Advances in Applied Mathematics and Mechanics
Adv. Appl. Math. Mech., Vol. **2**, No. 3, pp. 286-302

DOI: 10.4208/aamm.09-m0948
June 2010

Unsteady Hydromagnetic Couette Flow within Porous plates in a Rotating System

G. S. Seth[1,*], Md. S. Ansari[1] and R. Nandkeolyar[1]

[1] *Department of Applied Mathematics, Indian School of Mines, Dhanbad-826004, India*

Received 29 May 2009; Accepted (in revised version) 25 November 2009

Available online 25 March 2010

Abstract. Unsteady hydromagnetic Couette flow of a viscous incompressible electrically conducting fluid in a rotating system is studied when the fluid flow within the channel is induced due to the impulsive movement of the one of the plates of the channel. The plates of the channel are considered porous and the magnetic field is fixed relative to the moving plate. Exact solution of the governing equations is obtained by Laplace transform technique. The expression for the shear stress at the moving plate is also obtained. Asymptotic behaviour of the solution is analyzed for small as well as large values of time t to highlight the transient approach to the final steady state flow and the effects of rotation, magnetic field and suction/injection. It is found that suction has retarding influence on the primary as well as secondary flow where as injection and time have accelerating influence on the primary and secondary flows.

AMS subject classifications: 76W05, 76U05

Key words: MHD Couette flow, suction/injection, magnetic field, impulsive movement of the plate, Ekman-Hartmann boundary layer, Rayleigh boundary layer, spatial oscillations, inertial oscillations.

1 Introduction

Theoretical and/or experimental investigation of the problems of the flow of an electrically conducting fluid in the presence of electromagnetic fields is carried out by many researchers under different conditions and configurations to discuss various aspects of the problems and to find its application in science and engineering. There are many natural phenomena and engineering problems susceptible to magnetohydrodynamic analysis. It is useful in Astrophysics because much of the universe is filled with

*Corresponding author.
Email: gsseth_ism@yahoo.com (G.S. Seth), shariffuddin@gmail.com (Md.S. Ansari), rajnandkeolyar@gmail.com (R. Nandkeolyar)

widely spaced charged particles and permeated by magnetic fields. Geophysicists encounter MHD phenomena in the interactions of conducting fluids and magnetic fields that are present in and around heavenly bodies. Engineers employ MHD principles in the design of heat exchangers, pumps and flow meters, in solving space vehicle propulsion, control and reentry problems; in creating novel power generating systems and in developing confinement schemes for controlled fusion.

In general, the governing equations of MHD flow problems are inherently nonlinear. Simplified models are, therefore, studied in literature with a view to analyze different aspects of fluid flow features. Of these models, the one corresponding to MHD Couette flow is known to lead to the equations for which analytical solution can be obtained in principle [1–9]. The study of unsteady MHD Couette flow is important from practical point of view because fluid transient may be expected at the start-up time of MHD devices, namely, MHD generators, MHD pumps, MHD accelerators, flow meters and nuclear reactors. Keeping in view this fact Katagiri [2] investigated unsteady MHD Couette flow of a viscous incompressible electrically conducting fluid in the presence of a uniform transverse magnetic field when the fluid flow within the channel is induced due to the impulsive motion of one of the plates. Katagiri [2] analyzed this problem when the magnetic field is fixed relative to fluid. Singh and Kumar [9] considered the problem studied by Katagiri [2] when the magnetic field is fixed relative to the moving plate. They also studied this problem when the fluid motion within the channel is induced due to uniformly accelerated movement of one of the plates.

The theory of rotating fluids [10] is highly important due to its occurrence in various natural phenomena and for its applications in various technological situations which are directly governed by the action of Coriolis force. The broad subjects of Oceanography, Meteorology, Atmospheric science and Limnology all contain some important and essential features of rotating fluids. The fluid flow problems in rotating medium have attracted many scholars and there appeared a number of studies in literature viz. Greenspan and Howard [11], Holton [12], Walin [13], Siegmann [14], Puri [15], Puri and Kulshrestha [16], Mazumder [17], Ganapathy [18], Das et al. [19], Hayat et al. [20] and Hayat and Hutter [21]. The study of simultaneous effects of rotation and magnetic field on MHD flow problem may find applications in the areas of Geophysics, Astrophysics and fluid engineering. Keeping in view this fact, several researchers, namely, Hide and Roberts [22], Nanda and Mohanty [23], Gupta [24], Sounalgekar and Pop [25], Gupta and Soundalgekar [26], Debnath [27, 28], Acheson [29], Seth and Jana [30], Seth and Maiti [31], Prasad Rao et al. [32], Seth et al. [33, 34], Chandran et al. [35], Singh et al. [36], Singh [37], Hayat et al. [38–44], Hayat and Abelman [45], Wang and Hayat [46] and Das et al. [47] investigated MHD flow problems in rotating medium considering different aspects of the problems.

Unsteady hydromagnetic Couette flow of a viscous incompressible electrically conducting fluid in a rotating channel is investigated by Seth et al. [33, 34], Singh [37] and Das et al. [47] when the magnetic field is fixed relative to the fluid where as Chandran et al. [35] and Singh et al. [36] considered this problem when the magnetic field is fixed