BOOK REVIEWS

Blume, Zake,
Ivanov, and Mikhailov

HEAT AND MASS TRANSFER IN AN ELECTROMAGNETIC FIELD*

Reviewed by V. E. Aerov, V. A. Bunov,
P. M. Kolesnikov, B. A. Kolovandin,
and O. G. Martynenko

The book before the reader is devoted to problems of the transfer of heat of moving conducting media in an electromagnetic field. The book consists of an introduction and seven chapters, which deal with the results of theoretical and experimental research, carried out by the authors. Moreover, the book contains extensive bibliographical material.

The first chapter is devoted to an investigation of the motion of a liquid near the interface boundary. The authors propose an approximate description of the double electric layer formed at the boundary of phase separation. The approximate mathematical model of the double layer is quite useful in solving a number of applied problems with respect to convection heat transfer. With consideration of the adopted model of the double layer, they derive the equations of motion for the liquid at the phase separation boundary, and these equations are transformed to boundary-layer-type equations. By means of these equations they derive solutions for certain practical problems: the falling of particles in an electrolyte under the action of the force of gravity; the motion of a particle under the action of the force of gravity; the motion of a particle under the action of an external electric field, etc. In the first chapter we also find the derivation of similarity criteria to describe the double layer and the motion of the liquid near the interphase boundary, with the similarity parameters classified by groups, depending on the phenomena being considered.

In the second chapter we find the results from an original experimental investigation of the motion of a liquid drop in an electrically conductive medium in the gravity field, in the presence of an electromagnetic field. The purpose of this research was to test the assumptions adopted in the examination of the motion of a liquid near the interphase boundary at high Reynolds numbers, using a simpler mathematical model of the electric double layer than the classical Stern model. As is well known, great influence is exerted on the motion of a liquid in the region of the interphase boundary by the double-layer parameters, and we have reference specifically to the density of the surface charge and the velocity of its transfer. Unlike the familiar experimental investigations of the motion of a drop under the action of external body forces, performed at low Re, the authors conduct their investigations at large Reynolds numbers ($Re = 10^2$-10^4), and they examine the interaction of a particle with a wake, a phenomenon that is statistical in nature. It is this last circumstance that governed the selection of the method for the experimental study.

The statistical study of drop trajectories in this case is particularly difficult, since the trajectory functions are not ergodic. The authors therefore carried out their observations on the effect of electric and magnetic fields on the correlation function in a selective manner and drew the conclusion that this effect is insignificant. Moreover, a thorough study was undertaken of the relationship between the drop-trajectory distribution function and the position of the transverse field of a different polarity; in addition, they investigated the relationship between the trajectory-distribution dispersion and the path covered by the drop.

The authors found a relationship between the free-fall velocity of the drop and the viscosity of the solution, and they also determined the effect of the electrolyte conductivity on the free-fall velocity of a mercury drop.

*Izd-vo Zinatne, Riga, 1967.

Translated from Inzhenerno-Fisicheskii Zhurnal, Vol. 16, No. 3, pp. 539-541, March, 1969.

It was demonstrated through a study of the effect of electric and magnetic fields on the free-fall velocity of a mercury drop that the horizontal electric field exerts no significant effect and leads exclusively to the appearance of an additional (horizontal) component of drop velocity. The horizontal magnetic field alters the horizontal motion of the drop and the free-fall velocity.

The relationships between the similarity criteria derived earlier (Chapter I) are analyzed in the third chapter. An overall evaluation of the characteristic phenomena and effects examined by the authors on the example of a number of specific problems is presented with respect to the motion of a liquid near the interphase boundary.

The fourth chapter is devoted to a study of the effect of the electric double layer on the phenomena of transfer in two-phase systems. Here the authors devote particular attention to a study of the problem relating to the effect – on the transfer processes – of the orientation of the double layer and of the physical characteristics of the substance in the double layer.

