CHAPTER I

INTRODUCTION

The transport of solid particles by fluids has attracted the attention of several scientists and engineers since a very long time. This topic finds applications in the study of the problems of transportation of sediment by water and air, the centrifugal separation of particulate matter from fluids, fluid-droplet sprays, fluidized beds and other two-phase flow phenomena of interest in chemical processing, the electrostatic precipitation of dust, etc. Of late, the scientific interest in this study has been enormously enhanced by the investigation of the motion of solid particles in rocket motor exhaust.

On the basis of the experimental investigations of Lee W. Briggs, the trend-setting observation that the addition of dust to air, flowing in turbulent motion through a pipe, reduces the resistance coefficient, was made by Wayne T. Sproull [8]. Saffman interpreted this phenomenon to be the consequence of the damping of the turbulence by the addition of dust to the fluid. The larger inertia of a given volume of dust particles compared to that of an equivalent volume of the fluid, causes the reduction in turbulent fluctuations. Due to the drag between the fluid and dust particles, energy gets dissipated and dust particles extract energy from the turbulent fluctuations.

It was given to Saffman [6] to create the mathematical
frames to the observation made by his predecessors. He dealt extensively with the stability of the laminar flow of dusty gas. To simplify the mathematical treatment, Saffman assumed that the dust particles are uniform in size and shape and the bulk concentration (i.e. concentration by volume) of the dust to be very small. The mass concentration (i.e. concentration by mass) of the dust particles can be a significant fraction of unity. He explained the effect of dust in terms of two parameters, viz., the mass concentration and relaxation time of the dust particles. The relaxation time of the dust particles is a measure of the time taken by them to get adjusted to changes in the fluid velocity. The finer the dust, the smaller the relaxation time, compared to the characteristic time scale associated with the fluid flow. Consequently, the addition of fine dust tends to destabilize the fluid flow whereas the coarse dust has the opposite effect.


The topic of interest in this dissertation being the dusty viscous flow between two parallel plates, a brief report of the work done in this direction by some of the earlier researchers is presented below.
Sharma [7] has studied the motion of a dusty viscous fluid, initially at rest, under the influence of a constant pressure gradient applied parallel to the bounding parallel plates. The only non-zero velocity components \( W_1 \) and \( W_2 \) of the fluid and dust particles are functions of time and the transverse coordinate. Using the Laplace Transform, the dimensionless velocity distributions are found and the following conclusions are made. The velocity of dust particles is plausible only when the dimensionless time \( T > 2 \) and this is due to the fact that the dust particles have greater inertia than the fluid particles. The velocity of the dust particles is less than that of the fluid. As is expected, the dust particles take a longer time to attain the steady state. For any fixed dimensionless distance \( Y \) , \( W_1 \) and \( W_2 \) increase with \( T \) and attain maximum values on the axis of the channel.

The above problem was numerically analysed by Dube and Sharma [2] and they arrived at the conclusion that the maximum velocities of fluid and dust particles are within \( 1/\% \) of their steady state values at \( T = 3 \) and 5 respectively. This time lag is due to the fact that the pressure gradient is directly exerted on the fluid and the dust particles are moved by Stokes' drag because of the relative velocity of the fluid with respect to dust particles.

Dube and Jaipal Singh [1] studied the problem of dusty
viscous flow between two parallel plates, when the pressure gradient varies linearly and exponentially with time. With the help of numerical computations they arrived at the following conclusions. In the former case, for small values of the relaxation time $\tau$, the velocity of dust particles is greater than that of the fluid particles. As $\tau (\tau > 1)$ increases, the velocity of the fluid particles increases, whereas that of the dust particles decreases. If the dust particles are so coarse that $\tau > 10$, then the dust particles move backward and consequently there will be a flow of clean fluid. The transient parts of the velocities are significant for very large $\tau$, the dimensionless time. In the latter case, it was observed that as $\tau \to 0$, the velocity of the dusty fluid becomes equal to that of the clean fluid.

Janaki Raja [3] has solved the problem of the flow of a dusty viscous fluid between two parallel plates, the motion being generated by the application of a periodic pressure gradient of large period. Expressions for the velocities of the fluid and dust particles and the shearing stress at the plates are obtained. It is shown that, when the relaxation time of dust particles, vis. $\tau$, tends to zero, the velocities of fluid and dust particles become identical and when $\tau$ tends to infinity, the velocity of the dust particles vanishes identically.

Krishnamoorthy [4] has studied the flow of an electrically conducting dusty viscous fluid of infinite extent bound by one
or two vertical planes under the influence of transverse magnetic field. The motion is generated by forced oscillations of the boundaries. A detailed analysis of the boundary layer thickness is presented. It is observed that the width of the region influenced by the motion of the boundary or boundaries is diminished by the introduction of the magnetic field. It is also observed that the skin friction increases with the strength of the magnetic field. The skin friction in the case of a single plane is greater than that in the case of two planes, and as the Hartmann number increases, the difference between the two values of the skin friction decreases.

In this dissertation, the problem of the flow of a dusty viscous fluid between two parallel plates is studied. The system is initially in a state of rigid rotation with a constant angular velocity. The motion is generated by the non-torsional oscillations of the plates. Following Mukherjee and Debnath [5], a closed form solution is obtained.