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NANOFLUID FLOW IN PRESENCE OF GYROTACTIC MICROORGANISMS ON THE STRETCHING SURFACE WITH MAGNETIC FIELD AND ACTIVATION ENERGY

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ABSTRACT

In this paper, reaction of magnetic field and activation energy is applied on nanoparticles and swimming gyrotactic microorganisms under the viscous dissipation is inspecting. The effect of thermophoresis and Brownian motion is also considered. The PDEs are naturalized into ODEs by using similarity transformations. To solving the PDEs by using RK-Fehlberg with shooting approach by MATLAB software. The effect of magnetic parameter, Schmidt number, Prandtl number, Brownian motion, thermophoresis, Peclet number, porosity parameter, on velocity, temperature, concentration, motile microorganism density portrait is in detailed it is discussed and the eventualities are demonstrated in graphs. The effects of these factors on Nusselt number, skin friction coefficient, Sherwood number and density number of motile microorganisms are concluded using tabular form.

Keywords: *Thermophoresis, Prandtl number, Eckert number and heat and mass transfer*

1. INTRODUCTION

Nanofluids has better thermal conductivity as like as normal fluids. So many researchers explained nanofluid flow under the different presumptions. A creature that can only be observed under a microscope. Algae, fungi, bacteria, and protozoa are examples of microorganisms. These types of fluids have a plenty of useful applications in heat transfer, electronic cooling, the transportation industry, bio-medical devices, and spacecraft equipment. This investigation looked at the appearance of partial slides on the disc surface. Salahuddin et al. (2022) examined under the influence of varying thickness and slip circumstances, the hybrid nanofluid's flow moved through a stretchy hot cylindrical wave at a 3D stagnation point. Bilal et al. (2021), investigated Carbon nanotubes (CNTs) and ferric oxide water-based hybrid nanofluid flow created by a wavy fluctuating spinning disc with energy propagation is numerically simulated. The nanofluid is created in the power of carbon nanotubes and magnetic nanoparticles Nano particles of iron with carbon nanotubes have been intensively studied for their extraordinary Electrical and thermal conductivity, flexibility, and tensile strength. The goal of the suggested analysis is to improve the efficiency of transport of heat energy for many industrial and medicinal purposes. The incidents are explained by a number of partial differential equations (PDEs) that include equations for momentum, energy, concentration, and motile microorganisms.

Muthuku et al. (2014) introduce the sake of introducing motile microorganisms into the nanoparticle suspension was present improved nanofluid consistency, microscale fraternization, greater mass transmission, and application in micro volumes. Khan W. A (2014) Many bio microsystems, such as nanochips, can use nanofluids with bacteria to test toxicity and cellulose optimization. Nanofluids with microorganisms are also useful micro volumes are used in enzyme biosensors and microfluidics and micro mixers mechanized. Our discoveries could help improve the performance of microbial fuel cells. Gyrotactic microorganisms can additionally increase the flow's nanofluids stability. The effects of gyrotactic organisms on nanofluid flows have been extensively researched. Heat and mass transmission gyrotactic creatures and nanoparticles in the flow were investigated by Ramzan et al. (2017). The flow of nanofluids containing gyrotactic microorganism was studied in an experiment., Chakraborty et al. (2018) noticed by raising the magnetic field factor, temperature transit area, reduced flow of motile bacteria through the fluid media and lowered boundary layer thickness, while nanoparticle absorption enhanced. Tausif et al. (2016) described the movement of nanofluid with motile microorganisms and nanoparticles and several slipstream effects. To achieve critical outcomes in the polymer sector, the values of a number of slip parameters were increased, allowing fluid qualities such as microbe, rate of mass and flux or rate of heat transfer to be reduced or improved. Iqbal et al. (2017) nanofluid flowing steadily in two dimensions. with nanoparticles and gyrotactic bacteria was examined. This study includes the flow of a discursively striking nanofluid at its stagnation point. Atif et al. (2019) the density of motile microorganisms was raised by buoyancy ratio parameters but declined by micro polar parameters, according to the research. Atashafrooz, M., et al (2021) discussed Three-dimensional analysis of entropy generation for forced convection over an inclined step with presence of solid nanoparticles and magnetic force. Atashafrooz, M. et al investigate (2020) "Interacting influences of Lorentz force and bleeding on the hydrothermal behaviours of nanofluid flow in a trapezoidal recess with the second law of thermodynamics analysis. Atashafrooz, M., (2020) studied Influence of radiative heat transfer on the thermal characteristics of nanofluid flow over an inclined step in the presence of an axial magnetic field. Atashafrooz, M., (2019) invented the

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effects of buoyancy force on mixed convection heat transfer of MHD nanofluid flow and entropy generation in an inclined duct with separation considering Brownian motion effects. Atashafrooz, M.,(2019), Interaction effects of an inclined magnetic field and nanofluid on forced convection heat transfer and flow irreversibility in a duct with an abrupt contraction. They took into account the thermal radiation and Joule heating effects. The effect of rising microbe density by cause of Peclet and Lewis numbers was examined by Acharya et al. (2016). The Keller box method was used to investigate the numeral solutions, which revealed that as the Peclet number increased, the concentration of microorganisms decreased. Shaw et al. (2018) nonlinear differential equations must be solved representing the movement of gyrotactic motile creatures and nanofluid, researchers used a spectrum relaxation technique. This bio convection flow was studied using a spherical submerged in a permeable material. Kuznetsov (2012) revealed the unpredictability of both non-oscillatory and oscillatory circumstances for nanofluid flows, with creatures that are oxytactic resulting in density stratification due to creatures with oxytactic motion or nanoparticle disposal.

