Int. J. Heat Mass Transfer. Vol. 10, pp. 1131–1132. Pergamon Press Ltd. 1967. Printed in Great Britain

BOOK REVIEW

W. M. Kays, **Convective Heat and Mass Transfer,** 387 pp. McGraw–Hill, New York (1966).

During the past thirty years heat transfer has made the transition from an empirical art to something of a science. Many sub-areas in the field are sufficiently well understood to enable design work to be accomplished with either no experimentation or with just sufficient experimentation to confirm the design. The present book is representative of the level of sophistication attained in the specialized area of forced convection heat and mass transfer to the inside of tubes and to the outside of reasonably regular surfaces. The treatment, by the author's choice of subject matter, excludes natural convection, heat exchangers, non-steady flows, two-phase flows, boiling, evaporation and condensation, non-Newtonian fluids, the effects of radiation on convection, rarefied gases, magnetohydrodynamics, plasmas and the interaction between heat and mass transfer.

The large list of omitted topics might appear on first glance to leave little for discussion in the text; however, there has been developed over the last three decades a substantial amount of literature in the purely forced convection heat- and mass-transfer areas, and with this development a requirement for bringing together these analyses and results into an integrated volume for ready access by researchers, engineers and students. Professor Kays' book accomplishes this task and in so doing reflects the characteristically high quality effort for which he has become known. As with most books at this level it is not perfect and the careful reader will find points with which one can take issue, but these opportunities are fairly rare. Also, the coverage is not exhaustive with but limited reference to the fairly extensive literature on the subject.

Professor Kays develops the subject of forced convection heat transfer by first introducing the idea of the "heat-transfer conductance" or the "heat-transfer coefficient", which is a dynamic property of the flow field, and the determination of which, in terms of relevant variables, is the central problem of convective heat-transfer analysis.

The conservation principles of mass, momentum and thermal energy are considered in terms of the "control volume". From this basis and such input information as the Fourier Law of Heat Conduction, Fick's Law of Diffusion and knowledge of transport properties, the differential equations for the boundary layer are developed for continuity, momentum, energy and mass diffusion. In addition to the boundary layer form for the momentum equations the full Navier–Stokes equations are stated for reference. The energy equation for the boundary layer is developed to include variable fluid properties, mass diffusion, chemical reaction and viscous dissipation.

Following the development of the differential equations for the boundary layer, the integral form of the momentum equation is developed and the displacement and momentum thicknesses are defined. The integral form of the energy equation is developed and the enthalpy and conduction thicknesses defined. Alternate forms are shown for each equation.

The fundamental work described above is accomplished in the first five chapters. Chapters 6 and 7 are devoted to the solutions and results therefrom of the momentum equation for laminar and turbulent flow in tubes and over surfaces. The discussion of flow in tubes includes treatment of the hydrodynamic entrance length, fully developed flow, nature of turbulence, turbulent transport phenomena, diffusivities, universal velocity profiles, shear laws, surface roughness effects, and effects from curved pipes. The discussion of flow over surfaces is based essentially on the notion of similarity solutions for the flat plate, the "wedge flows" and effects of blowing and suction at the surface. Approximate solutions for laminar flow are discussed. Discussed also are the subjects of transition to turbulence, approximate solutions for the turbulent boundary layer in terms of empirical shear laws at the wall, application to bodies of revolution and in a short paragraph the reverse transition from turbulent to laminar boundary-layer flow.

In Chapters 8–11 the discussion treats in order, laminar heat transfer to tubes, turbulent heat transfer to tubes, laminar heat transfer to surfaces, and turbulent heat transfer to surfaces.

The treatment of laminar heat transfer in tubes, includes the fully developed flow situation with boundary conditions for constant heat rate and constant wall temperature, peripheral heat flux variations, annuli with axisymmetric heating, tubes with non-circular cross section, tube bundles in axial flow and for single tubes the axial variation of heat flux and surface temperature. The combination of simultaneously developing hydrodynamic and thermal entry lengths are discussed briefly.

The treatment of turbulent heat transfer in tubes after a brief discussion of Reynolds and Prandtl analogies is based on the Prandtl–Kármán analogy as modified by Boelter and Martinelli. The treatment is reasonably complete with discussion of the effects of high and low Prandtl numbers, peripheral heat flux variation, thermal entry length, non-circular tubes and surface roughness effects. Algebraic, approximate equations are presented for ease in application to design.

The discussion of the external, laminar boundary layer includes treatment of plates, wedge flows, three dimensional flows by means of the Mangler transform, suction and blowing at the surface, unheated starting length, bodies of arbitrary shape with arbitrary surface boundary conditions and boundary-layer separation.

The turbulent boundary-layer heat-transfer discussion is of necessity based on the analogies that are available, and includes discussions on unheated starting lengths, arbitrary variation of surface temperature and surface heat flux, blowing at the surface and film cooling.

Chapter 12 is devoted to the effects of variation of fluid properties on the laminar and turbulent boundary-layer heat transfer.

Chapter 13 is limited to the discussion of heat transfer, laminar and turbulent, at high velocities where the effects of compressibility and viscous dissipation are important. Certain reference temperatures which reduce the formulations to those of constant property flow and heat transfer are discussed, as are cases where specific fluid property variation permits solutions to the equations.

Chapters 14–16 are given over to mass-transfer considerations. Chapter 14 and 15 treat the mass-transfer equations, boundary conditions, interfacial conditions, mass transfer with simple chemical reactions, mass-transfer driving forces, similarity solutions, effects of variable properties, laminar and turbulent flow mass transfer, and the analogy between mass transfer and heat transfer.

Chapter 16 discusses and treats examples of mass-transfer driving forces through the devices of psychrometry, drying surfaces, evaporative cooling, volatile fuel in air, graphite in air, graphite ablation, heat transfer with dissociation in the boundary layer and transpiration cooling by means of gas injection.

Several useful appendices are provided in support of the text. There is an appendix showing graphically the various thermophysical properties as functions of temperature. A table on properties of the atmosphere to 250 000 feet. A table of Schmidt numbers for binary mixtures. An appendix of dimensions and dimensional equivalents. An appendix of mathematical functions useful in boundary-layer analysis. An appendix on certain vector operations. The index is brief, but accurate.

This book has much to commend it to the student who wishes a first look at the heat and mass forced convection processes at an advanced level, and to the experienced heat-transfer engineer who will find the text a useful reference in his work.

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