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Effects of thermal radiation, Soret and Dufour on an unsteady heat and mass transfer flow of a chemically reacting fluid past a semi-infinite vertical plate with viscous dissipation

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Abstract

In this paper, the influence of some thermo-physical properties of fluid on heat and mass transfer flow past semi-infinite moving vertical plate is considered. The fluid considered is optically thin such that the thermal radiative heat loss on the fluid is modeled using Rosseland approximation. The governing equations representing the physical model is a system of partial differential equations which are transformed into systems of coupled non-linear partial differential equation by introducing non-dimensional variables. The resulting equations are solved using the spectral relaxation method (SRM). The result shows that an increase in Eckert number of the fluid actually increases the velocity and temperature profiles of the flow. Whereas an increase in thermal radiation parameter reduces the temperature distribution when the plate is being cooled. The computational results for velocity, temperature and the concentration profiles are displayed graphically for various flow pertinent parameters.

Keywords: Soret and Dufour effect; Heat transfer; Viscous dissipation; Thermal radiation; Chemical reaction; Spectral relaxation method

1. Inroduction

The study of natural convection induced by the simultaneous action of buoyancy forces resulting from thermal and mass diffusion is of considerable interest in many industrial applications such as geophysics, drying process etc.

The thermal physics of MHD problems with mass transfer is of interest in power engineering and metallurgy. Prasad and Reddy [1] have studied the radiation and mass transfer effects on an unsteady MHD convective flow past a heated vertical plate in a porous medium with viscous dissipation. Ferdows et al. [2] studied soret and dufour effects on natural convection heat and mass transfer flow in a porous medium considering internal heat generation. While analyzing the heat and mass transfer characteristic of flow using exponential form of internal heat generation, they suggested that the velocity, temperature and concentration flow fields are appreciably influenced by dufour and soret

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effects. Worth note in their analysis is the fact that with increasing Dufour number and decreasing Soret number the velocity and concentration distributions reduced significantly, while temperature distribution increases along the flow field when IHG is present or absent. Motsa and Shateri [3] studied the effects of soret and dufour on steady MHD natural convection flow past a semi-infinite moving vertical plate in a porous medium with viscous dissipation in the presence of a chemical reaction. In the analysis of the model, they remarked that an increase in soret and dufor parameters increase significantly the velocity and concentration profiles of the flow but noted that dufour effect enhances flow velocity much more than soret. In many chemical engineering processes, there occurred chemical reaction between a foreign mass and the fluid in which the plate is moving. Rajesh and Vijaya [4] investigated radiation and mass transfer effects on MHD free convection flow past an exponentially accelerated vertical plate with variable temperature. Gnaneswara and Bhaskar [5] studied the effects of soret and dufour on steady MHD free convection flow past a semi-infinite moving vertical plate in a porous medium with viscous dissipation. Vempati and Laxmi-Narayana-Gari [6] investigated the effects of soret and dufour on unsteady MHD flow past an infinite vertical porous plate with thermal radiation. Gbadeyan et al. [7] studied the heat and mass transfer for soret and dufour effect on mixed convection boundary layer flow over a stretcing vertical surface in a porous medium filled with a viscoelastic fluid in the presence of magnetic field. soret and dufour effects on transient MHD flow past a semi-infinite vertical porous plate with chemical reaction was investigated by Shivaiah and Anand [8].

Heat and mass transfer (or double diffusion) finds applications in a variety of engineering process such as heat exchanger devices, petroleum reservoirs, chemical catalytic reactors and processes, nuclear waste disposal and others. Double diffusive flow is driven by buoyancy due to temperature and concentration gradients. When heat and mass transfer occur simultaneously in a moving fluid, the relations between the energy fluxes generated by the transverse action of both temperature and composition gradients and the driving potentials are more complicated. The energy flux caused by a composition gradient is called Dufour or diffusion-thermal effect. Temperature gradient can also creates mass fluxes, and this is the called Soret or thermal-diffusion effect. Generally, the thermal-diffusion and the diffusion thermo effects are of smaller order of magnitude than the effects prescribed by Fick's laws and are often neglected in heat and mass transfer processes by many researchers. The effects of soret for instance has been utilized for isotope separation. Subhakar and Gangadhar [9] investigated the effects of soret and dufour on MHD free convection heat and mass transfer flow over a stretching vertical plate with suction and heat source/sink. Olarewaju [10] studied similarity solution for natural convection from a moving vertical plate with internal heat generation and a convective boundary condition in the presence of thermal radiation and viscous dissipation. In the like manner, Makinde and Mutuku [11] examined the effect of the complex interaction between the electrical conductivity of the conventional base fluid and that of the nanoparticles under the influence of magnetic field in a boundary layer flow with heat transfer over a convectively heated flat surface using numerical approach called Runge–Kutta–Fehlberg method with shooting technique. Hayat et al. [12] investigated soret and dufour effects on magnetohydrodynamic (MHD) flow of casson fluid. Progress has been considerably made in the study of heat and mass transfer on magnetohydrodynamic (MHD) flows due to its application in many devices such as the MHD power generators and hall accelerators. Madhusudhana and Reddy [13] studied the effects of soret and dufour on hydromagnetic heat and mass transfer over a vertical plate in a porous medium with a convective surface boundary condition and chemical reaction. Bhavana et al. [14] investigated the soret effect on free convective unsteady MHD flow over a vertical plate with heat source. Venkateswarlu et al. [15] examined the effects of chemical reaction and heat generation on MHD boundary layer flow of a moving vertical plate with suction and dissipation. Sarada and Shanker [16] studied the effects of soret and dufour on an unsteady MHD free convection flow past a vertical porous plate in the presence of suction or injection. Prabhakar [17] examined radiation and viscous dissipation effects on unsteady MHD free convective mass transfer flow past an infinite vertical porous plate with hall current in the presence of chemical reaction.

The role of thermal radiation on the flow and heat transfer process is of major importance in the design of many advanced energy conversion system operating at higher temperature. Thermal radiation within this system is usually as a result of emission by hot walls and the working fluid, Seigel and Howell [18]. Effect of radiation and soret in the presence of heat source/sink on unsteady MHD flow past a semi-infinite vertical plate was studied by Srihari and Srinivas [19]. Makinde et al. [20] examined combined effects of buoyancy force, convective heating, Brownian motion, thermophoresis and magnetic field on stagnation point flow and heat transfer due to nanofluid flow towards a stretching/shrinking sheet. They observed that both the skin friction coefficient and the local Sherwood number decrease, while the local Nusselt number increases with increasing intensity of buoyancy force and note that dual solution exists for shrinking case. Effect of partial slip on hydromagnetic flow over a porous stretching sheet with