Vijaya N. et al (2020) in this work, Arrhenius activation energy, viscous dissipation, and joule heating are taken into consideration as we examine the improvements in electrically conducting Casson fluid generated by a porous elongated surface. Vijaya N. et al, (2020) the current study intends to examine the characteristics of thermophoresis and Brownian motion-induced heat and mass transport processes in a liquid thin film of Casson Nano fluid across an extended sheet. In the current study, first-order chemical reaction, radiation, a continuous heat source, and an oscillating vertical wall embedded in a porous media are used to study the thermophysical properties of a Casson fluid. Vijaya N.et al (2018) discussed. Radha Madhavi, M., numerically examined how radiative and viscous dissipation affect an incompressible viscous MHD hydro nanofluid flow of an upright plate in (2021). P. S. S. Naga Lakshmi, (2022) discussed about entropy generation in Bingham Nanofluid flow with carbon nanotubes. Thermophoresis, joule heating, and Soret & Dufour effects' impacts on mixed convective Jeffery fluid flow across an extended sheet in discussed Radha Madhavi. M., Ganesh, G. R., Sridhar W. (2020) are investigating an exponentially permeable stretched sheet with chemical reaction and hall effect is used in a numerical technique to study the heat and mass transfer of MHD Casson fluid under radiation. Sridhar W. (2021) discussed on an extending upward sheet contained in a porous medium, mixed convection boundary layer flow of MHD Casson fluid with slip effects. Dharmaiah G., et al. in (2020) present Magneto-titanium alloy nano liquid Hall and ion slip impact with diffusion, thermodynamics, and radiation absorption. Raghavendra G Ganesh et al. (2022) invented Casson nanofluid flow and entropy exploration under the influence of the viscous dissipation, radiation, and higher-order chemical reaction. Dharmaiah, G et al, (2018) discussed a vertical plate with a radiative and impulsive surface is passed by a nanofluid in MHD boundary layer flow, transferring heat. Vedavathi, N. (2019) et al are investigates an investigation of rotating frame nanofluids with MHD boundary layers and chemical reactions. Sohail Ahmad et.al., (2022) in this study investigates Impact of Swimming Gyrotactic Microorganisms on Nanoparticles flow through a Porous Media. Sheikholeslami, M., Sajjadi, H., et al (2019) studied “Magnetic force and radiation influences on nanofluid transportation through a permeable media considering Al2O3 nanoparticles. Sajjadi, H., Amiri Delouei, A., etal., (2019) explained Simulation of three dimensional MHD natural convection using double MRT Lattice Boltzmann method. Atashafrooz, M., et al, (2018) invented Effects of Ag-water nanofluid on hydrodynamics and thermal behaviours of three-dimensional separated step flow. Sajjadi, H., et al., (2018) investigated Double MRT Lattice Boltzmann simulation of 3-D MHD natural convection in a cubic cavity with sinusoidal temperature distribution utilizing nanofluid. Govindaraj, N., (2020) investigated Fluid flow and heat transfer over a stretching sheet with temperature dependent Prandtl number and viscosity. Kranthi Kumar, K., (2021), refers MHD Casson fluid flow with an inclined Plate in the presence of Hall and aligned magnetic effects. Mira Das, et al(2021) is studied Unsteady MHD rotating and chemically reacting fluid flow over an oscillating vertical surface in a Darcian porous regime.

The major objective of this study to explore nanofluid flow in the presence of Gyrotactic Microbes on the stretching surface. The aspects of magnetic field and activation energy are also incorporated to study these special types of flows. Graphical portrayal is depicted using the powerful bvc4c via MATLAB software.

2. PHYSICAL MODEL DESCRIPTION

In this paper the study of nanofluids and gyrotactic microorganisms through the magnetic field and activation energy. Nanoparticles volume fractions are 1% more efficient than microorganisms. Motion of microorganisms are interrupted by nanoparticles. Solid nanoparticles mixed together, and microorganisms is prefix to the general fluid to achieve the appropriate bio convection stability. An atmosphere temperature, concentration of the fluid and microorganisms far from the surface of stretching sheet is revealed in the figure1. In the x-axis represents the flow direction with velocity component u. The y-axis is aligned with the sheet’s velocity components v. In the sheet was confined with the porous media take nanoparticles and gyrotactic microorganisms in it. Microorganisms moving around cause the bio convection to occur. In relation to the Nano entities, the microorganisms migrated separately.

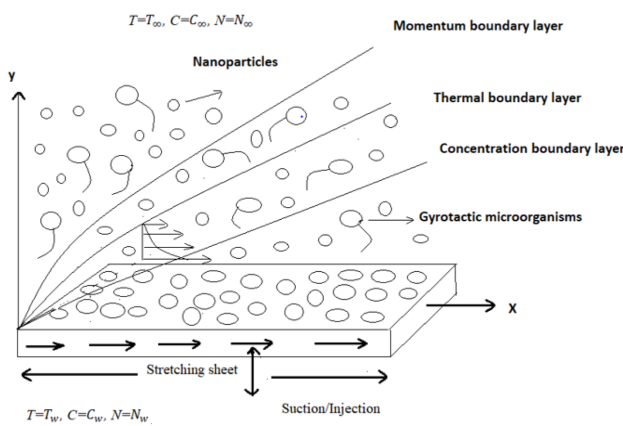

Fig. 1 Geometry of the problem

The nonlinear PDEs govern in the following, may be composed in Shahid, A., (2018), Acharya, N., (2016), Ahmed, s., (2020):

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

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=\nu\frac{\partial^2 u}{\partial y^2}+u_e\frac{\partial u_e}{\partial x}+\frac{\mu}{\rho k^*}(u_e-u)-\frac{\sigma B_0^2}{\rho}(u_e-u) \tag{2}$$

$$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=\alpha\frac{\partial^2 T}{\partial y^2}+\frac{\mu}{\rho c_p}\left(\frac{\partial u}{\partial y}\right)^2+\frac{\tau D_T}{T_\infty}\left(\frac{\partial T}{\partial y}\right)^2+\tau D_B\frac{\partial C}{\partial y}\frac{\partial T}{\partial y} \tag{3}$$

$$u\frac{\partial C}{\partial x}+v\frac{\partial C}{\partial y}=D_B\frac{\partial^2 C}{\partial y^2}+\frac{D_T}{T_\infty}\frac{\partial^2 T}{\partial y^2}-\mathrm{k}_\mathrm{r}^2(\mathrm{C}-\mathrm{C}_\infty)\left(\frac{\mathrm{T}}{\mathrm{T}_\infty}\right)^\mathrm{n}\exp\left(\frac{-\mathrm{E_a}}{\mathrm{kT}}\right) \tag{4}$$

$$u\frac{\partial N}{\partial x}+v\frac{\partial N}{\partial y}+\frac{1}{C_w-C_\infty}\frac{\partial}{\partial y}\left[N\left(\frac{\partial C}{\partial y}\right)\right]bW_c=D_n\frac{\partial^2 N}{\partial y^2} \tag{5}$$

The terms involved in the above equations are $\nu,\ \alpha,\ \tau,\ D_T,\ D_B,\mathrm{T},\mathrm{T}_\infty,\mathrm{C},\mathrm{C}_\infty,bW_c,D_n,N$ are represents, kinematic viscosity, thermal conductivity, heat capacity, thermophoresis term, Brownian diffusion

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coefficient, temperature of fluid, ambient temperature, concentration of fluid, ambient concentration, cell swimming speed, diffusivity of microorganism, microorganism concentration respectively. Boundary conditions of surface far from the sheet is given as

$$y=0,\ u=cx^m,\ v=v_w(x),\ T=T_w,\ C=C_w,\ N=N_w, \tag{6}$$

$$y\to\infty,\ u=ax^m,\ T=T_\infty,\ C=C_\infty,\ N=N_\infty, \tag{7}$$

Where $u_e(x)=ax^m$, atmosphere velocity and $u_w(x)=cx^m$ is stretching velocity, where m is fixed which represents nonlinear (m>1) of stretching/shrinking sheet. Non dimensional variables are making use of (2022) to PDEs.

$$\eta=\sqrt{\frac{a}{\nu}x^{m-1}}y,\ \psi=\sqrt{\nu a x^{m+1}}f(\eta),\ \theta(\eta)=\frac{C-C_\infty}{C_w-C_\infty},$$
$$\emptyset(\eta)=\frac{T-T_\infty}{T_w-T_\infty},\ G(\eta)=\frac{N-N_\infty}{N_w-N_\infty}, \tag{8}$$

Now we describe the flow operation $\psi(x,y)$ as

$$v=-\frac{\partial\psi}{\partial x},\ u=\frac{\partial\psi}{\partial y} \tag{9}$$

By using similarity transformations (8) equations (1-5) are transformed in the following dimensionless non-linear ODEs are achieved.

