S Y N O P S I S

The study of heat transfer problems has received, in recent years, considerable attention in connection with the motion of air-planes and missiles at high altitudes. The higher the velocities with which the air-crafts and the space vehicles move through the atmosphere the higher are the temperatures developed in the boundary layers surrounding such objects. Accordingly, special studies are recently made towards a clarification of the influence of ionization of the air atoms on heat transfer. Also, the process of transpiration-cooling which is considered as an effective means to protect the surfaces of the space-crafts, has instilled in the researchers, a renewed interest. Moreover, the heat exchange processes in the presence of heat generation or absorption have been engaging the attention of research workers because of their several applications in chemical processes associated with combustion and disassociation and in the re-entry problem of a space-ship as well as in the cooling of a nuclear reactor.

In the literature of fluid-flows and heat transfer there is not much evidence to show that sufficient work has been done either experimentally or theoretically in the field of flow and heat transfer taking account of heat generation/absorption, constant or variable, when one or more of the fluid properties depend on the fluid temperature; such situations are very common in mechanisms where higher temperatures are generated. The author has therefore made a humble attempt to explain adequately

the behaviours of flow and heat transfer characteristics in certain free convection and combined convection heat transfer problems in the presence of heat sources/sinks (constant or variable) in fluids when one or more of the fluid properties varies with the temperature. The outcome of such investigations has been the present thesis. Four chapters comprise it. Chapter I is titled "Laminar convective flow and heat transfer in the presence of heat sources or sinks" wherein the historical background, the fluid flow and heat transfer processes, some earlier developments in viscous flow theory and heat transfer analysis, the flow and heat transfer literature relevant to the present work are explained in detail, along with the equations of motion, summary of present work and prospects for future work.

Chapter II is made up of two parts. Part I deals with convective flow and heat transfer of a viscous incompressible fluid confined between two long, parallel, vertical walls as affected by constant heat sources and non-linear density-temperature variations. Part II is concerned with the study of the effect of variable fluid properties and constant heat sources on the free convective flow of air/water confined between two parallel vertical walls. In Part I of Chapter I there is a detailed analysis of two problems; one deals with fully developed laminar free convection flow between two parallel vertical walls kept at constant wall temperatures and the other with combined free and forced convection-flow and heat transfer between two parallel vertical walls with linearly varying wall temperatures. In problem 1 of Chapter II the effect of nonlinear variation of density with temperature - (NDT) in the buoyancy force term has been assessed. It has been found that when the wall temperature ratio m or the free convection parameter K is moderately large the fluid temperatures and velocities for the NDT-case exceed the corresponding values of the linear-density temperatures (LDT) variation and this increase is more pronounced in the presence of heat sources. As a special case the problem for the case of quadratic-density temperature (QDT) variation has been discussed when the heat sources are present. In problem 2 it has been observed that both the fluid velocity and the fluid temperature increase with the convection parameter K, the wall temperature ratio m and the heat source parameter α, while they diminish as either the Rayleigh number Ra or the NDT parameter γ increases. A comparative study of the results of NDT case with their LDT-counterparts has been also made. As a special case here too the case for QDT variation has been made which is expected to throw adequate light on fully developed flow and heat transfer of water at 4°C confined between two parallel vertical walls with linearly varying wall temperatures. Several qualitatively interesting behaviours of the flow and heat transfer-characteristics have been pointed out after making a comparative study of the QDT-results with the LDT-counterparts. In Part II the governing equations of the problem have been reduced to two coupled nonlinear ordinary differential equations which have been solved numerically by the Runge-Kutta method as modified by Gill. Several qualitatively interesting behaviours of the flow and heat transfer-characteristics have been pointed out after making a comparative study of the variable fluid property (VFP)-results with the constant fluid property (CFP)-counterparts, which results encourage further studies of the effect of variable fluid properties on the flow and heat transfer characteristics.

In Chapter III the problem laminar free convection heat transfer of a viscous incompressible heat generating fluid-flow past a vertical porous plate in the presence of free-stream oscillations has been analysed with a view to estimate the effect of the temperature-dependent heat source or sinks on the oscillatory flow and heat transfer. The governing equations have been reduced to two nonlinear ordinary differential equations which have been solved approximately subject to the relevant boundary conditions. The flow- and heat-transfer characteristics have been found to depend on the heat source parameter α besides the usual free convection parameter G, the wall temperature ratio m, the Prandtl number P and the Eckert number E. For convenience the work has been divided into two parts, Part I dealing with the mean flow and heat transfer and Part II with the unsteady flow and heat transfer. In general the heat source parameter α has been found to delay the fluid flow reversal present in the case of air to act as a catalyst (retarding agent) to the frequency parameter ω in augmenting (diminishing) the amplitude (phase) of the rate of heat transfer at the wall.

