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Numerical investigation of MHD free convection flow of a non-Newtonian fluid past an impulsively started vertical plate in the presence of thermal diffusion and radiation absorption



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Abstract A numerical investigation is carried out on an unsteady MHD free convection flow of a well-known non-Newtonian visco elastic second order Rivlin-Erickson fluid past an impulsively started semi-infinite vertical plate in the presence of homogeneous chemical reaction, thermal radiation, thermal diffusion, radiation absorption and heat absorption with constant mass flux. The presence of viscous dissipation is also considered at the plate under the influence of uniform transverse magnetic field. The flow is governed by a coupled nonlinear system of partial differential equations which are solved numerically by using finite difference method. The effects of various physical parameters on the flow quantities viz. velocity, temperature, concentration, Skin friction, Nusselt number and Sherwood number are studied numerically. The results are discussed with the help of graphs. We observed that the velocity decreases with an increase in magnetic field parameter, Schmidt number, and Prandtl number while it increases with an increase in Grashof number, modified Grashof number, visco-elastic parameter and Soret number. Temperature increases with an increase in radiation absorption parameter, Eckert number and visco-elastic parameter while it decreases with increasing values of radiation parameter, Prandtl number and heat absorption parameter. Concentration increases with increase in Soret number while it decreases with an increase in Schmidt number and chemical reaction parameter.

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1. Introduction

MHD free convective flow plays an important role in petrochemical industry, cooling of nuclear reactors, heat exchanger design and geophysics as well as magneto-hydrodynamic power generation system. Chen [1] studied combined heat and mass transfer in MHD free convection from a vertical surface with Ohmic heating and viscous dissipation. Chamkha [2] analyzed MHD flow of a uniformly stretched vertical permeable surface in the presence of heat generation/absorption and a chemical reaction. Hayat and Mehmood [3] analyzed slip effects on MHD flow of third order fluid in a planar channel. Pal and Chatterjee [4] found heat and mass transfer in MHD non-Darcian flow of a micro polar fluid over a stretching sheet embedded in a porous media with non-uniform heat source and thermal radiation. Kim [5] studied unsteady MHD convective heat transfer past a semi-infinite vertical porous moving plate with variable suction. Chamkha [6] discussed unsteady MHD convective heat and mass transfer past a semi-infinite vertical permeable moving plate with heat absorption.

Convective flows with simultaneous heat and mass transfer under the influence of the chemical reaction arise in many transport processes both naturally and artificially in various branches of science and engineering. This phenomenon plays an important role in the chemical industry, power and cooling industry for drying, chemical vapor deposition on surfaces, cooling of nuclear reactors, and petroleum industries. Das [7] studied free convective MHD flow and heat transfer in a viscous incompressible fluid confined between a long vertical wavy wall and a parallel flat wall. Soundalgekar [8] examined free-convection effects on steady MHD flow past a vertical porous plate. Hossain et al. [9] studied the effect of radiation on free convection from a porous vertical plate. Srinivasacharya and Mendu [10] studied free convection in MHD micro polar fluid with radiation and chemical reaction effects. Srinivasacharya and RamReddy [11] studied natural convection heat and mass transfer in a micro polar fluid with thermal and mass stratification.

The fluid under consideration undergoes in some chemical reactions e.g. air and benzene reacts chemically, so also water and sulfuric acid. During such chemical reactions, there is always generation of heat. Combined heat and mass transfer problems with chemical reaction have importance in many processes and therefore received a considerable amount of attention in the recent years. In many chemical engineering processes chemical reactions take place between a foreign mass and working fluid which moves due to the stretch of a surface. The order of the chemical reactions depends on several factors. One of the simplest chemical reactions is the first-order reaction in which the rate of the reaction is directly proportional to the species concentration. The chemical reactions can be codified as either heterogeneous or homogenous processes. In most cases of chemical reactions the reaction rate depends on the concentration of the species itself. If the rate of reaction is directly proportional to the concentration then the reaction is said to be homogeneous reaction or first order reaction. Makinde et al. [12] investigated unsteady convection with chemical reaction and radiative heat transfer past a flat porous plate moving through a binary mixture. Kandasamy et al. [13] have analyzed effects of chemical reaction, heat and mass

transfer along a wedge with heat source and concentration in the presence of suction or injection. Das et al. [14] analyzed effects of mass transfer on flow past an impulsively started infinite vertical plate with constant heat flux and chemical reaction. Anjalidevi and Kandasamy [15] studied effects of chemical reaction, heat and mass transfer on laminar flow along a semi-infinite horizontal plate. Seddeek et al. [16] found effects of chemical reaction and variable viscosity on hydro-magnetic mixed convection heat and mass transfer for Hienmenz flow through porous media with radiation. Ibrahim et al. [17] studied effect of the chemical reaction and radiation absorption on the unsteady MHD free convection flow past a semi-infinite vertical permeable moving plate with heat source and suction. Patil and Kulkarni [18] investigated effects of chemical reaction on free convective flow of a polar fluid through a porous medium in the presence of internal heat generation. Pal and Mondal [19] discussed effects of Soret, Dufour, chemical reaction and thermal radiation on MHD non-Darcy unsteady mixed convective heat and mass transfer over a stretching sheet. Pal and Talukdar [20] analyzed analytically, unsteady magneto hydrodynamic convective heat and mass transfer in a boundary layer slip flow past a vertical permeable plate with thermal radiation and chemical reaction. Muthucumaraswamy and Ganesan [21] studied first-order chemical reaction on flow past an impulsively started vertical plate with uniform heat and mass flux. Dulal Pal [22] studied effect of chemical reaction on the dispersion of a solute in a porous medium. Mehta and Tiwari [23] analyzed dispersion in the presence of slip and chemical reactions in porous wall tube flow. Hayat and Nawaz [24] studied Soret and Dufour effects on the mixed convection flow of a second grade fluid subject to Hall and ion-slip currents. Patil et al. [25] analyzed double diffusive mixed convection flow over a moving vertical plate in the presence of internal heat generation and a chemical reaction. Srinivasacharya and Kaladhar [26] studied mixed convection flow of chemically reacting couple stress fluid in a vertical channel with Soret and Dufour effects. Srinivasacharya and Upendar [27] studied Soret and Dufour effects on MHD free convection in a micro polar fluid. Kaladhar and Srinivasacharya [28] analyzed mixed convection flow of chemically reacting couple stress fluid in an annulus with Soret and Dufour effects. Srinivasacharya and Kaladhar [29] examined Soret and Dufour effects on mixed convection flow of couple stress fluid in a non-Darcy porous medium with heat and mass fluxes. Srinivasacharya and Swamy Reddy [30] studied Soret and Dufour effects on mixed convection from a vertical plate in power-law fluid saturated porous medium. Hsiao [31] analyzed MHD mixed convection for visco-elastic fluid past a porous wedge. Hsiao [32] studied heat and Mass mixed convection for MHD visco-elastic fluid past a stretching Sheet with Ohmic dissipation.

Motivated by the above studies, an investigation has been carried out to study the MHD free convection flow of a non-Newtonian fluid past an impulsively started vertical plate in the presence of chemical reaction, thermal diffusion, radiation absorption, thermal radiation and heat absorption with constant mass flux. We have extended the work of Saravana et al. [33], who studied mass transfer effects on MHD viscous flow past an impulsively started infinite vertical plate with constant mass flux. This is not a simple extension of the previous work, and it varies in many aspects with the existing problem. The novelty of this study is the consideration of simultaneous

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