$$f'''=-\frac{(m+1)}{2}ff''-(P_0+M)(1-f')+m(f'^2-1) \tag{10}$$

$$\theta''=P_r(-N_b\theta'\emptyset'-\frac{(m+1)}{2}f\theta'-E_cf''^2-N_t\theta'^2) \tag{11}$$

$$\emptyset''=-\frac{N_t}{N_b}\theta''-Le\frac{(m+1)}{2}f\theta'+Le\sigma(1+\delta\theta)^n exp\left(\frac{-E}{1+\delta\theta}\right)\emptyset \tag{12}$$

$$G''=-Sc\frac{(m+1)}{2}fG'+Pe(G'\emptyset'+(\emptyset''(G+\Omega)) \tag{13}$$

The comparable boundary circumstances (6) and (7) take the form:

$$\eta=0,\quad f=1,\ f'=\alpha,\ \emptyset=1,\ \theta=1,$$
$$\eta\to\infty,\quad f\longrightarrow 1,\ \theta\longrightarrow 0,\ \emptyset\longrightarrow 0,\ G\longrightarrow 0, \tag{14}$$

Where α is the stretching (if α > 0) or contracting (if α < 0) of surface parameter. The other common variables used in equations (10)–(13) as follows.

Where $\Omega=\frac{N_\infty}{N_w-N_\infty}$, $Le=\frac{\nu}{D_B}$, $Pe=\frac{bW_c}{D_n}$, $Ec=\frac{u_e^2}{C_p(T_w-T_\infty)}$, $N_b=\frac{\tau D_B(C_w-C_\infty)}{\nu}$, $N_t=\frac{\tau D_T(T_w-T_\infty)}{\nu T_\infty}$, $Pr=\frac{\nu}{\alpha}$, $Sc=\frac{\nu}{D_n}$, $P_o=\frac{\nu x}{k^*u_e}$, $M=\frac{\sigma B_0^2x}{\rho u_e}$, $\sigma=\frac{k_r^2x}{u_e}$, $E=\frac{E_a}{kT_\infty}$, $\delta=\frac{T_w-T_\infty}{T_\infty}$, (15)

where Ω is the motile microbes' parameter, Le is the Lewis number, Pe is the Peclet number, Ec is the Eckert number, N_b is the Brownian motion, Nt is the thermophoresis parameter, Pr is the Prandtl number, Sc is the bio convection Schmidt number, P_0 is the porosity parameter, and M is the Magnetic field, σ is chemical reaction parameter, E is activation energy parameter, δ is temperature difference additionally, dimensionless coordinates of technical interest like skin friction, Nusselt and Sherwood numbers and regional density index of motile microbes may be defined as

$$Re_x^{1/2}Cf_x=f''(0),\ Nu_xRe_x^{-1/2}=-\theta'(0),\ Sh_xRe_x^{-1/2}=-\emptyset'(0),$$
$$Nn_xRe_x^{-1/2}=-G'(0), \tag{16}$$

3. NUMERICAL SOLUTIONS

Using boundary layer theory, the PDEs (1) to (5) that regulate the flow of nanofluids issues are turned into nonlinear coupled ODEs. When it comes to boundary conditions (14), These strongly linked, ODEs. (10) to (13) are numerically solved using MATLAB's famed BVP4C solver. The BVP4C solver is based on a three-stage Lobatto IIIa collocation algorithm, with a collocation polynomial that produces a C1 continuous solution that is fourth-order accurate over the entire domain

3.1 Runge - Kutta method

Before going to apply the Runge-Kutta method, first apply the PDEs into ODEs of first order. Let us consider $x_1=\eta$, $x_2=f$, $x_3=f'$, $x_4=f''$, $x_5=\theta$, $x_6=\theta'$, $x_7=\emptyset$, $x_8=\emptyset'$, $x_9=G$, $x_{10}=G'$. Following system is obtained.

$$\begin{pmatrix} x_1' \\ x_2' \\ x_3' \\ x_4' \\ x_5' \\ x_6' \\ x_7' \\ x_8' \\ x_9' \\ x_{10}' \end{pmatrix}=\begin{pmatrix} 1 \\ x_3 \\ x_4 \\ -\frac{(m+1)}{2}x_2x_3-(P_0+M)(1-x_3)+m(x_3{}^2-1) \\ x_6 \\ P_r(-N_bx_6x_8-\frac{(m+1)}{2}x_2x_6-E_cx_4{}^2-N_tx_6{}^2) \\ x_8 \\ -\frac{N_t}{N_b}x_6'-Le\frac{(m+1)}{2}x_2x_6+Le\sigma(1+\delta x_5)^n exp\left(\frac{-E}{1+\delta\theta}\right)x_7 \\ x_{10} \\ -Sc\frac{(m+1)}{2}x_2x_{10}+Pe(x_8x_{10}+(x_8'(x_9+\Omega)) \end{pmatrix} \tag{17}$$

The boundary conditions are

$$\begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \\ x_7 \\ x_8 \\ x_9 \\ x_{10} \end{pmatrix}=\begin{pmatrix} 1 \\ \alpha \\ 1 \\ u_1 \\ 1 \\ u_2 \\ 1 \\ u_3 \\ 1 \\ u_4 \end{pmatrix} \tag{18}$$

By using Runge-Kutta method equations (17) and (18) are solved. Appropriate initial circumstances u_1, u_2, u_3 and u_4 are estimated using the Newton's technique until the boundary conditions at $f'(\infty)=1$, $\theta(\infty)=0$, $\emptyset(\infty)=0$, $G(\infty)=0$.

4. RESULTS AND DISCUSSIONS

In this paper propose that, the effect of activation energy on nanoparticles through the porous media. With the help of physical representations numerical results are explore. The system of equations from (10 – 13) by using the boundary conditions (14). The velocity, temperature, concentration, motile microbe's density distributions, and heat and mass transfer allocations can be analyzed by using a number of estimates parameters, in Fig. (2) - (20) and table.

M=2, m=1, P_0=0.5, Pr=3.2, $N_b=0.5$, N_t=0.5, Ec=0.5, Le=1, n=0.1, E=2, δ=0.1, $\sigma=1$, Ω=1, Sc=1, Pe=0.3.

In Fig. 2 the velocity profiles are increase if upgrading the values of M. Magnetic field produces Lorentz force opposes nanofluid velocity results decreases in the thickness boundary layer, but it is increases it formed contradictory because of the nature of the greater strength of the fluid. The velocity profiles in porous term are depicted in Fig. 3, elevating the values of porosity parameters the velocity profiles are increased. Because the porous media has little impact on heat or mass transport. the region is the size of the microorganisms is larger than the size of pore size of the medium, so the moment of the microorganisms are not affected by the porous media having small permeability.

When the porosity of the medium is increased, it offers superior solutions for bio convection parameters than when the porosity is decreased. It's worth noting that when porosity is high, the density of microorganisms is more stable. The values of Positive constant for nonlinear stretching sheet m are increased the velocity depictions are enhanced it is depicted in Fig. 4, the temperature, the concentration and the motile microbe's density distributions are decreased depicts in Fig. 5, Fig. 14 and Fig. 19 respectively. Fig. 6 illustrates if the values of Prandtl number increases profiles of temperature is decline. By the definition of Pr raising the values of Pr results in either a larger momentum diffusivity or a lower thermal diffusivity, which reduces the thickness of the thermal layer. The temperature profiles are increasing for escalates the values of Ec. It is shown in Fig. 7. The heat transfer is more in the fluid as the values of the Eckert number raises. This event alters the thickness of the boundary layer and raises the temperature.

