EFFECT OF GYROTACTIC MICROORGANISMS ON ELECTRICALLY CONDUCTING CARREAU NANOFLUID FLOW ALONG AN EXPONENTIALLY STRETCHING SURFACE IN THE PRESENCE OF CHEMICAL REACTION

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Abstract

In this article, we have discussed the effects of gyrotactic microorganisms on electrically conducting carreau nanofluid across an exponentially stretching surface over a thermal radiation in the presence of chemical reaction. The governing partial differential equations and boundary conditions are converted into a system of non-linear ordinary differential equations by the using of similarity transformations which are then solved numerically using shooting technique with the help of MATLAB program. The fluid velocity is an increasing function of the local Weissenberg number, according to this research. Magnetic field influence reduces the thickness of the momentum boundary layer. Due to increased values of thermophoresis and Brownian motion effects, there is an increasing trend in carreau fluid temperature. Brownian motion causes the concentration field to decrease, whereas thermophoresis causes it to increase. The concentration profile is enhanced by activation energy, but the Schmidt number is reduced. Present results are compared with the previously published results in some limiting cases and results are found to be in an excellent agreement.

Introduction

Because of the vast variety of practical applications in the boundary layer flow and heat transfer of nanofluid over a stretched sheet are an important area of research like metal spinning and drawing, and the use of plastic and rubber sheets, Cooling of continuous strips or filaments, crystals, and polymeric films, Growing, glass blowing, and paper manufacture, are few of the important applications for this research. Biomedical process also finds this type of applications. By introducing different physical aspects like, suction, porosity, thermal radiative motion and magnetic field impact on Newtonian and non-Newtonian fluids by many researchers which are mentioned in. Makinde and Aziz also reported the boundary layer flow pattern of a nanofluid through a stretchable surface along with conditions on convective boundary. Research works by authors to discuss the flow and heat transfer characteristics based on exponentially stretching surfaces which are noteworthy.

The occurrence of bio-convection in flow pattern is due to the involvement of microscopic organisms in the assumed fluid. Motile microorganisms are somewhat denser than water in suspensions, and these self-propelled motile bacteria often swim upward, increasing the density of the base fluid. This research might also find applications in sophisticated nanomechanical bioconvection energy conversion devices, bio-nano-coolant systems, and so on. The field of nanofluid bioconvection research has a young history. Bioconvection in suspensions comprising tiny solid particles and gyrotactic bacteria was initially proposed by Kuznetsov and Avramenko. Later several investigations are being carried by researchers. Some of the numerous works are mentioned here. The steady magneto rheological flow of Carreau nanofluid with microorganisms along a moving wedge under the influence of velocity slip and thermal radiation is studied by Muhammad et al. Farooq et al. discussed the bioconvection aspects in Carreau nanofluid over a stretching cylinder along with modified Cattaneo-Christov expressions and heat source. Considering a three dimensional bioconvective flow of a Carreau nanofluid over a moving surface Waqas et al. carried out a numerical investigation with motile microorganisms and a heat source / sink. Shafiq et al.

reported the results for a modeling of bioconvective tangent hyperbolic flow of a nanofluid along an expoenetially stretched surface by means of response surface methodology. Numerical analysis is reported by Pal et al. To analyze the impacts of thermal radiation on transfer of heat in water-based nanofluid involving motile gyrotactic microorganisms through an exponentially stretching sheet.

Based on the above works, a numerical treatment is made in this article to study the behavior of motile microorganisms in the Carreau nanofluid flow past an exponentially stretching surface under the impacts of thermal radiation, in the presence of chemical reaction with the effect of MHD. The obtained outcomes of the present analysis are deliberated through graphs.

Mathematical modeling

In this modeling, we consider a steady two-dimensional incompressible viscous boundary layer flow of an electrically conducting nanoliquid with motile gyrotactic microorganisms along an exponentially stretching surface.

By using the similarity transformation, the equations of continuity, Momentum, energy, nanopartical concentration and gyrotactic microorganism are as follows:

$$\left.\begin{array}{l} f=0,\ f'=1+Pf'',\ \theta=1,\ \theta=1,\ \chi=1\ at\ \eta=0 \\ f\to 0,\ \theta\to 0,\ \phi\to 0,\ \chi\to 0\ as\ \eta\to\infty \end{array}\right\}$$

$$\left(1+We^2 f''^2\right)^{\frac{n-3}{2}}\left(1+n\,We^2 f''^2\right)f'''+f\,f''-2\,f'^2$$

$$+2\,\lambda\,e^{\left(\frac{a-4}{2}\right)X}\left[\theta-Nr\phi-Rb\chi\right]-2\,M\,e^{-X}f'-2\,\chi\,e^{-X}f'=0$$

(1)

$$\left(1+\frac{4R}{3}\right)\theta''+Pr\left[f\,\theta'-a\,f'\,\theta+Ec.e^{\frac{X}{2}(4-a)}.f''^2+2\,M.Ec.e^{\frac{X}{2}(2-a)}f'^2+S\,e^{-X}\,\theta\right]=0$$

(2)

$$\phi''+¿\left(f\,\phi'-a\,f'\,\phi\right)+\left(\frac{N_t}{N_b}\right)\theta''-¿\,\Gamma\,e^{-X}\left(1+\Lambda\,e^{aX/2}\theta\right)^m\exp\left[\frac{-E}{1+\Lambda\,e^{aX/2}\theta}\right]\phi=0$$

(3)

$$\chi'' + Lb(f\chi' - af'\chi) - Pe\left[e^{aX/2}\phi'\chi'' + (\Omega + e^{\frac{aX}{2}})\phi''\right] = 0$$
(4)

And the resultant boundary conditions are

$$\left.\begin{aligned} &f=0, f'=1+Pf'', \theta=1, \phi=1, \chi=1 \, at\, \eta=0 \\ &f' \to 0, \theta \to 0, \phi \to 0, \chi \to 0 \, as\, \eta \to \infty \end{aligned}\right\} \quad (5)$$

Results and Discussion

Numerical calculations are obtained by performing the shooting technique together with RK-4th order method on the reduced system of equations (1) – (4) along with boundary conditions in (5) for a particular set of values given to the pertinent parameters of the study. The responses in velocity profiles, temperature and concentration profiles, micro-organism profiles are deliberated by means of plots and discussed in detail.

Variations in velocity profile :

The responses in nanofluid velocity for relevant parameters are displayed in figures (2) to (8). It is clear from the fig.2 that the velocity of the fluid is heightened by (λ) but opposite tendency is notified while increasing(Nr). The effects of Weissenberg number (We) and (Rb) are shown in fig.3. Larger values of (We) causes the increment in velocity but it is reduced by a rise in(Rb). Impacts of magnetic field (M) and (k) are captured in fig.4. The hike in velocity profiles are identified due to those parameters. The influences of power-law index (n) and fitted rate constant (m) are shown in fig.5. Rising profiles of velocity is noticed due to those parameters. Effects of Activation energy (E) and (a) are shown in fig.6. Velocity is suppressed by both increments in activation energy (E) and (a). Velocity changes due to the parameters (Lb), (Pe) and (Ω) are depicted from the fig.7. Increased values in these parameters causes an upsurge in velocity profiles. Fig.8 is the evidence of the impacts of the parameters (R),(S) and (Pr) on velocity field. Velocity seen to be increased due to an increment in radiation $(R)$and (S) where as a decrement in velocity is noticed by intensified values of Prandtl number

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