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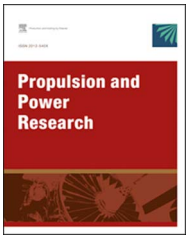

ORIGINAL ARTICLE

Effect of magnetic field on Oldroyd-B type nanofluid flow over a permeable stretching surface

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Abstract This article is conceded to explore the influence of magnetic flux on a two dimensional incompressible Oldroyd-B type nanofluid past a heat generating/absorbing permeable expanding surface. Guided by some appropriate similarity transformations, the fundamental PDEs are converted into a self similar system of coupled, non-linear ODEs. The findings are gained by taking the help of the Runge–Kutta Gill based Shooting practice. To visualize the influences of related parameters concerning the flow, on velocity, temperature and concentration distributions are represented through graphs. Numerical fallouts for the local Nusselt number and Sherwood number are charted for various parametric situations to offer interesting aspects of the investigation. In existence of magnetic flux the momentum boundary layer width declines rapidly with relaxation time and velocity slip whereas, the temperature boundary layer width enhances significantly with heat source, Brownian motion and thermophoresis parameters. The Nusselt number falls a lot with heat source, velocity slip and Brownian motion parameter but reverse result is notified for Sherwood number for the same. Also, the obtained numerical outcomes for particular cases are compared with those of the existing data in the open literature and, are found in excellent harmony.

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1. Introduction

The research on nanofluid past a linearly expanding sheet has acknowledged great scientific attention between researchers because of its plentiful applications in industrial manufacture. The boundary layer flow problem along a solid flat plate was pioneered by Sakiadis [1]. The idea of Sakiadis [1] was carried forward by Crane [2] by considering the flow over both linearly and exponentially stretched sheet. Casson fluid flow along a plane which shrinks exponentially was depicted by Nadeem et al. [3]. A stagnation point flow over along an expanded deformable plate was discussed by Mahapatra et al. [4]. Apart from regular fluid, Khan and Pop [5] studied nature of nanofluid flow near boundary of an expanding surface. This is notable that the flow of fluid along permeable surface has enormous practical usage in industry, science and engineering. A few examples of permeable surface that it is detected in nature as well as in living animal are beach sand, limestone, the human lung, small blood vessels etc. Chakraborty et al. [6] obtained an analytical expression for velocity and temperature of stagnation point flow of a Jeffrey nanofluid. Thermosolutal convection in a Walters-B type visco-elastic liquid down with suspended particles in a permeable medium was discussed by Rana [7]. By Visco-elasticity we make out the phenomena of materials that display the viscous and elastic individuality while passes through deformation. The Oldroyd-B type model is a basic model which is usually taken to clarify the flow performance of viscoelastic fluids. This model is significant of its use in making of plastic sheet and extrusion of polymers passing through a slot die in polymer industry. Nadeem et al. [8] discussed the heat flux of a nanofluid flow along a stretched surface by considering an Oldroyd-B model. Of late, a three dimensional flow of an Oldroyd-B nanofluid past an expanding sheet which is heat generating/absorbing was discussed by Khan et al. [9]. The nanofluid flow over a stretched surface with different flow situations are found in some recent articles of Nadeem et al. [10–12]. Model-based examination of micropolar nanofluid flow towards a stretching surface was presented by Hussain et al. [13].

The flow with Slippage phenomena occurs when the characteristic size of the flow system is small or the flow pressure is very low. As per continuum physics in no-slip flow situation, the velocity of fluid is presumed to be zero close to the solid-fluid boundary. But in condition of slip-flow the velocity of liquid in proximity of surface is non zero. Matthews and Hill [14] replaced the regular no-slip boundary situation with a non-linear Navier boundary state in the boundary layer equation and conveyed the after effect. The hydrodynamic boundary layer flow along with the existence of partial slip along an expanding surface was analyzed by Wang [15]. Yazdi et al. [16] discussed the heat transport of slip flow along a absorbent medium. In presence of heat source/sink the slip impacts on magneto-hydrodynamic (MHD) nanofluid flow towards a stretching/shrinking sheet was revealed by Nandy and Mahapatra [17]. Recently, the nanofluid stream in the direction of a permeable expanded surface with slip conditions was depicted by Das et al. [18].

The impression of magnetic flux on the fluid flow and heat transport problems of regular fluid has been examined by several authors, but to the author's knowledge some of researches [19–26] have been executed with regard to convective heat transfer in a nanofluid over a stretched permeable medium. The magnetic flux which is applied externally provides definite rigidity and elasticity properties to the liquid, which are related to the stableness of the same. Chakraborty et al. [27] have framed the impression of magnetic flux on bioconvection flow of a nanofluid over a stretched plate. Malvandi and Ganji [28] depicted the nanoparticles immigration and heat transport of water–alumina nanofluid coexistence of magnetic flux. Cu–water nanofluid flow and heat transport owing to convection in addition with Lorentz force was analyzed by Sheikholeslami et al. [29]. Lately, Mabood et al. [30] deliberated the MHD flow of nanofluid along a surface which is non-linearly stretched.

The aspire of this observation is to extend the research by Nadeem et al. [8] by considering the permeable expanding surface co-existing with heat source/sink and magnetic flux which is employed externally with slip velocity at the surface. Mathematical examination of the suggested problem has been formed after applying the boundary layer approach. The orientation of the residual portion of this manuscript is designed as follows: the mathematical formulations of the problem subjected with proper boundary conditions are derived in Segment 2; Segment 3 is all about numerical simulation; Segment 4 provides of the outcomes and comprehensive discussion and in Segment 5, the concluding remarks are discoursed.

2. Mathematical formulation

A stable, two-dimensional, viscous Oldroyd-B type nanofluid flow along an absorbent expanding surface reserved at a constant temperature T_w and concentration C_w. The distant values of the temperature and concentration are presumed to be T_∞ and C_∞ respectively. The flow happens on account of the expanding sheet and to be confined to $y>0$. The sheet is expanded alongside with the linear velocity $u_w(x)=ax$, where '$a>0$' is a dimensional constant and x is the coordinate accounted along the permeable expanded sheet. The geometrical outline of this study is established through Figure 1. Two similar forces having equal potential are applied to x-axis but, from the opposite directions, maintaining the origin fixed. Since the flow is laminar so, a transverse magnetic flux with uniform potential B_0 is employed perpendicularly to the sheet. It may be carefully considered that there is no outwardly applied electric sphere. Magnetic Reynolds number is insignificant such that the internal magnetic flux is inconsiderable compared to outwardly applied magnetic flux.

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