

# ON MHD MIXED CONVECTION WITH SORET AND DUFOUR EFFECTS PAST A VERTICAL PLATE EMBEDDED IN A POROUS MEDIUM

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**Abstract** --The paper studies the mixed convection flow of an incompressible Boussinesq fluid under the simultaneous action of buoyancy and transverse magnetic field with Soret and Dufour effects over a vertical porous plate with constant heat flux embedded in a porous medium. Under suitable nondimensionalization, the governing non-linear coupled differential equations are solved numerically using shooting quadrature. Tabular and graphical results are presented and discussed quantitatively. Results obtained which compare favourably well with published data show that the local skin friction is enhanced by the Sorets and Dufour effects.

**Keywords** – MHD mixed convection; Vertical plate; Heat and mass transfer; Porous medium; Soret and Dufour effects

## I. INTRODUCTION

The study of mixed convection flow with simultaneous heat and mass transfer past a vertical plate under the influence of a magnetic field and chemical reaction has applications in many areas of science and engineering (Chen and Armaly, 1987). Heat and mass transfer occur in processes, such as drying, evaporation at the surface of a water body, and energy transfer in a wet cooling tower. In astrophysics and geophysics, it is applied to study the stellar and solar structures, interstellar matter and radio propagation through the ionosphere. In industries, it finds its application in cooling of nuclear reactors and magnetohydrodynamic (MHD) power generators, MHD pump, chemical vapour deposition on surfaces, formation and dispersion of fog, distribution of temperature and moisture over agriculture fields, etc. The problem of mixed convection under the influence of magnetic field has attracted numerous researchers in view of its wide applications. Soundalgekar *et al.* (1979) investigated the problem of free convection effects on stokes problem for a vertical plate with transverse applied magnetic field whereas Elbashbeshy (1997) studied MHD heat and mass transfer problem along a vertical plate under the combined buoyancy effects of thermal and species diffusion. Singh and Dikshit (1988) studied hydrodynamic flow past a continuously moving semi-infinite plate with large suction, while in Bestman (1990) the focus was on chemically reacting species. Abd El-Aziz (2007) studied the combined effects of MHD heat and mass transfer on a boundary layer flow of a viscous incompressible fluid having temperature dependent viscosity over a stretching surface. A comprehensive account of the boundary layers flow over a

vertical flat plate embedded in a porous medium can be found in Pop and Ingham (2001), Geindreau and Auriault (2002), Makinde and Ogulu (2008).

In all these studies Soret–Dufour effects were assumed to be negligible. However, when chemical species are introduced at a surface in fluid domain, with different (lower) density than the surrounding fluid, both Soret (thermo-diffusion) and Dufour (diffusion-thermal) effects can be influential. The effect of diffusion-thermo and thermal diffusion of heat and mass has been developed from the kinetic theory of gases by Chapman and Cowling (1952) and Hirshfelder *et al.* (1954). They explained the phenomena and derived the necessary formulae to calculate the thermal diffusion coefficient and the thermal-diffusion factor for monatomic gases or for polyatomic gas mixtures. Recently, Bég *et al.* (2009) investigated numerically the free convection magnetohydrodynamic heat and mass transfer from a stretching surface to a saturated porous medium with Soret and Dufour effects.

The present study extends the recent work of Makinde (2009) to include MHD mixed convection with Dufour and Soret effects past a vertical plate embedded in a porous medium. Solutions are presented in both graphical and tabular form and given in terms of the local skin friction, plate surface temperature and local mass transfer rate for various parametric values. It is hoped that the results obtained will not only provide useful information for applications, but also serve as a complement to the previous studies.

## II. MATHEMATICAL FORMULATION

We consider steady, unidirectional flow of a laminar, incompressible, electrically conducting fluid past a semi-infinite porous vertical plate with constant heat flux embedded in a porous medium in the presence of a transversely imposed magnetic field (see Fig. 1). In addition, there is no applied electric field and all of the Hall effects are neglected. Since the magnetic Reynolds number is very small for most fluid used in industrial applications, we assume that the induced magnetic field is negligible. Let the  $x$ -axis be taken along the direction of plate and  $y$ -axis normal to it, then under the Boussinesq and boundary-layer approximations, the fluid equations for momentum, energy balance and concentration governing the problem under consideration can be written in dimensionless form as;

$$-\frac{du}{dy} = \frac{d^2u}{dy^2} + Gr\theta + Gm\phi + M(U-u) + \frac{U-u}{K}, \quad (1)$$