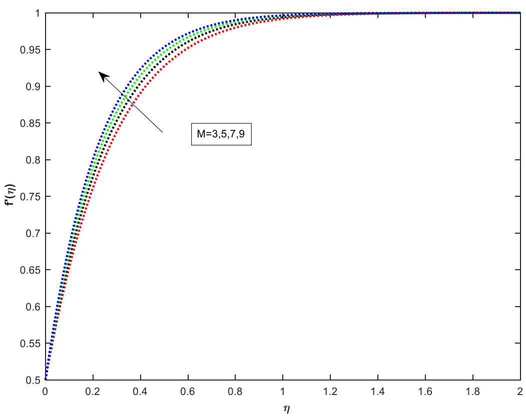

Fig. 2 $f'(\eta)$ for several variations in M

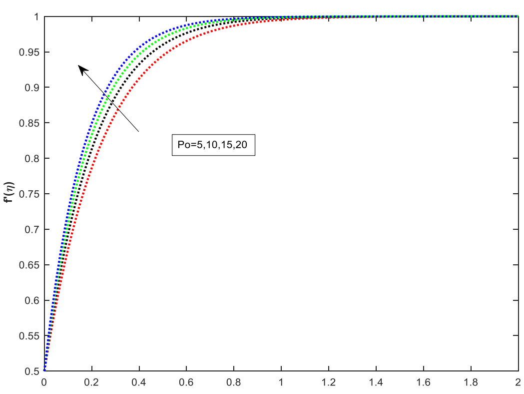

Fig. 3 $f'(\eta)$ for several variations in P_0

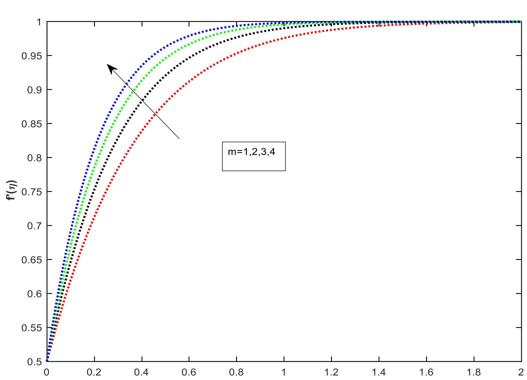

Fig. 4 $f'(\eta)$ for several variations in m

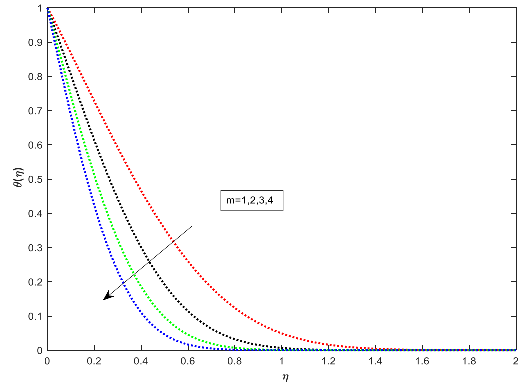

Fig. 5 $\theta(\eta)$ for several variations in m

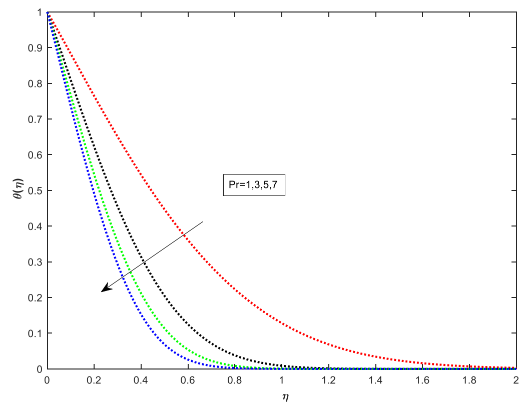

Fig. 6 $\theta(\eta)$ for several variations in Pr

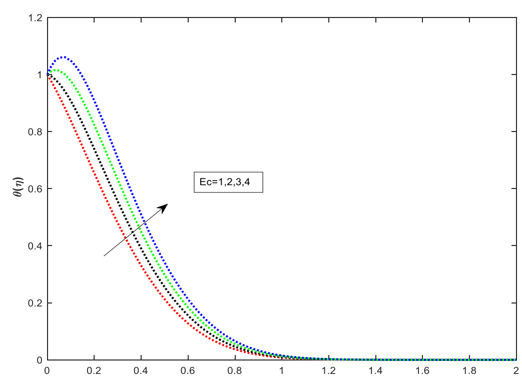

Fig. 7 $\theta(\eta)$ for several variations in Ec

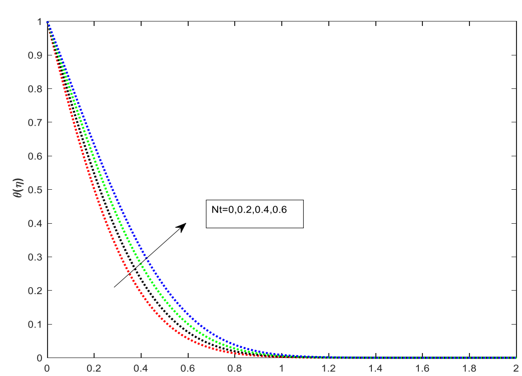

Fig. 8 $\theta(\eta)$ for several variations in N_t

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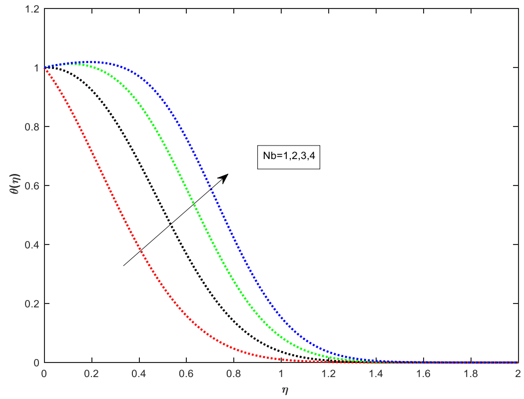

