density, thermal conductivity and heat capacity for base fluid while, $\rho_{\rm s}$, $k_{\rm s}$, $\rho(C_p)_{\rm s}$ are the corresponding notations for nanofluid. Moreover, $\mu_{\rm f}$ is the viscosity of pure fluid while the volumetric fraction of gold-nanoparticles is φ. The thermophysical characteristics of base and nanofluid are described numerically in tab. 1 [6, 25].

Table 1. Thermophysical properties of base fluid and nanoparticles

Material	Density [kgm^{-3}]	Specific Heat [Jkg^{-1}K^{-1}]	Thermal Conductivity [Wm^{-1}K^{-1}]
Blood	1050	3617	0.52
Gold	19300	129	318

For simplification of q_r using the Rosseland approximation [25, 32]:

$$q_r=-\frac{4}{3}\left(\frac{\sigma^*\partial T^4}{\kappa^*\partial \hat{y}}\right) \tag{9}$$

where σ^*, κ^* are termed as Stefan Boltzmann constant and the coefficient of Rosseland mean absorption such that $\sigma^* = 5.6697 \cdot 10^{-8}$ W/m^{2}K^4. If the thermal gradient is sufficiently small within the flow of fluid then T^4 can be simplified by using Taylor's expansion [32]:

$$T^4 \cong 4TT_t^3 - T_t^4 \tag{10}$$

In light of eqs. (9) and (10) we have from eq. (5):

$$\hat{u}\frac{\partial T}{\partial \hat{x}} + \hat{v}\frac{\partial T}{\partial \hat{y}} = \frac{k_{\text{nf}}}{\left(\rho C_p\right)_{\text{nf}}}\left(\frac{\partial^2 T}{\partial \hat{x}^2} + \frac{\partial^2 T}{\partial \hat{y}^2}\right) + \frac{1}{\left(\rho C_p\right)_{\text{nf}}}\left(\frac{16\sigma^* T_t^3}{3\kappa^*}\frac{\partial^2 T}{\partial \hat{y}^2}\right) \tag{11}$$

The set of variables [5, 6, 21] will convert the leading equations into dimensionless form:

$$\begin{gathered} x = \frac{\hat{x}}{H},\ P = \frac{\hat{p}}{\rho_f {v_b}^2},\ u = \frac{\hat{u}}{v_b},\ v = \frac{\hat{v}}{v_b},\ \theta(\eta) = \frac{T - T_t}{T_b - T_t} \\ \phi(\eta) = \frac{C - C_t}{C_b - C_t},\ \chi(\eta) = \frac{n - n_t}{n_b - n_t},\ N = -\frac{x v_b G(\eta)}{H} \ \text{ with } \ \eta = \frac{y}{H} \end{gathered} \tag{12}$$

The dimensionless velocity components are assumed:

$$u(x,\eta) = x f'(\eta),\ v(x,\eta) = -f(\eta) \tag{13}$$

By incorporating eqs. (12) and (13) into eqs. (1)-(4), (6), and (11) we have:

$$\left(1 + (1-\varphi)^{2.5} K\right) f^{(iv)} - (1-\varphi)^{2.5} K G'' - \left(1 - \varphi + \varphi\frac{\rho_{\text{s}}}{\rho_{\text{f}}}\right)(1-\varphi)^{2.5}\,\text{Re}\left(f' f'' - f f'''\right) - \frac{1}{\text{Da}} f'' = 0 \tag{14}$$

$$\left[1 + (1-\varphi)^{2.5}\frac{K}{2}\right] G'' + K(1-\varphi)^{2.5}\left(f'' - 2G\right) + \text{Re}\left(1 - \varphi + \frac{\rho_{\text{s}}}{\rho_{\text{f}}}\varphi\right)(1-\varphi)^{2.5}\left(f G' - f' G\right) = 0 \tag{15}$$

$$\left(\frac{k_{\text{nf}}}{k_{\text{f}}} + \frac{4}{3}R_d\right)\theta'' + \left(1 - \varphi + \frac{\left(\rho C_p\right)_{\text{s}}}{\left(\rho C_p\right)_{\text{f}}}\right)\text{Pr}\,\text{Re}\,\theta' f = 0 \tag{16}$$

$$\chi'' - \text{Re}\,L_b f \chi' + \text{Pe}\left[\chi'\phi' + (\delta + \chi)\phi''\right] = 0 \tag{17}$$