Chapter IV is devoted to the analysis of free convective heat transfer of a viscous, incompressible fluid confined between a long, vertical, wavy wall and a parallel, flat wall in the presence of heat sources or sinks which is expected to throw adequate light on the flow and heat transfer-characteristics as affected by the waviness of one of the two long vertical walls between which an infinite amount of incompressible viscous fluid is confined and set in motion as a result of the difference in the wall temperatures. The equations governing the fluid flow and heat transfer of the problem are solved subject to the relevant boundary conditions by assuming that the complete solution consists of two parts, a mean part and the other disturbance part or the pertubed part. While obtaining the perturbed part of solution use has been made of long wave approximation. The mean part (zeroth-order) of the solution has been found to be in good agreement with that of Ostrach with certain necessary modifications resulting from the two different ways of non-dimensionalizations employed by Ostrach and the present author, while the perturbed part of the solution is the contribution of the waviness of the wall. The zeroth-order, the first order and the total solutions of the problem have been numerically evaluated for several sets of values given to the various parameters entering the problem. Certain qualitatively interesting phenomena of the flow and heat transfer-characteristics, along with the changes in the fluid pressure on the wavy wall and that on the flat wall, have been recorded and some of them are as follows :

(a). When the Prandtl number takes small or large values, the effect of the frequency parameter λ on the first-order velocity u_1 is to increase it significantly in the presence of heat sources $(\alpha > 0)$ and to diminish it considerably either in the absence of heat sources ($\alpha = 0$) or in the presence of heat sinks ($\alpha < 0$). This observation holds in the first half of the channel ($0 \leq y \leq 0.5$) and the reverse is the case in the other half. The effect of the free convection parameter G on the first-order velocity u_1 is similar in nature to that of the frequency parameter λ.

(b). For all Prandtl numbers, the effect of the frequency parameter λ is to diminish the values of the first-order velocity v_1 when $\alpha \geqslant 0$. The effect of the free convection parameter G on the first-order velocity v_1 is again similar to that of λ.

(c). The effect of any parameter (G or λ or P or α) on the first-order temperature Θ_1 is similar in nature to that on the fluid velocity v_1. Those results noted in (a), (b) and (c) hold good as the average of the wall temperatures equal the static temperature of the fluid.

(d). When the wall temperatures are unequal ($m = 2$) the total fluid velocity u is always an increasing function of G or λ and this holds for all values of α. When $m = 2$, the total fluid temperature Θ decreases in the presence of heat sinks ($\alpha < 0$) and increases significantly when $\alpha \geqslant 0$ as the free convection parameter G takes increasing values. This observation of Θ with G holds more or less qualitatively even when the frequency parameter λ takes increasing values.

(e). The skin friction at the wavy wall is an increasing function of either G or P or λ or α and the reverse is the behaviour of the skin friction at the flat wall. Out of all the parameters considered in the problem, the free convection parameter G has the strongest effect on the skin friction.

(f). The behaviours of the heat transfer coefficients at the wavy wall and at the flat wall are qualitatively similar to those of the skin friction at the corresponding walls.

(g). As the average of the wall temperatures equals that of the static fluid $(m = -1)$, the fluid pressure at those points of the wavy wall which correspond to $\lambda x = 0$ exceed that on the flat wall when $P = 0.71$ and when the heat sources are taken into account and the reverse is the situation in all other cases. As the wall temperatures are equal and when $\alpha = -5$, the fluid pressure on the wavy wall always exceeds that on the flat wall.

(h). When $m = 2$ and when $\lambda x = \pi/2$, there is no chance for the fluid pressure on the wavy wall to exceed that on the flat wall, while when $m = -1$, $\alpha < 0$ and when all other parameters take high values, the fluid pressure on the wavy wall lags behind that on the flat wall.

The numerical calculations contained in the thesis have been carried out on IBM 1620 and EC 1030 installed at Indian Institute of Technology, Kharagpur, India and on IBM 370 installed at Indian Institute of Technology, Madras, India.