Fig. 9 $\theta(\eta)$ for several variations in N_b

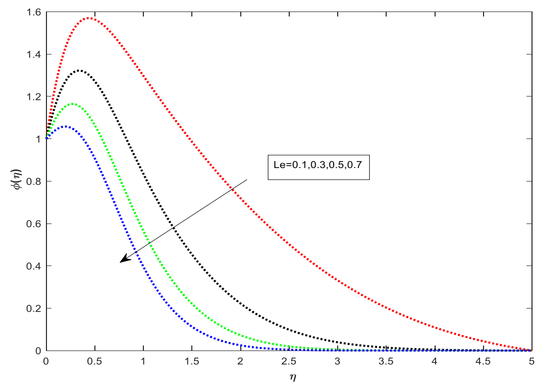

Fig. 10 $\emptyset(\eta)$ for several variations in Le

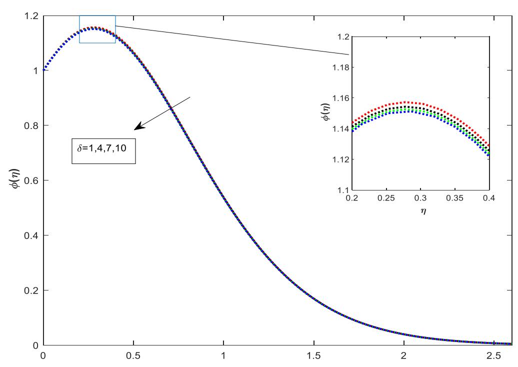

Fig. 11 $\emptyset(\eta)$ for several variations in δ

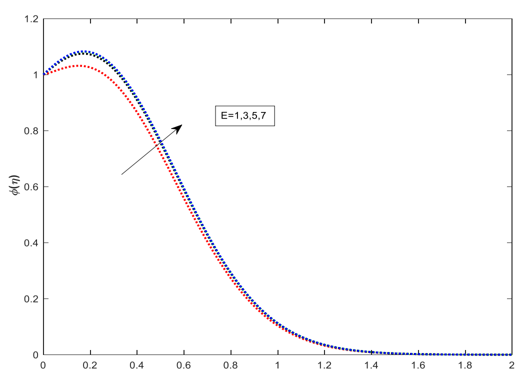

Fig. 12 $\emptyset(\eta)$ for several variations in E

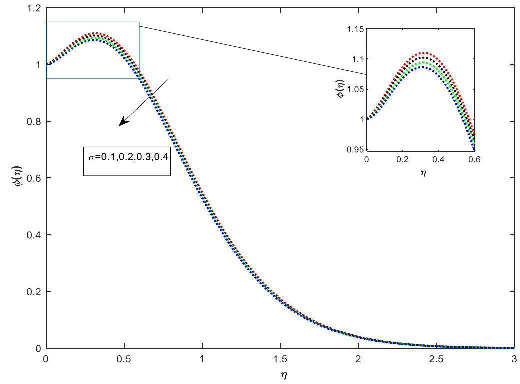

Fig. 13 $\emptyset(\eta)$for several variations in σ

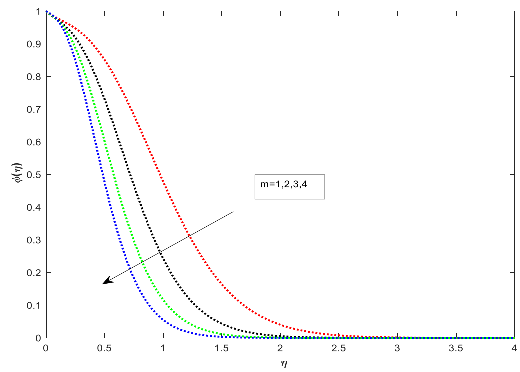

Fig. 14 $\emptyset(\eta)$ for several variations in m

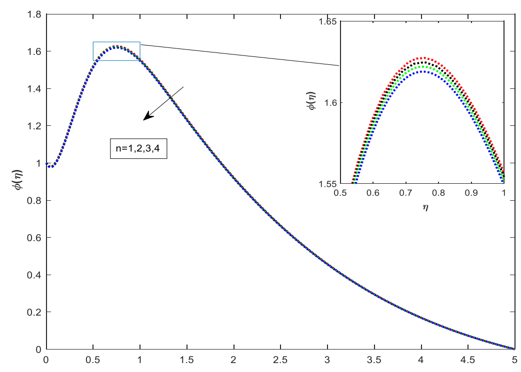

Fig. 15 $\emptyset(\eta)$ for several variations in n

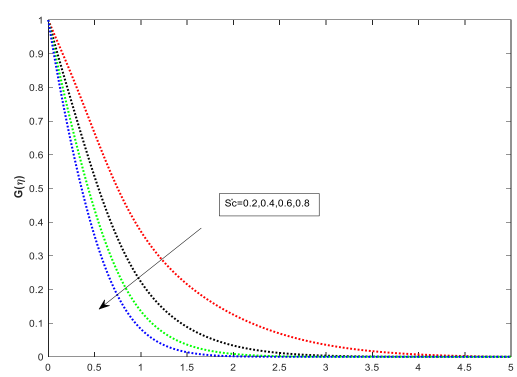

Fig. 16 $G(\eta)$ for several variations in Sc

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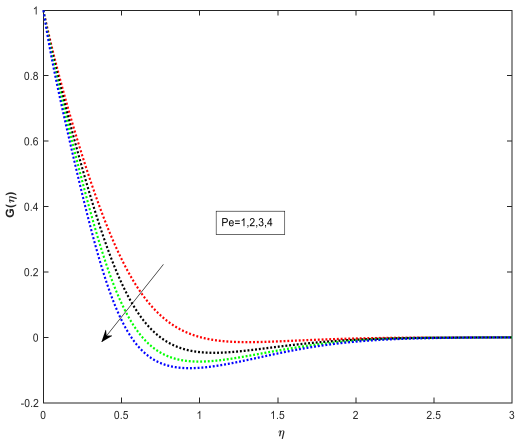

Fig. 17 $G(\eta)$ for several variations in Pe

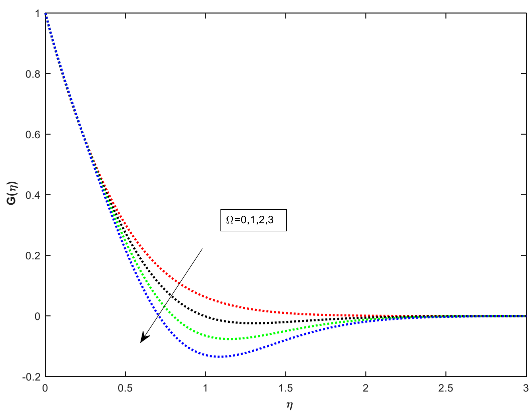

Fig. 18 $G(\eta)$ for several variations in Ω

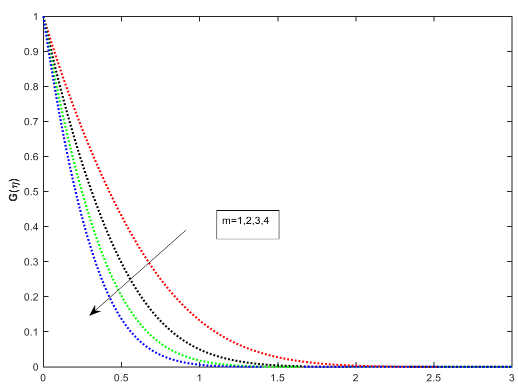

Fig. 19 $G(\eta)$ for several variations in m

The values of N_t and N_b developed the temperature profiles are increases it is shown in the Figs. 8 & 9. The boundary layer's temperature differential created the thermophoretic force, which plays a role in the diffusion of nanoparticles from an area of higher temperature to one of lower temperature causes enhance in the thickness of the thermal and solutal boundary layer.

