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ORIGINAL ARTICLE

Numerical investigation of magnetohydrodynamic stagnation point flow with variable properties

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Abstract This article is concerned with the two-dimensional flow of Powell–Eyring fluid with variable thermal conductivity. The flow is caused due to a stretching cylinder. Temperature dependent thermal conductivity is considered. Both numerical and analytic solutions are obtained and compared. Analytic solution is found by homotopy analysis method. Numerical solution by shooting technique is presented. Discussion to different physical parameters for the velocity and temperature is assigned. It is observed that the velocity profile enhances for larger magnetic parameter. It is also further noted that for increasing the value of Prandtl number temperature profile decreases.

1. Introduction

The researchers at present have much interest in the investigation of non-Newtonian liquids. It is due to their exceedingly significance in numerous organic, mechanical and designing procedures, for example, glass arrangement, fiber sheet fabricating, wire drawing, sustenance items, paper creation, precious stone development and so on. Analysis of boundary layer flow has special significance in the situations when fluid is passing over the surface. The researchers in recent times are looking for increasing the efficiency of various machines through reduction of drag/friction forces. Different endeavors therefore have been made about lessening of drag powers/forces for flow over the surface of a wing, tail plane and wind turbine rotor and so forth. Hence heat transfer and boundary layer flow by a moving surface has wide coverage in the industrial manufacturing procedures. Few examples of such processes may include glass fiber creation, hot moving, paper generation, wire drawing, nonstop throwing, metal turning, metal and polymer expulsion, drawing of plastic movies and so on. The last item in toughening and diminishing of copper wires enormously relies on heat transfer rate at the stretched sheet. Such flow consideration in vicinity of magnetic field has pivotal role in the metallurgical process. Particular motivating flow problems containing non-Newtonian fluid can be found in the studies [1–10].

The investigation of magnetic field has a few restorative and designing applications in improved oil recuperation, magnetohydrodynamics generators, electronic bundles, pumps, thermal insulators, flow meters, power era and so on. The modern

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Nomenclature

u, v	velocity components	q_w	surface heat flux
μ	dynamic viscosity	a	radius of cylinder
ρ	fluid density	k_∞	thermal conductivity of ambient fluid
c, β	characteristics of Eyring Powell	K	Hartman number
B_0	magnetic field intensity	τ	extra stress tensor
U_e	free stream velocity	Pr	Prandtl number
U_w	stretching velocity	υ	kinematic viscosity
K^*	variable thermal conductivity	Nu_x	local Nusselt number
T	temperature	Cf_x	skin friction coefficient
T_∞	ambient temperature	Re_x	local Reynolds number
l	characteristics length	ε	small scaler parameter
σ	Electrical conductivity	γ	curvature parameter
a, b	dimensional constant	θ	dimensionless temperature
T_w	uniform temperature over the surface	λ	fluid parameter

devices are bothered by the collaboration between the electrically leading liquid and the magnetic field. The flow act solidly builds upon the orientation and the intensity of the applied magnetic field. The suspended particles are molded by applied magnetic field. In boundary layer flow the force and heat exchange by stretched surface are controlled by MHD. Hayat et al. [11] studied MHD flow of nanofluid over permeable stretching sheet with convective boundary conditions. Raju et al. [12] considered nanofluid by a nonlinear permeable stretched surface with three dimensional (MHD) flow. Hayat et al. [13] studied Cattaneo–Christov heat flux in MHD flow of Oldroyd-B fluid with homogeneous-heterogeneous reactions. Magnetohydrodynamic three-dimensional flow of nanofluid by a porous shrinking surface is studied by Hayat et al. [14]. Sandeep et al. [15] worked on comparative study of convective heat and mass transfer in non-Newtonian nanofluid flow past a permeable stretching sheet. Turkyilmazoglu [16] found the exact solution of MHD flow over three dimensional deforming bodies. Zaidi et al. [17] analyzed MHD effects in two dimensional wall jet flow with convective heat transfer. Unequal diffusivities case of homogeneous-heterogeneous reactions within viscoelastic fluid flow in the presence of induced magnetic field and nonlinear thermal radiation is studied by Annimasun et al. [18]. Rashidi and Erfani [19] considered analytical method for solving steady MHD convective and slip flow due to a rotating Disk with Viscous Dissipation and Ohmic Heating. Heat and mass transfer in MHD non-Newtonian bio-convection flow over a rotating cone/plate with cross diffusion is analyzed by Raju and Sandeep [20]. Mixed convective heat transfer for MHD viscoelastic fluid flow over a porous wedge with thermal radiation is considered by Rashidi et al. [21]. Raju et al. [22] considered dual solutions of MHD boundary layer flow past an exponentially stretching sheet with non-uniform heat source/sink.

The Powell–Eyring model discussed in [23] becomes more composite and deserves our attention because it has certain advantages over the Power-law model and Prandtl–Eyring model. The theory of rate processes is used to derive the Eyring–Powell model for describing the shear of a non-Newtonian flow. In some cases this model predicts the viscous behavior of polymer solutions and viscoelastic suspension over a wide range of shear rates. Eyring–Powell model is used to describe the shear rates of non-Newtonian flow. Impacts of magnetohydrodynamics (MHDs) and thermal radiation in flow of Eyring–Powell liquid are reported by Hayat et al. [24]. Analysis of Eyring–Powell liquid over a stretched surface is presented by Javed et al. [25]. Impact of heat transfer in unsteady stretched flow of Eyring–Powell liquid is presented by Khader and Megahed [26]. Elbade et al. [27] studied the flow of Eyring-Powell liquid saturating porous medium. Recently effects of radiation in flow of Eyring–Powell nanofluid are explored by Hayat et al. [28]. Raju et al. [29] studied heat and mass transfer in MHD Eyring–Powell nanofluid flow due to cone in porous medium.

The present analysis discusses the (MHD) stagnation point flow Powell–Eyring fluid by a stretching cylinder. Numerical solutions by using shooting technique are obtained and compared with the analytical solutions derived by homotopy analysis method (HAM) [30–45]. Also the obtained results through graphs and tabulated values are examined for various emerging parameters. Comparison for numerical and analytic solution is excellent.

2. Formulation

Here magnetohydrodynamic (MHD) stagnation point flow of Powell–Eyring fluid toward a stretching cylinder is considered (see Fig. 1). The fluid is assumed electrically conducting in the presence of a uniform magnetic field. Induced magnetic and

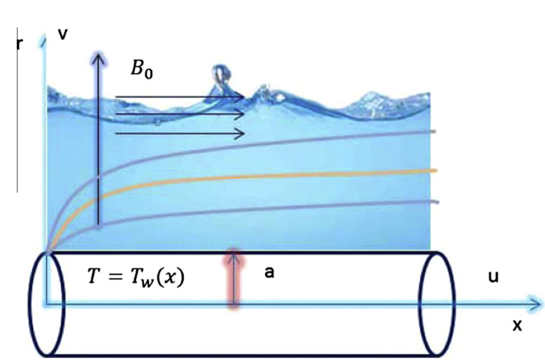

Figure 1 Geometry of the problem.

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