Considerable attention is devoted in the book (Chapter V) to an examination of problems associated with electrical conductivity of a high-temperature flow. Here, in particular, we find an examination of the phenomenon of electrical transport. In high-temperature two-phase and multicomponent flows the effect of ionization, recombination, and similar physical processes is examined in connection with electrical conductivity; there is a discussion of the methods employed to measure electrical conductivity, including their positive and negative aspects. The authors dwell in some detail on the properties of a plasma and the phenomena of electrical transport in a constant electric field; in addition, they deal with the methods of determining the permittivity of a plasma and the manner in which the latter is affected by such various factors as temperature, concentration, etc. In this part of the book we also find discussions of the properties of disperse systems and their behavior in a variable electric field.

Considerable attention is devoted in the book to the examination of convection heat transfer in magnetohydrodynamic laminar and turbulent flows. In examining the transfer of heat in laminar MHD flows (Chapter VI) the authors dwell, in particular, on a study of the specific features involved in the effect exerted by a transverse magnetic field on the transfer of heat in the initial segment of a flat channel. Here they deal with two types of problems: the transfer of heat in a completely developed velocity profile (the Graetz–Nusselt problem for Hartmann flow) and in the case of simultaneous development of temperature and velocity profiles. These problems were solved by the authors by mumerical integration of the transport equations. Examining the first of the above problems, the authors dealt particularly with the problem of the effect exerted on the formation of the temperature field for viscous and Joule dissipation.

Moreover, here we find a discussion of certain of the specific features encountered in the thermophysical phenomena accompanying the flow of a plasma in a magnetic field. From the great diversity of physical phenomena taking place within a plasma, the authors analyze those that are most important. On the basis of general considerations confirmed by specific calculations, they note a significant effect on the part of thermal radiation on the heat transfer in Hartmann flow, and it is indicated that there exists a possibility of intensifying the radiative heat exchange in a magnetic field. They deal with the problem of the effect exerted on a magnetohydrodynamic flow by the nonlinear relationship between the thermophysical characteristics of a plasma – electrical conductivity, thermal conductivity, viscosity, etc. – and temperature. It is indicated that the nonlinear properties of the plasma lead to new physical effects such as, for example, the appearance of hysteresis phenomena and current redistribution. The discussion centers on the effect of the anisotropy of plasma characteristics, produced by Hall currents on the processes of heat transfer, as well as the effect of the nonequilibrium of the processes on the electrical conductivity and the magnetogasdynamic flow in a boundary layer and in the channels of MHD generators, as well as on the processes of heat transfer under conditions of extensive rarefaction.

Finally, this chapter deals with the conditions of similarity in MHD flows contained by walls and the possibility of modeling the heat-transfer processes in the flows of a weakly ionized gas at temperatures of 2000-3000°K with solutions of powerful electrolytes or liquid metals.

The concluding seventh chapter is devoted to an examination of certain properties of the transfer of heat in turbulent magnetohydrodynamic flows in channels. The approximate analysis of heat transfer in turbulent flows, as given by the authors, is based on the smearing of the average equations of momentum and heat transfer by means of Prandtl–Boussinesq relationships, in the assumption that the coefficients of turbulent viscosity and thermal conductivity are functions, in particular, of the interaction parameters for the flow and magnetic and electric fields. Following the two-layer model of turbulent flow near a wall, the authors cite certain results from the calculation of the integral heat-transfer characteristics, with the magnetic field oriented variously with respect to the direction of flow, when a change in heat transfer is brought about by the interaction of the field exclusively with the fluxating motion or is determined by the combined effect of both Hartmann deceleration and the suppression of the fluctuating motion.

Particular attention is devoted in this chapter to a discussion of the results from an experimental investigation into the effect of a magnetic field on the convection heat transfer of turbulent magnetohydrodynamic flows.