Brownian motion is the random nanoparticle movement in the base fluid and is greater influence by its base fluid's tangent moving atoms. Brownian motion is related to the size of nanoparticles. In Fig. 10 it depicts that the Lewis number escalates the concentration profiles are declined. Le is defined as the product of thermal diffusivity and mass diffusivity. So, a thermal concentration boundary layer results from a rise in the Lewis number, which causes increased thermal diffusivity and decreased mass diffusivity. In Fig. 11 the concentration profiles increases if temperature difference parameter increases the behaviour of temperature difference parameter δ on because of the increase in the temperature difference between the wall and the surrounding area, thickness decreases and a thinner concentration profile appears. Fig. 12 depicts the function of concentration by varying the infinite activation energy E. The illustration makes it clear that concentration profiles are escalating function of E. Enhancing E at lower temperatures leads to a slower constant reaction rate and, ultimately, a smaller response. This improves the concentration solvent. The demeanour of non-dimensional rate constant σ and constant fitted rate n over concentration field are shown in Figs. 13 and 15. Examined is the fact that increased σ and n values produce an increase and decrease in concentration boundary layer thickness that eventually improves concentration respectively. The effect of Schmidt number for the bio convection of motile organisms Fig. 16 illustrates this. The increasing values of Schmidt number Sc are connected with a diminishing concentration profile. The density of motile microorganism declines as the rate of viscous diffusion escalates. Fig. 17 clarifies that increasing the values of Peclet number the values of density of microorganism concentration profiles are diminishes. Microorganisms swimming up the upper surface of the fluid cause bio convection. The action of microorganisms in this problem is caused by viscous drag and gravitational torques. An upgrade in the Peclet number's values Pe improves the rate of advective transport associated with dispersion while simultaneously increasing the flux of self-swimming motile microorganisms. The velocity of swimming motile microorganisms is produced by the bio convection Peclet number in the fluid, which causes a slowing regarding thickness of the motile organisms approaching the exterior. The concentration difference of microorganism's parameter are increases then the density of microorganism concentration profiles is diminishing this is seen in Fig. 18. The density of motile microorganisms is significantly affected by bio convection factors. A layer of heated fluid condenses on top of a layer of colder fluid at the boundary, this is known as thermal or temperature inversion. Thermal inversion (reversal) is caused by the viscous dissipation effect, which causes more heat to be created near the boundary. This is why certain graphs (slightly) depart from the imposed border restrictions.

In table 1 it is considering the difference of base paper and present paper there is very small variation in the articles. In present article comparing the Porous term differences.

Table 1 Contrast of $f''(0)$ for different P_o with M= E= n = σ = δ= 0

P_o	A Sohail et al. [28]	Present result
0.5	3.685314	3.807836
1	4.850155	4.941155
2	5.766371	5.841966
3	6.546654	6.612698

Skin friction, Nusselt, local density number of motile microorganisms, and Sherwood numbers vary for M, P_0, N_b, N_t, P_r and Le parameters. It is given in table 2. The boldface numbers in this table indicate that the values of those specific physical characteristics are being increased while the additional parameter values remain unchanged. In table 3 it can be identified that the variations of Skin friction, Nusselt, local density number of motile microorganisms, and Sherwood numbers for σ, $\boldsymbol{\delta}$, n, E, Pe and Ω parameters.

5. CONCLUSIONS

This paper studies the Gyrotactic nanofluids and microbes flow via porous medium. A stream is taking in the nonlinear stretching sheet. According to this test's results, the use of gyrotactic microorganisms and nanoparticles are said to drive the flow toward uniformity and stability. The important outcomes are given in the following:

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i)In this article Porosity parameter need not affected because microorganism size is more than the size of pores.
ii) An escalates in the motile microbe's parameter and bio convection he Schmidt number increases. As bio convection parameters rise, however, a declining tendency in the density profiles of mobile microorganisms is seen.
iii) The magnetic field and porosity parameters are increased the velocity profiles are increased.
iv) Thermophoresis, Brownian motion, Eckert number these parameters are increases the profiles of temperatures are increased and Prandtl number rises the temperature profiles are diminishing.
v) The concentration profiles are decreases if the Lewis number, reaction rate parameter, temperature difference parameter, power constant n are rises. The Activation energy parameter values are increases then the concentration profiles are increased.
vi) Schmidt number, Peclet number, concentration difference of microorganisms these parameters are increases then density of motile microorganism's profiles are decreases.

Table 2 $\mathrm{Re_x}$, $\mathrm{Nu_x}$, $\mathrm{Sh_x}$ and $\mathrm{Nn_x}$ variations for different parameters.

M	P_0	N_b	N_t	P_r	Le	$Re_x^{1/2}C_f$	$Nu_xRe_x^{-1/2}$	$Sh_xRe_x^{-1/2}$	$Nn_xRe_x^{-1/2}$
3						1.800064	1.860293	0.363261	2.080065
5						1.963969	1.801649	0.429678	2.108272
7						2.112913	1.747849	0.489849	2.133526
9						2.250322	1.697848	0.545213	2.156534
	5					2.076868	1.760899	0.475315	2.127457
	10					2.409297	1.639605	0.609118	2.182832
	15					2.695202	1.534009	0.723646	2.229422
	20					2.949842	1.439149	0.825337	2.270231
		1				1.692388	1.002654	1.648438	2.511135
		2				1.692388	0.458053	1.875370	2.586457
		3				1.692388	0.218712	1.855293	2.577855
		4				1.692388	0.192468	1.831248	2.568869
			0			1.692388	2.758310	1.864908	2.579417
			0.2			1.692388	2.384769	1.055866	2.304567
			0.4			1.692388	2.050936	0.509064	2.122657
			0.6			1.692388	1.755202	0.178579	2.016953
				1		1.692388	1.140020	1.003716	2.294569
				3		1.692388	1.848717	0.365705	2.077188
				5		1.692388	2.268475	0.328169	1.940901
				7		1.692388	2.578707	0.323955	1.837764
					0.1	1.692388	3.745670	3.132349	0.927333
					0.3	1.692388	3.063487	2.010099	1.288276
					0.5	1.692388	2.598493	1.180573	1.559868
					0.7	1.692388	2.260968	0.512355	1.781655

NOMENCLATURE

C_∞	Ambient concentration
T_∞	Ambient temperature
D_B	Brownian diffusion $(\mathrm{m^2 s^{-1}})$
C	Concentration of fluid
ρ	Fluid density
Le	Lewis number
M	Magnetic parameter
D_n	Microorganisms diffusion $(\mathrm{m^2 s^{-1}})$
Nu_x	Nusselt number
T	Temperature of fluid (K)
D_T	Thermophoresis diffusion $(\mathrm{m^2 s^{-1}})$

Greek Symbols

σ	Electrical conductivity
η	Similarity variable
ψ	Stream function
α	Thermal diffusivity

Superscripts

m	Constant

Subscripts

∞	Ambient
f	Base fluid
w	Condition in stretching surface
0	Initial condition in stretching sheet

Table 3 $\mathrm{Re_x}$, $\mathrm{Nu_x}$, $\mathrm{Sh_x}$ and $\mathrm{Nn_x}$ variations for different parameters.

