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Hall effects on the magnetohydrodynamic shear flow past an infinite porous flat plate subjected to uniform suction or blowing

A.S. Gupta [a], M. Guria [b,*], R.N. Jana [b]

[a] Department of Mathematics, Indian Institute of Technology, Kharagpur 721302, India
[b] Department of Applied Mathematics with Oceanology and Computer Programming, Vidyasagar University, Midnapore 721102, India

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ABSTRACT

An analysis is made of Hall effects on the steady shear flow of a viscous incompressible electrically conducting fluid past an infinite porous plate in the presence of a uniform transverse magnetic field. It is shown that for suction at the plate, steady shear flow solution exists only when $S^2 < Q$, where S and Q are the suction and magnetic parameters, respectively. The primary flow velocity decreases with increase in Hall parameter m. But the cross-flow velocity first increases and then decreases with increase in m. Similar results are obtained for variation of the induced magnetic field with m. It is further found that for blowing at the plate, steady shear flow solution exists only when $S_1^2 < Q$, where S_1 is the blowing parameter.

1. Introduction

In the study of high-speed viscous flow past a two-dimensional blunt body, it is generally necessary to consider a curved shock wave formed near the body. This shock produces a layer of large entropy gradients and high vorticity close to the surface of the body. Downstream of the nose of the body the pressure as determined from the inviscid flow theory, will be uniform through the vorticity layer. Such a situation prevails, for instance in the study of hypersonic viscous flow past a flat plate where the inviscid free stream flow is rotational.

With the advent of very high-speed (hypersonic) flight, the subject of magnetohydrodynamics (MHD) has assumed great significance. This is due to the fact that ahead of a high-speed body entering the atmosphere a shock wave, as mentioned earlier is formed between the wave and body surface and there will be a layer of gas at extremely high temperature due to shock compression as well as frictional heating in the boundary layer. At such high temperatures, the gas becomes ionized and hence becomes electrically conducting. Hence it can be expected that by the application of a suitably oriented magnetic field to the flow in the shock layer, the flow pattern can be modified and this in turn causes a change in the rate of heat transfer to the surface. When the ionized gas is sufficiently dense, the electron-atom collision frequency is large enough so that the tendency for the electrons to spiral around the magnetic field lines is suppressed. However, if the gas density is low (as in a partially ionized gas) and/or the magnetic field is very strong so that the electron cyclotron frequency $\omega = eB/m$ (where e, B and m denote the electron charge, the applied magnetic field and mass of an electron) exceeds the collision frequency, the electron can make number of cyclotron orbits between collisions and will drift in a direction perpendicular to the direction of the magnetic and electric fields. Thus if an electric field is applied at right angle to the magnetic field, the whole current will not flow along the electric field. This tendency of the electric current to flow across an electric field in the presence of a magnetic field is called Hall effect and the corresponding current is known as Hall current [1]. Further the gyromotion of the electrons decreases the electrical conductivity of the gas normal to the magnetic field. Thus in this case the electrical conductivity becomes a tensor. It should be recognized that the approximation of tensor conductivity is a good one for compressible gaseous plasmas.

Hall effects are likely to be important in many astrophysical situations as well as in Laboratory plasma. Sherman and Sutton [2] studied the effect of Hall current on the efficiency of a MHD generator. It is important to note that the efficiency of a generator depends on how much of the power is delivered to the external load and how much is dissipated in internal resistance. This consideration involves such problem as Hall current flow which tends to reduce the efficiency. This problem is overcome to a great extent by using segmented electrodes which tend to reduce the flow of Hall current [2]. Sato [3] and Tani [4] investigated Hall effects in steady flows of a partially ionized gas between two stationary parallel plates. Couette motion of an ionized gas between two parallel plates with Hall effect was examined by

* Corresponding author.
E-mail address: mrinmoy9832@yahoo.com (M. Guria).

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