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Effects of conduction and convection on magneto hydrodynamic flow along a vertical flat plate with viscous dissipation and heat generation

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Abstract

Combined effects of conduction and convection on magneto hydrodynamic (MHD) boundary layer flow with viscous dissipation and heat generation along a vertical flat plate have been described in the present work. The governing boundary layer equations with associated boundary conditions for this phenomenon are converted to non-dimensional form using a suitable transformation. The resulting non-linear partial differential equations are then solved using the implicit finite difference method with Keller–box scheme. The numerical results in terms of the skin friction coefficient, the surface temperature, the velocity and the temperature profiles over the whole boundary layer are shown graphically for different values of the Prandtl number Pr, the magnetic parameter M, viscous dissipation parameter N and the heat generation parameter Q.

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Keywords: Magneto hydrodynamic ; Free convection ; Prandtl number ;Viscous dissipation ; Heat generation.

1. Introduction

Free convection flow is often encountered in cooling of nuclear reactors or in the study of the structure of stars and planets. Along with the free convection flow the phenomenon of the boundary layer flow of an electrically conducting fluid up a vertical flat plate in the presence of a strong magnetic field is also very common because of its application in nuclear engineering in connection with the cooling of reactors. Gebhart [1] has shown that the viscous dissipation effect plays an important role in natural convection in various devices which are subjected to large deceleration or which operate at high rotative speeds and also in strong gravitational field processes on large scales (on large planets) and in geological processes. The effect of pressure stress work and viscous dissipation in some

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natural convection flows has been analyzed by Joshi and Gebhart [1]..Alim *et al.* [3] investigated the Joule heating effect on the coupling of conduction with MHD free convection flow from a vertical flat plate. Alim *et al.* [4] also studied the effect of viscous dissipation & pressure stress work on free convection along a vertical flat plate with

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Joule heating and heat conduction.

Nomenclature

b	plate thickness	u,v	velocity components along x,y direction
C_{fx}	local skin-friction coefficient	x,y	streamwise and transverse co-ordinate
C_p	specific heat at constant pressure		
f	dimensionless stream function	***Greek symbols***	
h	dimensionless temperature	β	volumetric coefficient
H_0	applied magnetic field strength.	ψ	stream function
M	magnetic parameter	η	dimensionless similarity variable
N	viscous dissipation parameter	ρ	density of the fluid inside the boundary layer
Pr	Prandtl number	ν	kinematic viscosity
Q	Heat generation parameter	μ	viscosity of fluid
T	temperature of the flow fluid	θ	dimensionless temperature
T_b	temperature at outside of the plate	τ_w	shearing stress
T_∞	temperature of the ambient fluid		

Mamun *et al.* [6] analyzed effects of conduction and convection on MHD flow with viscous dissipation from a vertical flat. Merkin and Pop [7] studied the conjugate free convection on a vertical surface. Pozzi and Lupo [8] investigated the coupling of conduction with laminar convection along a flat plate.

At last Combined effects of viscous dissipation and temperature dependent thermal conductivity on MHD free convection flow with conduction and joule heating along a vertical flat plate has been investigated by Nasrin and Alim[9]. The present study is to incorporate the idea that the combined effects of conduction and convection on MHD free convection boundary layer flow with viscous dissipation and heat generation along a vertical flat plate. The governing boundary layer equations are transformed into a non-dimensional form and the resulting non-linear system of partial differential equations are solved numerically by very efficient implicit finite difference method together with Keller-box scheme [5].

2. Formulation of the Problem

At first we consider a steady, two-dimensional natural convection flow of an electrically conducting, viscous incompressible and electrically conducting along a vertical flat plate of length l and thickness b(Fig. 1).

It is assumed that heat is transferred from the outside surface of the plate, which is maintained at a constant

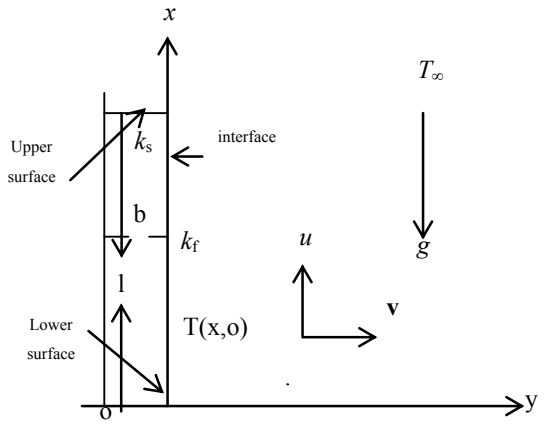

Fig. 1. Physical configuration and co-ordinate system