SYNOPSIS

Quite a few research workers have analysed the fluid flows over wavy walls since 1957. But it has been only recently realised after the work of Watson and Poots [1] and those of Vajravelu and Sastri [2,3] that there is a need to fill in the gap with adequate information regarding the response of skin friction, wall heat transfer rates and pressure drop to wall waviness in free convection as well as combined convection studies — in view of the fact that the results of such analyses have relevance to Aeronautics, Chemical Engineering and Electronics [4]. The purpose of the work contained in the present thesis has been therefore to provide exactly this needed information.

The thesis consists of four chapters other than the introduction, which contains a brief review of the relevant literature followed by a summary of the present work.

Chapter II deals with the steady flow and heat transfer of a viscous incompressible fluid confined in a vertical wavy channel whose temperatures vary linearly along their lengths. As pointed out by Ostrach [6,7] two different cases arise according as the channel walls are heated from above or from below. These two cases are analysed in detail when the fluid properties are all taken constant as well as when the viscosity is assumed to vary exponentially with temperature. Assuming the amplitude of the wall waviness to be much less than unity, the governing equations for the flow and heat transfer are linearised to yield two sets of ordinary differential equations which correspond to the cases of a flat wall (mean part) and to a small perturbation over the flat wall (perturbed part), being the contribution due to wall waviness. The equation of the mean part are non-linear and they are solved by Galerkin's method when the fluid properties are all constant. However, when the viscosity is variable these equations are transformed into a set of non-linear algebraic equations using a second order central difference scheme. They are then solved by the methods of Brown and Brent in the cases of heating from above and from below respectively. The numerical solutions obtained by these two methods when the fluid properties are constant are found to compare well with those obtained by Galerkin's method as well as with the already known solution of Ostrach. The linear simultaneous equations of the perturbed part are solved by Galerkin's in the case of constant fluid properties and numerically by the use of a fourth order finite difference scheme in the case of variable viscosity flows. The numerical solutions obtained for the perturbed part in the case of constant fluid properties case compare nicely with those obtained through the Galerkin's method. The qualitative behaviours of the flow and heat transfer characteristics evaluated from these solutions are discussed in detail some of which may be summarised as follows:

1) The effect of wall waviness on the shear stresses and heat transfer rates at the walls is almost to increase them in an absolute sense considerably; however these changes are more prominent for long waves than those for short waves.

2) The effect of frictional heating is to increase the flow and heat transfer characteristics in almost all the cases under consideration for small and moderate values of the Rayleigh numbers and is negligible for large values of the Rayleigh numbers.

3) The heat sources enhance the fluid velocities and temperatures in the case of heating from above while the reverse is the behaviour in the case of heating from below.

4) In the case of heating below, the viscosity variation tends to change the flow directions for small values of the Rayleigh numbers at and near their critical values.

5) The magnitudes of the fluid velocity and temperature are increased significantly due to the variation of viscosity with temperature.

In Chapter III, a detailed study is made on the flow and heat transfer characteristics when the mean flow is driven by a small additional time dependent pressure gradient of order δ where δ is less than unity but greater than ϵ, the amplitude of the wall waviness. This work is, in fact, an extension of the work carried out in Chapter II. Linearisation of the governing equations as before reduces them into four sets of ordinary differential equations, two sets each for the mean and perturbed parts. The two sets of equations corresponding to the steady mean and perturbed parts turnout to be the same as those analysed in the previous chapter. Hence attention is focussed on solving the other two sets of equations of the time dependent mean and perturbed parts which are the contributions due to the time dependent part of the pressure gradient. The equations of the mean part of this case admit an exact solution when the viscous dissipations are neglected. However these equations are solved numerically including the frictional heating terms as well as neglecting them. The numerical solution obtained with dissipation effects neglected are compared with the corresponding exact solution and they are found to agree upto three decimals. The equations of the perturbed part are solved using a fourth order central difference scheme by the method explained in Chapter II. The flow and heat transfer characteristics as contributed by the time variation are discussed in detail and few of them are summarised below.

1) The time dependent flow and temperature distributions are decreasing functions of the time dependent parameter R.

2) The contribution to the shear stresses, heat transfer rates and pressure drops at the walls of the time dependent perturbed parts are periodically varying functions of time.

3) All the flow and heat transfer quantities show diametrically opposite behaviours at the crest and flat positions of the wavy walls.

Chapter IV is concerned with the study of the flow and heat transfer of a viscous incompressible fluid as affected by time dependent wall temperature conditions in the presence of wall waviness and buoyancy. Attention is restricted to the analysis of the steady mean flow and heat transfer induced by the wall temperatures varying periodically with time and the subsequent flow and heat transfer arising from the waviness of the channel walls. Application of the usual method of linearisation transforms the governing equations of the fluid motion and temperature into two sets of ordinary differential equations corresponding to the mean and perturbed parts. The induced mean flow is of one order smaller than its unsteady counterpart and an attempt is made to throw light on the behaviours of this induced mean flow and heat transfer and the perturbed flow and heat transfer. The equations of the mean part are solved exactly while those of the perturbed part numerically by the method explained and used in earlier chapters. The flow and heat transfer characteristics as envisaged from these solutions are discussed in detail. Some of the important conclusions drawn from them are as follows.

1) All the flow and heat transfer characteristics are observed to be decreasing functions of the time dependent parameter R and increasing functions of the wall temperature ratio B.

2) The flow and heat transfer quantities undergo considerable increase in the presence of wall waviness especially at the crest positions of the wavy walls these changes being more prominent for long waves than for small waves.

3) The periodic variation of wall temperatures with time produce similar such fluctuations in all the flow and heat transfer quantities.

Chapter V deals with the flow and heat transfer of a viscous incompressible fluid confined in a vertical channel whose walls are heated by time dependent thermal waves travelling along the walls (the channel walls in this case are taken flat (not wavy) because of the reason that the contribution due to the wall waviness, if considered, will be of negligible effect). A small steady mean flow is induced by these thermal waves whose velocity and temperature behaviours are of main interest to us in this work. The governing equations are solved with a linearised approach. The effects of dissipation and convection terms which were hitherto neglected have been taken into account. Exact solutions are obtained for the fluid velocities and temperatures and the qualitative behaviours of the flow and heat transfer characteristics as effected by the thermal wave are studied in detail, some of which may be summarised as follows:

1) The fluid motion is observed to be in a direction opposite to that of the travelling thermal wave in the case of air.

2) The velocities and temperatures are found to be strongly dependent on the frequency parameter of the sinusoidal thermal wave.

3) With an increase in the temperature ratio of the thermal waves at the walls, the velocities and temperatures are observed to increase considerably.

4) The convective terms lose their influence over the fluid velocities and temperatures for decreasing values of the Eckert number.

5) The increasing values of the Grashof numbers increases the flow and heat transfer quantities.