Heat Transfer in Magnetohydrodynamic Flow of a Casson Fluid with Porous Medium and Newtonian Heating

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This paper deals with exact solutions for unsteady magnetohydrodynamic (MHD) flow of a Casson fluid over an infinite vertical oscillating plate embedded in a porous medium. The analysis of heat transfer in the presence of Newtonian heating is also considered. Some suitable non-dimensional variables are introduced. The governing equations together with imposed conditions are transformed into dimensionless forms. Expressions for the velocity and temperature fields are obtained using the Laplace transform. Skin-friction and Nusselt number are also evaluated. Solution for Newtonian fluid is also reduced as a special case. The graphical results show that velocity decreases significantly with increases of magnetic effects, but it increases when either conjugate parameter or porosity parameter increases. The main outcomes of the present work is that fluid flow can be controlled by the increasing the values of Prandtl number as well as by the increasing of Casson parameter.

KEYWORDS: Casson Fluid, MHD Flow, Porous Medium, Newtonian Heating, Exact Solutions.

1. INTRODUCTION

The flow of Casson fluids in the presence of heat transfer is widely used in the processing of chocolate, foams, syrups, nail, toffee and many other foodstuffs.¹ Casson² was the first who introduced this model to simulate industrial inks originally. Later on, a substantial study has been done on the Casson fluid flow because of its important practical applications. Mustafa et al.³ have studied the heat transfer flow of a Casson fluid over an impulsive motion of the plate using the homotopy method. The exact solution of forced convection boundary layer Casson fluid flow toward a linearly stretching surface with transpiration effects are reported by Mukhopadhyay et al.⁴ In the same year, Rao et al.⁵ considered the velocity and thermal slip conditions on the laminar boundary layer heat transfer flow of a Casson fluid past a vertical plate. Recently, Qasim and Noreen⁶ discussed the viscous dissipation effects on the Casson fluid flow over a porous shrinking surface. They reported that the dual solutions are possible for some values of suction parameter. Amongst the various investigation on Casson fluid, the reader is referred to some new attempts made in Refs. [7–11], and the references therein. Few other interesting studies on natural convection and non-Newtonian fluids are given in Refs. [12–15].

On the other hand, MHD problems in boundary layer flow through a porous medium has many important applications such as those involving heat removal from nuclear fuel debris, drug permeation through human skin, oil flow through porous rock and filtration of solids from liquids. Beg et al.¹⁶ have analyzed the MHD heat transfer flow with the thermal heat flux in the presence of porous medium. They obtained the solutions analytically by using the Laplace transform and numerically by Network Numerical Simulation methods. Muthucumaraswamy and Valliammal¹⁷ considered the chemical reaction effects on unsteady MHD flow with variable temperature and concentration over an exponentially accelerated vertical plate, and later Rajasekhar et al.¹⁸ extended the same problem by considering radiation effects. Peristaltic flow with inclined magnetic field and convective boundary conditions in an asymmetric inclined channel was studied Noreen and Qasim.¹⁹ They discussed three different cases namely, uniform, single acceleration and periodic acceleration of the plate by assuming ramped and isothermal