On the whole, the book encompasses an extremely broad range of problems relating to the transfer of heat and mass in the presence of an electromagnetic field. This fact, a positive aspect of the book, nevertheless gave rise to certain drawbacks which became evident, primarily, in the brevity of coverage allowed for certain very important problems. This is noted particularly in the reading of the second part of chapter VI, which discusses the specifics of thermophysical phenomena in plasma MHD flows.

Bearing in mind that the authors are responsible for the development of a number of new aspects of electromagnetic hydrodynamics, promising from the applied standpoint (this pertains particularly to the dynamics of two-phase and multicomponent systems in an electromagnetic field), we can reliably state that the Blume, Zake, Ivanov, and Mikhailov book is a valuable text for technicians and engineers engaged in problems of heat and mass transfer.

An outstanding achievement of the book is the attempt, on the part of the authors, to systematize the discussion of the fundamentals of the electromagnetic hydrodynamics of two-phase systems, which is gaining ever-increasing popularity for a broad class of technological processes.

N. I. Brazhnikov

ULTRASONIC METHODS*

Reviewed by A. G. Shashkov, V. I. Krylovich, and A. D. Solodukhin

We know that the acoustic characteristics of various media depend significantly on the conditions under which the medium being studied is found, including the thermal conditions. There are also numerous experimentally established instances demonstrating that an acoustic field affects the processes of heat and mass transfer. All of this leads to the conclusion that acoustics and acoustic methods of research are gaining increasing attention from thermophysicists. Thus, for example, the velocity of propagation for ultrasonic oscillations and the attenuation factor as functions of temperature and the thermophysical properties of materials are used in conjuction with acoustic methods to study thermophysical processes and to determine the thermophysical characteristics of various materials. Surface acoustic oscillations may serve as a good tool in investigating the boundary conditions, the boundary layer, and in determining the heat-transfer coefficient, etc.

An advantage of the acoustic methods rests in the fact that they are virtually free of inertia. Their use is therefore particularly promising in studying rapidly changing nonsteady processes. Moreover, as is well known, acoustic methods are useful as control and monitoring procedures that cannot be interupted.

Unfortunately, at the moment acoustic methods of research and control (of material properties) are used sparingly in thermophysics, both in the area of scientific and laboratory research, as well as in the area of monitoring and controlling production and technological processes. This is due to the fact that thermophysicists are not sufficiently acquainted with the potentials offered by acoustic methods.

In this connection, the book Ultrasonic Methods, by N. I. Brazhnikov, is of particular interest.

Factual material on control and metrological use of ultrasonic oscillations has been collected in this book, generalized, and reduced to a uniform system. Particular attention is also devoted to the physical fundamentals of ultrasonic methods, to the fundamental laws and properties of ultrasonic oscillations, and to the relationships between acoustic characteristics for various media and other physicochemical properties. All of this serves to make the book quite comprehensive, and the numerous collected experimental data represent an extremely valuable source of reference material.

The first chapter of the book – the largest – contains numerous data on the velocity and attenuation factor of ultrasound in solid and liquid media (metals, alloys, rock, refractories, ceramics, glass, plastics, water, liquified gases, metal melts, fused salts, petroleum, organic oils, solutions, acids, alkalis, etc.) and their relationship to other physical parameters. In particular, this chapter presents certain data on the temperature coefficient of the velocity of ultrasound.

The second chapter deals with existing methods of measuring the velocity of ultrasonic passage. A comparative analysis is presented for the various methods, in addition to certain useful recommendations.

The following three chapters of the book are concerned with the principles of constructing electronic circuits and designing individual assemblies of ultrasonic devices, various types of acoustics converters, and there is a description of certain domestic ultrasonic instruments used in studying and monitoring the physicochemical properties of materials.

At the end of the book we find an extensive bibliography, containing 429 titles, of which more than a third are by foreign authors.

*Idatel'tsvo Energiya, Moscow–Leningrad (1965).

Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 16, No. 3, pp. 542-543, March, 1969.