where $\text{Re} = v_b H/\nu_\text{f}$ is the Reynolds number, $\text{Da} = k/H^2$ – the Darcy number, $\text{Pr} = (\rho C_p)_\text{f}\,\nu_\text{f}/k_\text{f}$ – the Prandtl number, $K = k/\mu_\text{f}$ – the material parameter, $R_d = 4\sigma^* T_t^3/3\kappa^* k_\text{f}$ – the radiation parameter, $\Omega = T_b - T_t/T_t$ – the temperature parameter, $\text{Sc} = \nu_\text{f}/\text{DB}$ – the Schmidt number, $L_b = \nu_\text{f}/D_m$ – the bioconvection Lewis number, $\text{Pe} = bW_c/D_m$ – the Peclet number, and $\delta = n_t/n_b - n_t$ – the microorganism concentration difference parameter.

Related conditions at boundaries:

$$\begin{gathered} f'(0) = \lambda,\ f(0) = -\alpha,\ f'(1) = \gamma,\ f(1) = -\beta,\ \theta(0) = 1,\ \theta(1) = 0 \\ \chi(0) = 1,\ \chi(1) = 0,\ G(0) = kf''(0),\ G(1) = kf''(1) \end{gathered} \tag{18}$$

where

$$\beta = \frac{v_t}{v_b},\ \lambda = \frac{u_b}{v_b},\ \gamma = \frac{u_t}{v_b},\ \alpha = \begin{cases} 1, & \text{for injection} \\ -1, & \text{for suction} \end{cases} \tag{19}$$

Engineering quantities of interest

Different quantities of engineering interest for flow system under consideration can be expressed mathematically:

$$C_f = \frac{2}{\rho_\mathrm{f}\hat{u}^2}\left(\mu_\mathrm{nf} + \hat{k}\right)\frac{\partial \hat{u}}{\partial \hat{y}}\bigg|_{y=0}, \quad \mathrm{Nu} = \frac{x}{k_\mathrm{f}\left(T_b - T_t\right)}\left(k_\mathrm{nf} + \frac{16\sigma^* T_t^3}{3k^*}\right)\frac{\partial T}{\partial y}\bigg|_{y=0}$$
$$Nn = \frac{x}{D_m\left(n_b - n_t\right)}\left\{-D_m \frac{\partial n}{\partial y}\bigg|_{y=0}\right\} \tag{20}$$

Substituting eq. (7) in eq. (20) we have the dimensionless quantities:

$$C_f = \left[\left(1-\varphi\right)^{2.5} + K\right] f''(0), \quad \mathrm{Nu} = \frac{k_\mathrm{nf}}{k_\mathrm{f}}\left(1 + \frac{4}{3}R_d\right)\theta'(0), \quad Nn = -\chi'(0) \tag{21}$$

Discussion of results

The current work examines the flow and heat transfer for flow of blood that comprises of micropolar gold nanoparticles. A microorganism creation also affects the concentration of nanoparticles inside the channel. Suitable transformation has used to change the mathematical model to dimensionless form and then has solved by employing the homotopy analysis method. The impact upon different profiles of flow system in response of variations in physical parameter has comprehended.

