ABSTRACT

In several astrophysical and geophysical situations, it is possible that the conditions exterior to a surface may influence the flow of fluid in a layer adjacent to the surface. For example, removal of angular momentum from the surface layers of the Sun by the solar wind results in efficient turbulent exchange near the surface and a differential rotation. Natural flows where the turbulent processes transmit the direct effect of the boundary deeper into the fluid than the usual Ekman layer can be modeled by a geometry bounded at the bottom by a layer of permeable medium. Such a model is proposed by Bretherton and Spiegel. When the solid boundary at the bottom is replaced by a thin permeable layer, the vertical flux from the interior increases and the permeable medium imparts the new rotation rate to the incoming fluid very effectively. The entire process speeds up. Kroll and Veronis extended the ideas of Bretherton and Spiegel into a detailed theory. However, it should be noted that they used the Darcy's law to represent the motion in the porous medium. Since a porous solid can
not deform as a fluid would, in response to a changing angular velocity, the entire porous layer has uniform angular velocity in space and regarded as a convection zone. The centrifugal pumping occurs through the entire porous layer, in addition to the Ekman suction which is still present. There is no possibility for the development of shear layers in the porous medium. The Ekman layer appears only outside the porous layer, in the free fluid. This is a transition zone which arises to couple the zones of different angular velocities, namely, the zone near the boundary and the zone away from the boundary.

Though it is ideally assumed in previous works that the angular velocity is constant in space in a layer at the boundary, it is natural to expect that the angular velocity slowly decreases in space (nearly constant) in this layer, because of the fact that the turbulent exchange decreases with the distance from the boundary. Adjoining this layer arises a transition zone of the features described already. It is established in this paper that it is appropriate to model such flows using a highly permeable layer at the boundary using Brinkman's law rather than the Darcy's law. Since the Brinkman's law accounts for viscous stress and also takes convective terms into consideration, this allows the interstitial fluid to deform, in response to changing
angular velocity, to the extent permitted by the porosity of
the medium and simulates the flow of required nature.

Motivated by these ideas, a semi-infinite expanse of a
viscous incompressible fluid bounded below by a permeable
disk of finite thickness is considered. The entire system
is in a state of rigid rotation initially. An unsteady flow
over the state of rigid rotation is created by
differentially rotating the porous disk impulsively. We
consider the steady motion corresponding to this problem.
The Brinkman’s law is used to represent the fluid motion in
the porous medium and the Navier Stokes equation represents
the motion in the free fluid. The solution obtained in the
two regions subject to boundary conditions and far field
conditions are matched at the interface using the principle
of conservation of momentum across the interface

The steady flow consists of a layer of slowly
decreasing angular velocity in the porous medium and a
boundary layer flow on either side of the fluid porous
medium interface, providing smooth transition to the
interior. In comparison to the earlier works wherein the
angular velocity is uniform in space in a neighbourhood of
the boundary, the present model is an appropriate one to simulate a rotating flow with mixed layers near the surface.

Chapter I deals with the general description and governing equations for flows through porous media. Chapter II deals with the problem of simulating a rotating flow with mixed layers near the boundary, using a layer of high permeability on the surface of the rotating fluid.