σ	δ	n	E	Pe	Ω	$Re_x^{1/2}C_f$	$Nu_xRe_x^{-1/2}$	$Sh_xRe_x^{-1/2}$	$Nn_xRe_x^{-1/2}$
0.1						1.710909	1.891905	0.327043	2.064523
0.2						1.710909	1.914649	0.240936	2.034633
0.3						1.710909	1.930197	0.182560	2.014373
0.4						1.710909	1.946073	0.123371	1.993823
	1					1.710909	1.874950	0.399525	2.089840
	4					1.710909	1.919285	0.218194	2.026633
	7					1.710909	1.949610	0.106509	1.987865
	10					1.710909	1.972378	0.027156	1.960381
		1				1.710909	0.046797	0.970164	1.488818
		2				1.710909	0.048458	0.982662	1.503310
		3				1.710909	0.050243	0.996617	1.519497
		4				1.710909	0.052165	1.012240	1.263772
			1			1.710909	1.965617	0.092816	1.983907
			3			1.710909	1.858220	0.444090	2.105001
			5			1.710909	1.832589	0.543857	2.139653
			7			1.710909	1.824947	0.578621	2.151797
				1		1.692388	1.898444	0.319511	2.238578
				2		1.692388	1.898444	0.319511	2.520429
				3		1.692388	1.898444	0.319511	2.826213
				4		1.692388	1.898444	0.319511	3.148366
					0	1.692388	1.898444	0.319511	2.063611
					1	1.692388	1.898444	0.319511	2.068168
					2	1.692388	1.898444	0.319511	2.072725
					3	1.692388	1.898444	0.319511	2.077281

REFERENCES

Acharya, N., Das, K., Kundu, P. K., 2016, "Framing the effects of solar radiation on magneto-hydrodynamics bioconvection nanofluid flow in presence of gyrotactic microorganisms," Journal of Molecular Liquids, vol. 222, pp. 28–37. https://doi.org/10.1016/j.molliq.2016.07.023.

Ahmad, S., Ashraf, M., Ali, K., 2020, "Bioconvection due to gyrotactic microbes in a nanofluid flow through a porous medium," Heliyon, vol. 6, no. 12, article e05832. https://doi.org/10.1016/j.heliyon.2020.e05832.

Ahmad, S., Ashraf, M., Ali, K., 2020, "Nanofluid flow comprising gyrotactic microorganisms through a porous medium," Journal of Applied Fluid Mechanics, vol. 13, pp. 1539– 1549. https://dx.doi.org/10.36884/JAFM.13.05.31030.

Athif, S., Hussain, S., Sagheer, M., 2019, "Magnetohydrodynamic stratified bio convective flow of micro polar nanofluid due to gyrotactic microorganisms," AIP Advances, vol. 9, no. 2, article 025208. https://doi.org/10.1063/1.5085742.

Atashafrooz, M., 2018, "Effects of Ag-water nanofluid on hydrodynamics and thermal behaviors of three-dimensional separated step flow", Alexandria Engineering Journal, Vol. 57, pp. 4277-4285, https://doi.org/10.1016/j.aej.2017.07.016.

Atashafrooz, M., Sajjadi, H., Amiri Delouei, A., Tien-Fu Yang, Wei-Mon Yan, 2021, "Three-dimensional analysis of entropy generation for forced convection over an inclined step with presence of solid nanoparticles and magnetic force", Numerical Heat Transfer, Part A: Applications, Vol. 80 (6), pp. 318-335, https://doi.org/10.1080/10407782.2021.1944579.

Atashafrooz, M., Sajjadi, H., Amiri Delouei, A., 2020, "Interacting influences of Lorentz force and bleeding on the hydrothermal behaviors of nanofluid flow in a trapezoidal recess with the second law of thermodynamics analysis", International Communications in Heat and Mass Transfer, Vol. 110, Article 104411, https://doi.org/10.1016/j.icheatmasstransfer.2019.104411.

Atashafrooz, M., 2020 "Influence of radiative heat transfer on the thermal characteristics of nanofluid flow over an inclined step in the presence of an axial magnetic field", Journal of Thermal Analysis and Calorimetry, Vol. 139(5), pp. 3345-3360, https://doi/10.1007/s10973-019-08672-0.

Atashafrooz, M., 2019 "The effects of buoyancy force on mixed convection heat transfer of MHD nanofluid flow and entropy generation in an inclined duct with separation considering Brownian motion effects", Journal of Thermal Analysis and Calorimetry, Vol. 138, pp. 3109–3126, https://doi/10.1007/s10973-019-08363-w.

Atashafrooz, M., Sheikholeslami, M., Sajjadi, H., Amiri Delouei, A., 2019 "Interaction effects of an inclined magnetic field and nanofluid on forced convection heat transfer and flow irreversibility in a duct with an abrupt contraction", Journal of Magnetism and Magnetic Materials, Vol. 478, pp. 216-226, https://doi.org/10.1016/j.jmmm.2019.01.111.

Bilal, M., Saeed, A., et al., 2021, "Numerical approximation of microorganisms hybrid nanofluid flow induced by a wavy fluctuating spinning disc," Coatings, vol. 11, no. 9, p. 1032. https://doi.org/10.3390/coatings11091032.

Chakraborty, T., Das, K. P., Kundu, K., 2018, "Framing the impact of external magnetic field on bioconvection of a nanofluid flow containing gyrotactic microorganisms with convective boundary conditions," Alexandria Engineering Journal, vol. 57, no. 1, pp. 61–71. https://doi.org/10.1016/j.aej.2016.11.011.

Das, M. T. Sk. K., Kundu, P. K., 2016, "Multiple slip effects on bioconvection of nanofluid flow containing gyrotactic microorganisms and nanoparticles," Journal of Molecular Liquids, vol. 220, pp. 518–526. https://doi.org/10.1016/j.molliq.2016.04.097.

Dharmaiah, G.; Vedavathi, N.; Rani, C. H. Baby; Balamurugan, K. S. 2018, "MHD Boundary layer flow and heat transfer of a nanofluid past a radiative and impulsive vertical plate," Frontiers in heat and mass transfer, 11, https://doi.org/10.5098/hmt.11.14

Ganesh, G. R., Sridhar, W., 2021, "Numerical Approach Of Heat And Mass Transfer Of Mhd Casson Fluid Under Radiation Over An Exponentially Permeable Stretching Sheet With Chemical Reaction And Hall Effect," Frontiers in Heat and Mass Transfer (FHMT) 16(5) (2021), DOI: http://dx.doi.org/10.5098/hmt.16.5.

Govindaraj, N., Singh, A.K., Shukla, p., 2020, "Fluid flow and heat transfer over a stretching sheet with temperature dependent Prandtl number and viscosity", Frontiers in Heat and Mass Transfer, Vol.15-20, http://dx.doi.org/10.5098/hmt.15.20.

Iqbal, Z. Mehmood, Z., Maraj, E. N., 2017, "Oblique transport of gyrotactic microorganisms and bioconvection nanoparticles with convective mass flux," Physica E: Low-dimensional Systems and Nanostructures, vol. 88, pp. 265–271., https://doi.org/10.1016/j.physe.2017.01.011.

