SYNOPSIS

The thesis is devoted to the study of flow behaviour of incompressible non-Newtonian and dipolar fluids [1]. It consists of eight chapters, the first chapter being an introductory chapter in which a brief review of the various theories of non-Newtonian fluids and multipolar materials is given.

Chapter II deals with the study of general two dimensional flow of visco-elastic fluids with short memories due to an oscillating cylinder. Boundary layer equations for the Oldroyd's model [2] are derived and are solved by a process of successive approximations. It is found that the potential flow which is periodic with respect to time induces a steady secondary motion at a large distance from the cylinder. The general results are applied to the case of an oscillating circular cylinder. It is found that the flow consists of a small circulating flow within the boundary layer and an outer flow directed away from the cylinder along the lines of flow oscillations. The effect of elasticity of the fluid is to pull the dividing stream lines away from the cylinder, and it increases the streaming considerably. The total resistance on the cylinder has a phase lead over the cylinder oscillations and the elasticity of the fluid increases it. The normal stress difference $(t_{yy} - t_{xx})$ in addition to terms which oscillate with different frequencies, contains a time independent part.

In Chapter III steady simple shearing flow between two parallel plates and through a circular pipe is discussed for a class of non-Newtonian fluids obeying a four parameters constitutive equation which accounts for non-Newtonian viscosity as well as second order visco-elastic effects. The resulting non-linear differential equations are solved in closed form in each case. The results compare well with the experimental observations and findings.

Continuing our study of the above model in Chapter IV, we derive the boundary layer equations for these fluids. These are then integrated by an approximate momentum integral method. It is found that the flow characteristics depend on two parameters, the Weissenberg number $\beta = \frac{\omega_3 U_o^2}{\rho \nu^2}$ and the viscosity ratio number $\alpha = \frac{\omega_4 U_o^4}{\rho \nu^3}$, where U_o is the characteristic velocity, ρ is the density of the fluid, ν is the kinematic viscosity and ω_3, ω_4 are the material constants. Two particular cases of flow past a semi-infinite plate and of flow near a stagnation point are discussed in details. The effects of the parameters α and β on the boundary layer thickness, normal stress difference and shearing stress at the plate are studied in both the cases.

Chapter V is concerned with the steady Couette flow of a dipolar fluid between two concentric circular cylinders rotating with uniform angular velocities. An exact solution of the problem is obtained. The following particular cases are discussed in details:

(i) Single cylinder rotating with uniform angular velocity in an unbounded fluid.

(ii) Fluid contained in a cylinder rotating with uniform angular velocity.

(iii) Fluid contained between two cylinders of which the outer cylinder rotates while the inner is at rest.

The effect of the externally applied dipolar tractions and the material constants on the velocity field and the torque is studied in all the three cases.

Chapter VI is devoted to the study of certain oscillatory flows of dipolar fluids. The specific problems studied are:

(i) Oscillatory flow due to the forced oscillations of an infinite plate oscillating in its own plane.

(ii) Oscillatory flow between two parallel plates under the influence of a periodic pressure gradient.

In the first problem it is found that in general the velocity field consists of two wave modes propagating into the fluid in a direction perpendicular to the plate motion. The effect on the damping distance and the wave speed of the various parameters characterising the fluid is studied in a few limiting cases. The case when the plate is at rest and the flow is due to periodic dipolar tractions applied at the plate is also considered. This is an interesting case resulting in a velocity field entirely due to surface tractions. The velocity again consists of two transverse waves propagating with different speeds but having the same amplitude.

In the second problem the velocity field is governed by two parameters $L^2 = \frac{(h_1 + h_3)}{\mu h^2}$ and $k^2 = \frac{d^2}{h^2}$, where h is the distance between the plates, μ is the coefficient of viscosity, and h_1, h_3 and d are the material constants. It is found that for small frequencies the velocity is in phase with the exciting pressure gradient and the effect of the parameter k^2 is negligible. For large frequencies, the flow has a boundary layer character. Within a layer of thickness $\sqrt{\frac{2L^2}{\varpi k^2}}$, where ϖ is the frequency, the flow is affected by both the parameters. Outside this layer is a core about the axis governed by the parameter k^2.

Chapter VII deals with the three dimensional flow of dipolar fluids between two infinite disks, one rotating in its own plane with a uniform angular velocity Ω and the other at rest. Due to the complicated nature of the governing equations, the solutions presented are approximate, being valid for small values of the Reynold's number $R = \frac{\Omega \lambda^2}{\nu}$, where λ is the distance between the disks and ν is the kinematic viscosity. The influence of the material constants on the velocity field and the stresses at the disks is studied. The results are then compared with the available experimental findings. It is found that the main body of the fluid will be rotating with an angular velocity decreasing linearly with the axial distance from the rotating disk. The axial velocity attains its maximum value very close to the mid-plane at with the radial velocity will be zero. Beyond that plane the axial velocity decreases resulting in an inflow towards the axis. There is thus an out flow from the rotating disk and an inflow to the stationary disk. The magnitude of out-flow and in-flow decreases as $\alpha = \frac{\ell_1 + \ell_3}{\mu \lambda^2}$ increases, where μ is the coefficient of viscosity, ℓ_1 and ℓ_3 are the material constants characterising the dipolar fluid.

Finally, steady isothermal flow of dipolar fluids between two parallel plates is considered in Chapter VIII and two particular cases are discussed in details.

REFERENCES

[1] Bleustein, J.L. and Green, A.E. (1967) Int.J.Engng.Sci., Vol.5, 323.

[2] Oldroyd, J.G. (1950) Proc.Roy.Soc. A, Vol.200, 523.