Heat and Mass Transfer in MHD Flows

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Preface to the English Edition

During the past few decades scientists of the international communities have been focusing attention on the study of diverse aspects of how a magnetic field acts upon heat and mass transfer processes. Magnetohydrodynamic machines, technical devices using magnetic fluids and various problems of magnetobiology may serve as typical examples of the magnetic field application in controlling the hydrodynamics and thermophysical processes. It should be, however, noted that the literature devoted to magnetohydrodynamics does not treat systematically heat and mass transfer problems. Our book "Heat and Mass Transfer in a Magnetic Field" (Riga, "Zinātne" Publishers, 1980) was an attempt to fill a gap. The book sold well, and our colleagues encouraged us to submit an English version. We are indebted to the World Scientific Publishing Co. Pte. Ltd. for having undertaken the publication of this work.

In writing the present book we used the Russian edition of 1980, and this is the reason why the references to the most recent works are missing, except for some sections. The latest results published are introduced in Chapter 5.

We very much hope that readers will find useful information here and this would also stimulate the generation of new ideas. We are of course fully aware that our book is not devoid of drawbacks. Constructive criticisms and comments would, therefore be greatly appreciated.

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Riga, December 1985

PREFACE

Interest in the effects of applied magnetic field upon thermophysical processes dates back to over twenty years ago. Research development was stimulated by two major problems confronting the engineering sciences, protection of bodies in outer space from aerodynamic overheating or destruction in passing through dense layers of atmosphere and ensurance of working capacity of the structural elements of high-temperature MHD-generator installations for direct conversion of thermal energy into electrical. In the former case magnetohydrodynamic interaction with ionized gases appeared to offer a convenient means for controlling the hydrodynamics and the heat and mass processes, but in the latter this interaction was directly linked with the principle underlying the work of the converter, hence its presence was indispensable. Solving problems like these was accompanied by an upsurge in the growth in the numbers of analytical and thereupon also of experimental studies on heat transfer in MHD-boundary layers in pipe and channel flows. By and by these investigations came to be linked with new applied problems. Thus the successes in creating MHD devices for liquid metals attracted the attention of people engaged in metallurgy. Magnetic field turned out to be capable of contributing a lot to perfecting a great many technological processes. Development of atomic energetics, including huge reactors-breeders based on fast neutrons, as well as creation of the blanketing systems of the future thermo-nuclear reactors are unthinkable without extensive use of MHD devices. It is established that magnetic field can directly affect a variety of processes in chemical engineering. Control of the crystallization processes in metallurgy and the influence exerted by the magnetic field on particular chemical systems have now led to magnetohydrodynamics and thermophysics addressing themselves to problems which used to be the province of others at times far from being related disciplines (for example, physicochemical kinetics and biophysics).

Additional stimulus for tracing further interrelationships was provided by the research developing along the lines of probing the interaction of the field with magnetizable homo- and heterogeneous systems. In altering the kinetic processes, the magnetic properties of the components come largely into play. Inasmuch as ferrohydrodynamic processes are manifested mainly in the presence of temperature or concentration non-uniformities in the system, investigation into the physical phenomena in magnetizable media would pertain to the competency of thermophysics rather than to that of hydrodynamics. Growth of ferrohydrodynamics has substantially extended the range of practical applications of MHD-processes, impinging not only on energetics and chemical engineering but also on electrical and radio engineering, automation systems and so forth. And finally, the analogies traced in the influence of magnetic field upon mechanical and biological suspensions have brought about a situation with real possibilities of applying the results of thermophysical investigations in the magnetic field to a series of magnetobiological phenomena.

It should be pointed out that, notwithstanding the importance of the contributions to research on thermophysical processes subject to external magnetic influence, there are to date practically no generalizing works in this field. It is for a partial bridging of this gap that the authors of the present book have set themselves the aim of summing up the results of thermophysical investigations into incompressible conducting and magnetizable media. In writing the book the authors have drawn mainly on material based on research carried out in the Thermophysics Laboratory at the Physics Institute of the Academy of Sciences of the Latvian SSR. In addition, for a more comprehensive view of the problem as a whole the results of other works have also been largely used. In selecting their material, however, the authors were guided by the desire to throw light on the vastness of the research done and that is why certain specific questions concerning the methods of analytic or numerical solution of problems have remained outside the scope of the book. Striving to pay attention mainly to the physical aspects of the problems dealt with, we have tried to make maximum use of various approximation methods in analysis. On the basis of integral solution methods a degree of exactness is attained, which suffices in engineering calculations, and a rather obvious pattern of the major governing laws and applicability limits of diverse approximations is arrived at.

It stands to reason that not all the problems touched upon in the book have been investigated to equal degree. Thus, for example, the problems of heat transfer in MHD pipe flows turned out to have been more fully covered, whereas mass transfer problems in scientific literature have received little attention. Notwithstanding the comparatively large amount of work, experimental among it, research on turbulent heat and mass transfer in a magnetic field cannot be considered completed by far.

In dealing with thermophysical processes in magnetizable fluids we confined ourselves deliberately to analysis of the equilibrium quasi-stationary approximation considering questions linked with the relaxation of hydrodynamic and electromagnetic processes to be subject to special investigation.

With a view of attracting the attention of those engaged in thermophysics to new topical problems, we considered it to the point to include a chapter concerned with certain aspects of magnetobiology. To this end, questions were chosen, proving the feasibility of direct application of the investigation approaches and the results obtained in mechanical systems to biological media.

Fully aware of the present work not being free of short-comings, we are grateful in advance for possible matter-of-fact critical comments, which we shall regard as very useful in further work. We ask to forward your considerations to the address: Latvian SSR, Riga region, 229021, Salaspils, Physics Institute at the Acad. Sci. of Latvian SSR.

Chapter 1 was written by R. Ozols and Yu.A. Mikhailov, Chapter 7 by Yu.A. Mikhailov, E. Blūms and R. Ozols, Chapters 2 to 6 and Chapter 8 were contributed by E. Blūms.

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