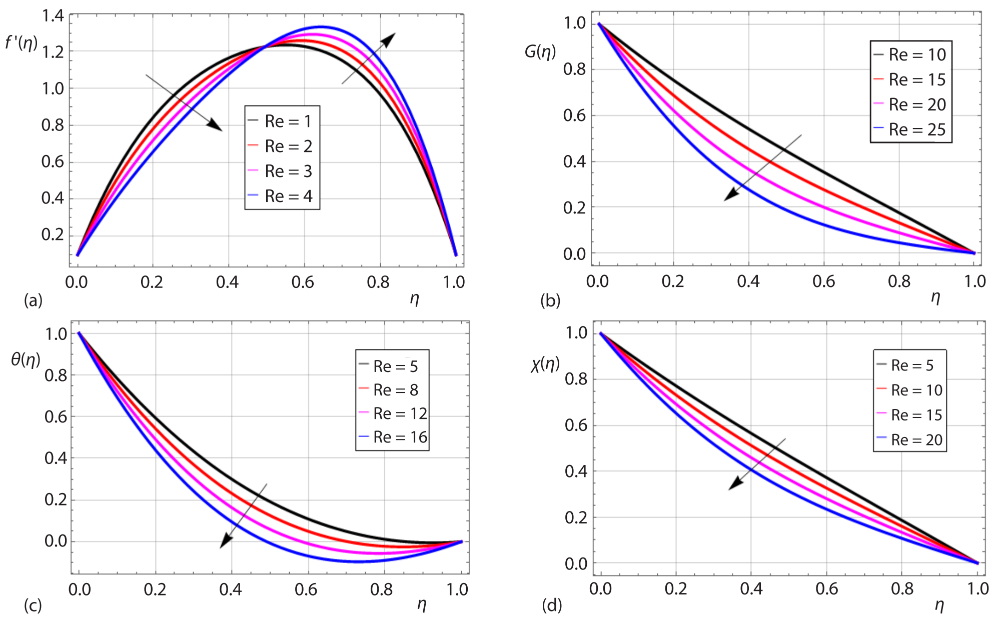

Figure 2. Impact of Re on; (a) $f'(\eta)$, (b) $G(\eta)$, (c) $\theta(\eta)$, and (d) $\chi(\eta)$

Figure 2 depicts the influence of Reynolds number upon different profiles of flow system. Since Reynolds number signifies the comparison of inertial force to viscous force, so augmentation in Reynolds numbe causes a domination of inertial to viscous force. This physical phenomenon declines the rotational flow, thermal characteristics and motility of micropolar nanoparticles. In case of linear velocity the flow behavior is two folded over the range $0 \le \eta \le 1$. The flow is declining on the range $0 \le \eta \le 0.5$ where as it is augmenting upon the range $0.5 \le \eta \le 1$.

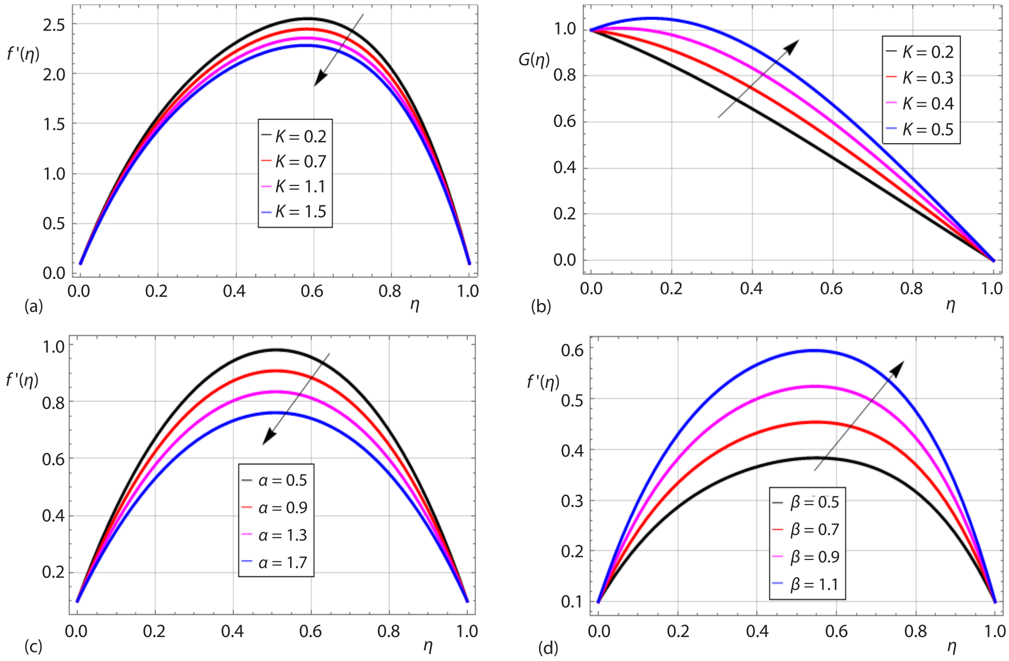

Figure 3. Impact of K on $f'(\eta)$ (a), K on $G(\eta)$ (b), α on $f'(\eta)$, (c) and β on $f'(\eta)$ (d)

Figure 3 describes the changing behavior of fluid's motion for variation in the values of material parameter K. From fig. 3(a) it has perceived that fluid's motion declines in closed locality of porous plate with augmentation in K due to a domination of vertex viscosity to dynamic viscosity. In this physical process the rotational effects enhanced in the fluid particles that causes an augmentation in microrotation flow of nanofluid as depicted in fig. 3(b). It has also noticed that the flow profiles have declined with augmentation in the suction parameter as depicted in fig. 3(c). Moreover, augmenting values of injection parameter has supported the velocity as depicted in fig. 3(d).

