SYNOPSIS

It is well known that when a vessel containing viscous liquid is emptied and kept aside, or when a flat plate is withdrawn from a reservoir containing viscous liquid, a thin film of liquid clings along the wall of the vessel or the plate, and flows downwards under the action of gravity. This problem of thin liquid films finds importance in many scientific and industrial applications, for example, painting, dip coating, lubrication of moving machine parts, electroplating, photographic film coating, and drainage of large process vessels and scientific instruments. The flow of liquids in thin films also occurs naturally in the flow of rain down the window panes, or inclined road ways, and sloping roofs and dams. The present thesis has been devoted to the study of flow in thin films of Newtonian and non-Newtonian liquids past vertical plane surfaces with and without magnetic field. The work has been divided into seven chapters.

Chapter I, which is introductory, commences by highlighting the importance of film flows. The discussion includes concepts of drainage, withdrawal, removal, flow of thin films of non-Newtonian fluids, flow of thin films of electrically conducting fluids and wavy laminar film flow.

Chapter II is concerned with the problem of flow of a Newtonian viscous liquid past a vertical porous plane surface to examine the effect of suction and injection on the flow characteristics. This problem is of importance in trickling filters, chemical process packing towers, cooling films, and flow past porous electrodes and electrochemical reactors. Considering two cases, when the plate is stationary, and when it is in motion, the effect of porosity on the flow has been determined. It is found that when the plate is stationary, the velocity of the liquid increases with increase in the suction velocity, and decreases with increase in the injection velocity, and for a given suction or injection velocity, the velocity of the liquid increases with increase in time, and approaches to the steady state case. But, when the plate is in motion, the velocity of the liquid decreases with increase in the suction velocity, and increases with increase in the injection velocity in the constant film thickness region and also in the dynamic meniscus region provided that the gravitational force is greater than the surface tension force. In this case, the stagnation point and the minimum pressure point on the free surface have also been obtained. In the case of injection, there always exists a unique stagnation point and also a minimum pressure point. But, in the case of suction, the stagnation point does not always exist, and there is no minimum pressure point. [Appl. Sci. Res., Vol.35, p.373-391 (1979)].

Chapter III is devoted to the study of the effect of magnetic field on viscous lifting and drainage of a conducting liquid past a vertical plane surface moving with a velocity f(t). Specializing to the case when the plane surface moves with a constant acceleration, it has been found that the film thickness, for large magnetic fields, increases with increase in the magnetic field. [Appl. Sci. Res., Vol. 33, p.141-149 (1977)].

Chapter IV discusses the problem for finding the stagnation and minimum pressure points for thin films of power-law and Bingham liquids. It has been found that stagnation point or minimum pressure point film thickness is a function of two parameters : one, characterizing the liquid, and the other, representing parallel flow film thickness. It has also been shown that in the case of power-law liquids, both the stagnation point and minimum pressure point exist, while in the case of Bingham liquids, the existence of one or both the points, for a given non-dimensional parallel flow film thickness, depends upon the value of the Bingham number. Furthermore, it has been found that there may be situations when both the points can coincide; for example, in the case of Newtonian liquids, the two points coincide, if the parallel flow film thickness is $\sqrt{2-\sqrt{3}}$. [A.I.Ch.E.J., Vol.25, p. 900-903 (1979)].

Chapter V relates to the problem of determining the flow characteristics of a thin film of conducting non-Newtonian power-law liquid adhering to a vertical plate in the presence of a magnetic field. The problem has been investigated for two cases, namely, the plate stationary and the plate withdrawn with a constant velocity from a liquid bath. It is found that the effect of magnetic field is to decrease the velocity in the case of stationary plate and to increase the velocity in the case of moving plate. The flow rate of the film, however, decreases with increase in the magnetic field in both the cases, and the flow of the film is thereby restricted. Moreover, when a dilatant liquid film flows along a stationary plate, there is found to exist a critical value of the generalized Hartmann number, and if the generalized Hartmann number exceeds its critical value, there appears a zone near the free surface in which the liquid flows like a quasi-solid body. This zone widens with increase in the generalized Hartmann number.

Chapter VI deals with the study of flows in thin films of viscoelastic liquids obeying the models proposed by Oldroyd, and Coleman and Noll. In the problem of drainage of visco-elastic liquids using Oldroyd's model, the exact solutions have been obtained. Qualitatively, the viscoelasticity has been found to decrease the flow rate and increase the film thickness. And, in the problem of unsteady laminar flow in a thin film of Coleman and Noll-liquid adhering to a vertical plate with four states of the plate : stationary, moving with constant velocity, moving with constant acceleration and oscillating, it has been found that the viscoelasticity resists the fall of the film. The film thickness has been found to increase with increase in the viscoelasticity.

Finally, Chapter VII consists of investigating the problem of wave motion in falling liquid films of variable viscosity. Such a case arises in the flow of a condensate down a wall with a linear temperature gradient through the film. The viscosity μ may also be taken to be governed by the relation

$$\mu = \mu_h e^{-\alpha \frac{y}{h}} ,$$

where μ_h is the viscosity at the free surface, h the thickness of the film, and α a constant signifying how rapidly μ changes with the increase in y, y being measured in the direction of h. The non-dimensional wave number, wavelength and Weber number have been obtained. It is found that for values of α in $0 \leq \alpha \leq \beta$, where $\beta \simeq 1.4799$, the wave number and Weber number exist if wave celerity < 3. However, for values of $\alpha > \beta$, the wave number and Weber number exist only if the wave celerity is greater than 3. The wavelength becomes infinite, if the Weber number is zero or infinite, and hence it attains a minimum value corresponding to a certain value of the Weber number for each α. The amplitude is found to increase with decrease in the wave celerity.