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Effect of Second Order Chemical Reaction on MHD Free Convective Radiating Flow over an Impulsively Started Vertical Plate

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Abstract An attempt has been made to study laminar convective heat and mass transfer flow of an incompressible, viscous and electrically conducting fluid over an impulsively started vertical plate with conduction-radiation embedded in a porous medium in presence of transverse magnetic field. The influence of both second order chemical reaction and heat generation are taken into account. The governing coupled partial differential equations are solved by Crank-Nicolson method. The effects of important physical parameters on the velocity, temperature and concentration have been analyzed through graphs. The results of the present study agree well with the previous solutions. Applications of the present study are shown in material processing systems and different industries. The important findings of present study are: chemical reaction parameter acts as resistive force to reduce the velocity whereas heat source parameter enhances the velocity.

Keywords MHD, Porous medium, Chemical reaction, Radiation, Heat source.

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1. Introduction

In several processes, there is a great importance of chemical reaction in the problems of MHD flow with heat and mass transfer and have therefore attracted a considerable amount of attention in the last several decades. If the rate of reaction is proportional to the nth power of concentration then the chemical reaction is said to be of order n. Also, we can say the order of a chemical reaction is defined as the sum of the powers of the concentration of the reactants in the rate equation of that particular chemical reaction. In a first order reaction, the rate of the reaction is doubled while in a second order reaction, the rate of the reaction is quadrupled. In first order reactions, the rate is proportional to the concentration raised to the first power. In second order reactions, the rate is proportional to the concentration raised to the second power. A second order reaction is a type of chemical reaction that depends on the concentrations of one second order reactant or on two first order reactants. This reaction proceeds at a rate proportional to the square of the concentration of one reactant or the product of the concentrations of two reactants. Some examples of second order reactions are

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$2NO2 \rightarrow 2NO + O2$, Nitrogen dioxide decomposing into nitrogen monoxide and oxygen molecule.

$2HI \rightarrow I2 + H2$, Hydrogen Iodide decomposing into iodine gas and hydrogen gas

$2NOBr \rightarrow 2NO + Br2$,In the gas phase, nitrosyl bromide decomposes into nitrogen oxide and bromine gas.

$NH4CNO \rightarrow H2NCONH2$, Ammonium cyanate in water isomerizes into urea.

According to the collision theory, the reactions occurs due to the collision of the reactant molecules. In the first and second order reactions the probability of collision is quite high as compared to the third and higher order reactions (It is quite unlikely that three or more than three molecules will collide at the same time). Due to this very low probability of colliding of molecules, the higher order reactions (> 3) are quite rare. Therefore, here only the second order reaction is considered. Possible applications of fluid flow with the second order equation can be found in many industries such as the power industry and chemical process industries. In many chemical engineering processes, there does occur the chemical reaction between a foreign mass and the fluid in which the plate is moving. These processes take place in numerous industrial applications viz., polymer production, manufacturing of ceramics or glassware and food processing.

Study of MHD flow with heat and mass transfer in porous and non-porous media due to the effect of magnetic fields on the boundary layer flow control and on the performance of many systems using electrically conducting fluids, has been a renewed interest for the researchers and scientists . This type of flow has also many applications in many engineering problems such as MHD generators, plasma studies, nuclear reactors, and geothermal energy extractions. Soundalgekar et al. [1] analysed the problem of free convection effects on Stokes problem for a vertical plate under the action of transversely applied magnetic field. Elbashbeshy [2] studied heat and mass transfer along a vertical plate under the combined buoyancy effects of thermal and species diffusion, in the presence of magnetic field. Helmy [3] presented an unsteady two-dimensional laminar free convection flow of an incompressible, electrically conducting (Newtonian or polar) fluid through a porous medium bounded by an infinite vertical plane surface of constant temperature. Ahmed et al. [4] studied the finite difference approach in porous media transport modelling for Magneto hydrodynamic unsteady flow over a vertical plate. Sheikholeslami et al. [5] investigated the impact of Lorentz forces on Fe3O4-water ferrofluid entropy and energy treatment within a permeable semi annulus. In their study, the behavior of magnetic nanofluid through a porous space with innovative computational method has been displayed and for involving porous media, non-Darcy approach was considered. Abro et al. [6] elucidated the heat transfer in magnetohydrodynamic free convection flow of generalized ferrofluid with magnetite nanoparticles. Lund et al. [7] reported the Dual solutions and stability analysis of a hybrid nanofluid over a stretching/shrinking sheet executing MHD flow.

In several processes, there is a great importance of chemical reaction in the combined heat and mass transfer problems and have therefore attracted a considerable amount of attention in the last several decades. Chemical reactions are either homogeneous or heterogeneous processes. The reaction is homogeneous, if it occurs uniformly through a given phase. In well mixed system, it takes place in the solution while a heterogeneous reaction occurs at the interface, i.e. in a restricted region or within the boundary of a phase. If the rate of reaction is proportional to