Figure 4 depicts the impact of volumetric fraction ϕ upon flow, microrotational flow and thermal profiles of micropolar nanofluid. Since the augmenting values of ϕ causes an enhancement in the viscous forces amongst the fluid nanoparticles due to which the fluid become more dense and viscous. During this process higher resistance is experienced by micropolar nanoparticles that decline the fluid-flow in all direction as shown in figs. 4(a) and 4(b) while augments the thermal profiles of micropolar nanofluid as depicted in fig. 4(c).

Figure 5 portrays that augmenting values in Darcy number, decays the flow profiles. Actually, the void spaces in the porous plates are augmenting with growing values of Darcy number that offer more confrontation the fluid's flow and decline the flow profile.

Figure 6 depicts the impact of Prandtl number and radiation parameter, R_d, upon thermal profiles. Figure 6(a) reveals a significant decline in thermal profiles. Actually, Prandtl number is inversely proportional to heat diffusion due to which the thermal profiles decline for augmenting values o Prandtl number. Figure 6(b) shows that for enhancing values of R_d more heat transfer takes place that augments the thermal profiles.

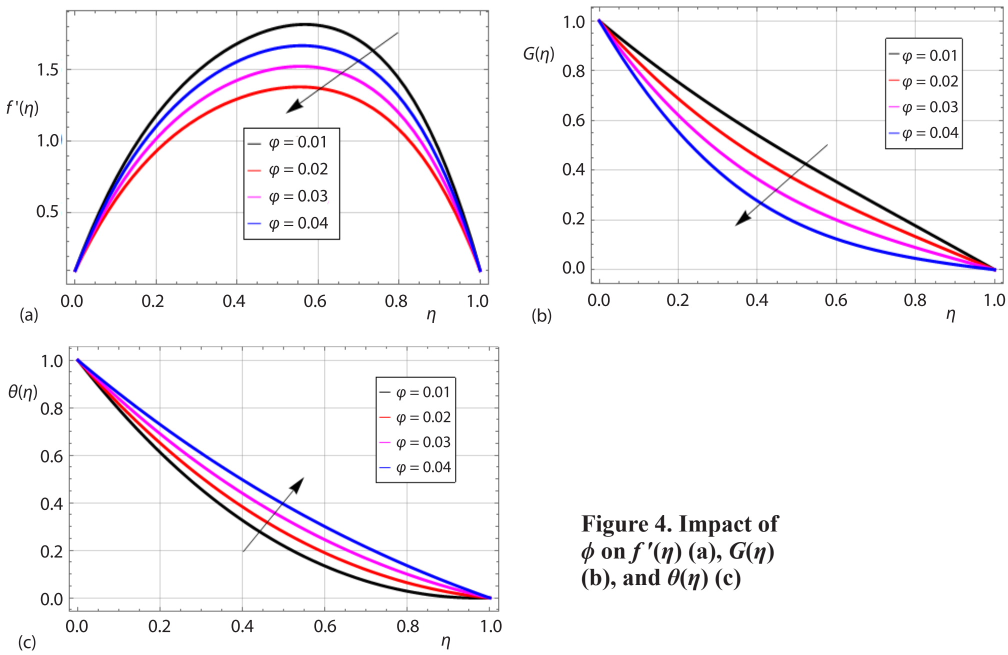

Figure 4. Impact of ϕ on $f'(\eta)$ (a), $G(\eta)$ (b), and $\theta(\eta)$ (c)

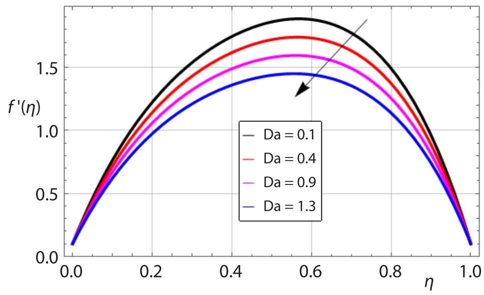

Figure 5. Impact of Da on $f'(\eta)$

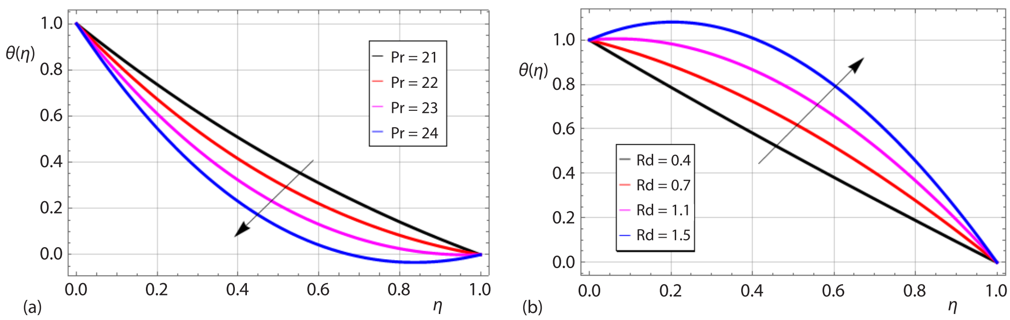

Figure 6. Impact of Pr on $\theta(\eta)$ (a) and Rd on $\theta(\eta)$ (b)