Khan, W. A., Makinde, O. D., Khan, Z. H., 2014, "MHD boundary layer flow of a nanofluid containing gyrotactic microorganisms past a vertical plate with Navier slip," International Journal of Heat and Mass Transfer, vol. 74, pp. 285–291., https://doi.org/10.1016/j.ijheatmasstransfer.2014.03.026.

Kranthi Kumar, K., Baby Rani, CH., Papa Rao, A.V., 2021, "MHD Casson fluid flow with an inclined Plate in the presence of Hall and aligned magnetic effects", Frontiers in Heat and Mass Transfer, Vol.17-2, http://dx.doi.org/10.5098/hmt.17.2.

Mira Das, Utpal Jyoti Das, 2021, "Unsteady MHD rotating and chemically reacting fluid flow over an oscillating vertical surface in a darcian porous regime", Frontiers in Heat and Mass Transfer (FHMT) **17** – 18, http://dx.doi.org/10.5098/hmt.17.18.

Mutuku, W. N., Makinde, O. D., 2014, "Hydromagnetic bioconvection of nanofluid over a permeable vertical plate due to gyrotactic microorganisms," Computers & Fluids, vol. 95, pp. 88–97, https://doi.org/10.1016/j.compfluid.2014.02.026.

Radha Madhavi, M., Sridhar, W., Nagesh, P., 2021, "Numerical investigations of MHD Casson nanofluid flow over a wedge through porous medium," AIP Conference Proceedings, 2375, 0066944, DOI: https://doi.org/10.1063/5.0066411.

Radha Madhavi, M., Veeranjaneyulu, M., Srimannarayana, N., Vijaya, N., 2020, "Impacts of thermophoresis, joule heating and soret & dufour effects on mixed convective jeffery fluid flow over an elongated sheet," International Journal of Advanced Science and Technology, 29(5), pp. 3060–3069.

Raghavendra Ganesh, G., Sridhar, W., Khaled Al-Farhany, Sameh Ahmed, E., 2022, "Electrically MHD Casson nanofluid flow and entropy exploration under the influence of the viscous dissipation, radiation, and higher-order chemical reaction," Physica Scripta, Volume 97, 065208 DOI: https://doi.org/10.1088/1402-4896/ac6e51.

Ramzan, M., Chung, J. D., Ullah, N., 2017, "Radiative magneto hydrodynamic nanofluid flow due to gyrotactic microorganisms with chemical reaction and non-linear thermal radiation," International Journal of Mechanical Sciences, vol. 130, pp. 31–40. https://doi.org/10.1016/j.ijmecsci.2017.06.009.

Sajjadi, H., Amiri Delouei, A., Sheikholeslami, M., Atashafrooz, M., Succi, S., 2019, "Simulation of three dimensional MHD natural convection using double MRT Lattice Boltzmann method", Physica A: Statistical Mechanics and its Applications, Vol. 515, pp. 474-496, 2019. https://doi.org/10.1016/j.physa.2018.09.164.

Sajjadi, H., Amiri Delouei, A., Atashafrooz, M., Sheikholeslami, M., 2018, "Double MRT Lattice Boltzmann simulation of 3-D MHD natural convection in a cubic cavity with sinusoidal temperature distribution utilizing nanofluid", International Journal of Heat and Mass Transfer, Vol. 126, pp. 489-503.
https://doi.org/10.1016/j.ijheatmasstransfer.2018.05.064.

Salahuddin, T., Siddique, N., Khan, M., Chu, Y.M., 2022, "A hybrid nanofluid flow near a highly magnetized heated wavy cylinder," Alexandria Engineering Journal, vol. 61, no. 2, pp. 1297–1308. https://doi.org/10.1016/j.aej.2021.06.014.

Shahid, A., Zhou, Z., Bhatti, M. M., Tripathi, D., 2018, "Magnetohydrodynamics nanofluid flow containing gyrotactic microorganisms propagating over a stretching surface by successive Taylor series linearization method," Microgravity Science and Technology, vol. 30, no. 4, pp. 445–455, 2018.
https://doi.org/10.1007/S12217-018-9600-2.

Sheikholeslami, M., Sajjadi, H., Amiri Delouei, A., Atashafrooz, M., Zhixiong Li, 2019, "Magnetic force and radiation influences on nanofluid transportation through a permeable media considering Al2O3 nanoparticles", Journal of Thermal Analysis and Calorimetry, Vol. 136(6), pp. 2477–2485.
https://doi.org/10.1007/s10973-018-7901-8.

Sohail Ahmad., Jihad Younis, 2022, "Impact of Swimming Gyrotactic Microorganisms and Viscous Dissipation on Nanoparticles Flow through a Permeable Medium: A Numerical Assessment" Journal of Nanomaterials," Article ID 4888128,
https://doi.org/10.1155/2022/4888128.

Sridhar, W., Ganesh, G. R., Appa Rao, B. V., Haile Gorfie, E., 2021, "Mixed convection boundary layer flow of MHD Casson fluid on an upward stretching sheet encapsulated in a porous medium with slip effects", JP Journal of Heat and Mass Transfer 22(2) , 133-149,
https://doi.org/10.17654/HM022020133.

Vedavathi, N; et al, 2019, "A study on mhd boundary layer flow rotating frame nanofluid with chemical reaction" Frontiers in heat and mass transfer,
Doi: http://dx.doi.org/10.5098/hmt.12.10.

Vijaya, N. Arifuzzaman, Raghavendra Sai, Manikya Rao N. Ch., 2020, "Analysis Of Arrhenius Activation Energy In Electrically Conducting Casson Fluid Flow Induced Due To Permeable Elongated Sheet With Chemical Reaction And Viscous Dissipation," S.M,Frontiers in Heat and Mass Transfer (FHMT) 15 - 26,
http://dx.doi.org/10.5098/hmt.15.26.

Vijaya N., Sunil Babu G, Vellanki Lakshmi N., 2020, "Influence Of Critical Parameters On Liquid Thin Film Flow Of Casson Nano Fluid Over Elongated Sheet Under Thermophoresis And Brownian Motion," Frontiers in Heat and Mass Transfer (FHMT) 15 - 23, http://dx.doi.org/10.5098/hmt.15.23.

Vijaya, N., Krishna Jyothi, P., Anupama, A., Leelavathi, R., Ambica, K. 2021, "Thermophoresis And Buoyancy Effects On Chemically Reactive Upper Convected Maxwell Fluid Flow Induced By An Exponentially Stretching Sheet: Application Of Cattaneo-Christov Heat Flux," Frontiers in Heat and Mass Transfer (FHMT) 17 - 23, http://dx.doi.org/10.5098/hmt.17.23.

Vijaya, N., Hari Krishna, Y., Kalyani, K., Reddy, G.V.R., 2018, "Soret And Radiation Effects On An Unsteady Flow Of A Casson Fluid Through Porous Vertical Channel With Expansion And Contraction," Frontiers in Heat and Mass Transfer (FHMT) 11 - 19, http://dx.doi.org/10.5098/hmt.11.19.

Nagalakshmi, P.S.S. and Vijaya, N., 2022, "Entropy generation of three dimensional Bingham Nanofluid flow with carbon nanotubes passing Through parallel plates", Frontiers in Heat and Mass Transfer (FHMT), 19, 17 (2022)
http://dx.doi.org/10.5098/hmt.19.17