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Effect of partial slip on hydromagnetic flow over a porous stretching sheet with non-uniform heat source/sink, thermal radiation and wall mass transfer

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Abstract In this work, we have investigated the effect of partial slip on hydromagnetic boundary layer flow in porous medium over a stretching surface with space and temperature dependent internal heat generation/absorption, thermal radiation and wall mass transfer (suction/blowing). The basic boundary layer equations for momentum and heat transfer, which are non-linear partial differential equations are converted into non-linear ordinary differential equations by means of similarity transformations. The dimensionless governing equations for this investigation are solved analytically using hypergeometric functions. The results are carried out for prescribed surface temperature (PST) and prescribed power law surface heat flux (PHF). The effect of partial slip parameter with magnetic parameter, porosity parameter, wall mass transfer parameter (suction/blowing), space and temperature dependent internal heat generation/absorption parameter, Prandtl number and radiation parameter on velocity and temperature distributions are depicted graphically and are analyzed in detail.

1. Introduction

Due to the numerous applications in industrial manufacturing processes, the problem of flow and heat transfer due to stretching surfaces has attracted the attention of researchers for the past four decades being a subject of considerable interest in the contemporary literature [1–5]. Some of the application areas are hot rolling, paper production, metal spinning, drawing plastic films, glass blowing, continuous casting of metals and spinning of fibers, etc. [6]. In all these cases, the quality of the final product depends on the rate of heat transfer at the stretching surface. Many of the flow properties were investigated by the followers [7–11] using no-slip condition on the wall. However, as stated in [12], when the fluid is particulate such as emulsions, suspensions, foams and polymer solutions, the no-slip condition is inadequate. In such cases the suitable boundary condition is the partial slip. Wang [13] discussed the partial slip effects on the planar stretching flow. Partial slip flow over a stretching sheet is investigated by many researchers [14–18].

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Nomenclature

B_0	magnetic field strength	q'''	non-uniform heat source/sink
Mn	magnetic parameter	A^*, B^*	space and temperature dependent internal heat generation/absorption
T	local temperature of the fluid	σ^*	Stefan–Boltzmann constant
Pr	Prandtl number	k^*	mean absorption coefficient
$Re_x^{1/2}$	Reynolds number	T_w	temperature of the sheet
C_f	local skin friction coefficient	T_∞	temperature of the fluid far away from the sheet
u, v	velocity component in x and y direction	l	the characteristic length
x, y	coordinates along and perpendicular to the sheet	M	confluent hypergeometric function
σ	electric conductivity	N	radiation parameter
K	permeability of the porous medium		
s	wall mass transfer	*Greek symbols*	
λ	porosity parameter,	θ	dimensionless temperature
L	partial slip parameter	η	dimensionless space variable
τ_w	wall shearing stress	ϑ	the kinematic viscosity
k	thermal conductivity	ρ	density
c_p	specific heat of constant pressure		

The applied magnetic field may play an important role in controlling momentum and heat transfers in the boundary layer flow of different fluids over a stretching sheet. Fang et al. [19] found an exact solution for MHD slip flow over a stretching sheet. Yazdi et al. [20] have investigated the MHD slip flow and heat transfer over non-linear permeable stretching surface with chemical reaction and Turkyilmazoglu [21] studied the effect of heat and mass transfer of the mixed hydro-dynamic/thermal slip MHD viscous flow over a stretching sheet. Recently, Mukhopadhyay [22] has done a work on slip effects on MHD boundary layer flow over an exponentially stretching sheet with suction/blowing and thermal radiation.

The study of convective flow through porous media has received a great deal of research interest over the last three decades due to its wide and important applications in environmental, geophysical and industrial problems. Prominent applications include the utilization of geothermal energy, the migration of moisture in fibrous insulation, drying of a porous solid, food processing, casting and welding in manufacturing processes, the dispersion of chemical contaminants in different industrial processes, the design of nuclear reactors, chemical catalytic reactors, compact heat exchangers, solar power and many others. Hayat et al. [23] investigated the slip flow and heat transfer of a second grade fluid past a stretching sheet through a porous space.

The study of heat generation or absorption effects is important in view of several physical problems such fluids undergoing exothermic or endothermic chemical reactions. Although, exact modeling of internal heat generation or absorption is quite difficult, some simple mathematical models can express its average behavior for most physical situations. Heat generation or absorption has been assumed to be constant, space-dependent or temperature-dependent. Very recently, Abdul Hakeem et al. [24] studied the effect of heat radiation in a Walter's liquid B fluid over a stretching sheet with non-uniform heat source/sink and elastic deformation with out considering the partial slip effect.

A close observation of the literature reveals that, to the best of authors' knowledge, so for no one has considered partial slip effect on MHD flow in porous medium over a stretching surface with space and temperature dependent internal heat generation/absorption, thermal radiation and wall mass transfer (suction/blowing). This fact motivates us to propose the same for the present investigation. The analytical results are carried out for prescribed surface temperature (PST) and prescribed power law surface heat flux (PHF).

2. Mathematical formulation

Consider a steady, laminar and two-dimensional radiative slip flow of an incompressible Newtonian fluid over a porous stretching sheet in the presence of transverse magnetic field of strength B_0 with space and temperature dependent heat source/sink and suction/blowing. The flow is assumed to be in the x-direction, which is chosen along the sheet and the y-axis perpendicular to it. The sheet issues from a thin slit at the origin $(0, 0)$. It is assumed that the speed of a point on the plate is proportional to its distance from the slit and that the boundary-layer approximations are still applicable. Let x-axis along the surface, y-axis being normal to it. Let u

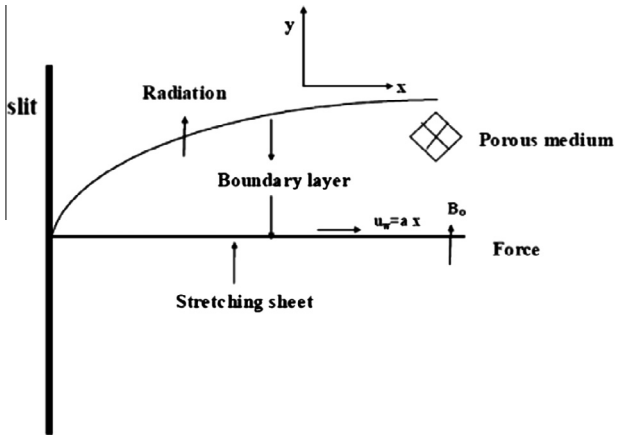

Figure 1 A sketch of the physical model.