Figure 7 depicts the effects of Peclet and L_b upon density number of motile microorganism. It has noticed from these figures that the growth in Peclet and L_b causes a decline in the spread of microorganism that weakens the strength of its boundary-layer. Hence the growing values of Peclet and L_b decline the density number of microorganism.

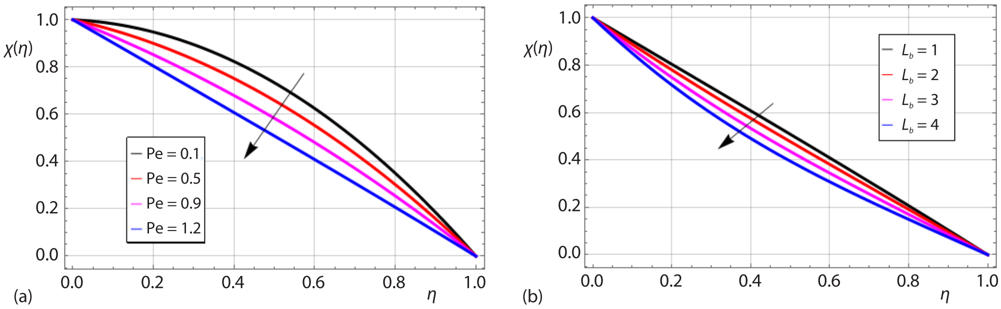

Figure 7. Impact of Pe on $\chi(\eta)$ (a) and L_b on $\chi(\eta)$ (b)

Tables discussion

The influence upon various physical quantities in response of different emerging parameters has been presented numerically in tabs. 2 and 3. The numerical results of velocity gradient C_f against different emerging parameter are deliberated in tab. 2. One can find that velocity gradient upsurges for particle concentration φ, Reynolds number, and Darcy number. Prominent performances of various engineering parameters on Nusselt number, is examined in tab. 3. As expected, the Nusselt number is augmented for expansion in radiation parameter R_d.

Table 2. Skin friction, C_f, variations for different values of φ, K, Re, and Da

φ	K	Re	Da	$f'(1)$	$f'(0)$
0.02	0.3	1	0.5	6.1963	–0.15248
0.04				6.98229	–0.21329
0.06				7.87492	–0.27577
	0.3			6.19630	–0.15248
	0.4			5.94500	–0.13451
	0.5			5.14270	–0.08936
		1		6.19630	–0.15248
		3		6.71085	–0.210436
		5		7.30327	–0.295691
			0.5	6.19630	–0.152480
			1	6.49150	–0.249460
			1.5	6.97020	–0.305632

Table 3. Nusselt number for variations in R_d

R_d	$\theta'(1)$	$\theta'(0)$
0.5	5.29822	–0.73111
	6.06530	–0.80198
	6.28720	–0.84279
	5.29822	–0.73111
	6.10851	–0.74766
	6.33041	–0.78847
0.35	5.29822	–0.73111
1	6.07098	–0.70144
1.5	6.29288	–0.74225

Conclusions

In this investigation the flow and heat transfer for flow of blood that comprises of micropolar gold nanoparticles. A microorganism creation also affects the concentration of nanoparticles inside the channel. The impact upon different profiles of flow system in response of variations in physical parameter has been discussed graphically. After detail inspection of the work some main pontes have been noted and appended are as follows.

- Reynolds number reduces all the profiles of flow system.

- The augmentation in material parameter and Darcy number declines the flow of fluid and upsurges the microrotation velocity of nanoparticles.
- The augmenting values of volumetric fraction causes an enhancement in viscous forces amongst the fluid nanoparticles and causes a reduction in flow of fluid in all direction while supports the thermal profiles.
- Thermal profiles are growing up with augmenting values of radiation parameter and decline by enhancement in Prandtl number.
- An augmentation in Bioconvection Lewis number and Peclet number opposes the growth in motile microorganism.

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Data availability statement

The data that support the findings of this study are available upon reasonable request from the authors.

Conflict of interest

The authors declare that they have no conflict of interest.

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