

Preface

The book is devoted to investigation of a series of problems of convective heat and mass transfer in rotating-disk systems. Such systems are widespread in scientific and engineering applications. As examples from the practical area, one can mention gas turbine and computer engineering, disk brakes of automobiles, rotating-disk air cleaners, systems of microclimate, extractors, dispensers of liquids, evaporators, circular saws, medical equipment, food process engineering, etc. Among the scientific applications, it is necessary to point out rotating-disk electrodes used for experimental determination of the diffusion coefficient in electrolytes. The system consisting of a fixed disk and a rotating cone that touches the disk by its vertex is widely used for measurement of the viscosity coefficient of liquids.

For time being, large volume of experimental and computational data on parameters of fluid flow, heat and mass transfer in different types of rotating-disk systems have been accumulated, and different theoretical approaches to their simulation have been developed. This obviously causes a need of systematization and generalization of these data in a book form.

Three books are widely known currently, which are completely or partially devoted to the considered subject. The classical books of L.A. Dorfman "Hydrodynamic Resistance and the Heat Loss of Rotating Solids" (Oliver and Boyd, Edinburgh, UK, 1963) and V.G. Levich "Physicochemical Hydrodynamics" (Prentice-Hall, Inc., Englewood Cliffs, N.J.: 1962) for decades became desk-top books for the specialists in the fields of convective heat transfer at air flow in rotating-disk systems and experimental determination of the diffusion coefficient in electrolytes with the help of the rotating-disk electrode technique, respectively. The fundamental monograph of J.M. Owen, R.H. Rogers "Flow and Heat Transfer in Rotating-Disk Systems" (Research Studies Press Ltd., UK, 1989 and 1995) represents an in-depth insight into the modern state-of-the-art of investigations in the field of secondary air cooling systems of gas turbines including data for a free rotating disk, rotor-stator systems, as well as rotating cavities formed by parallel co-rotating disks.

For the last two decades, considerable advance has been done in experimental and theoretical research of scientific and practical problems of convective heat and mass transfer, which the above-mentioned books are devoted to. However, degree of critical analysis and generalizations of the accumulated data, both in these books

and in newly published works of different authors, are frequently insufficient even at the level of similarity equations. A series of problems were successfully solved with the help of integral methods. However, theoretical foundations of the known integral methods have appeared insufficiently developed that in a number of cases resulted in essential errors of the solutions obtained on the basis of these methods. In a number of works, modelling approaches using exact self-similar solutions of the Navier–Stokes and energy equations have been worked out. However, for many problems in rotating-disk systems, possible self-similar forms of the solutions have not been found that essentially narrows down capabilities of theoretical modelling.

A number of other important scientific and practical problems are not elucidated in the aforementioned books. Among them, the following problems of convective heat transfer of a disk rotating in air are of interest from the point of view of this book: (a) non-stationary conjugate heat transfer; (b) impingement of uniform flow or a single co-axial jet onto an orthogonal disk; (c) flow and heat transfer in a gap between a rotating disk and/or a cone touching the disk by its vertex; (d) flow in a rotating-disk air cleaner. Also actual are problems of convective heat and mass transfer at Prandtl and Schmidt numbers: (e) moderately exceeding unity as applied to the technique of experimental measurement of mass transfer rate for naphthalene sublimation in air and (f) much exceeding unity with reference to problems of electrochemistry.

The problems mentioned above became motivation to undertake investigations that laid down the basis for preparation of this book.

The present book consists of eight chapters. The main attention in the book is given to heat transfer in air flow, except for Chap. 8, where problems of heat and mass transfer at Prandtl numbers or Schmidt larger than unity are considered.

Chapter 1 includes characterization of several known types of rotating-disk systems, description of forces that act on flow and general notations of momentum, continuity, energy and convective diffusion equations in different coordinate systems.

In Chap. 2, differential equations of motion and energy are written as applied to rotating-disk systems, methods of their solution known in the literature are briefly described, an integral method developed by the author is outlined and a general solution is written for the cases of disk rotation in a fluid rotating as a solid body and simultaneous imposed accelerating radial flow.

Chapter 3 represents analysis and generalization of the data and models of different authors for a free rotating disk. With the help of the integral method developed by the author, analytical and numerical solutions are obtained possessing essentially higher accuracy, than the solutions known before.

In Chap. 4, self-similar solutions of the problem of non-stationary heat convection, as well as analytical and numerical solutions of the problem of conjugate non-stationary heat transfer of the disk are represented. Peculiarities of application of transient experimental techniques for determination of heat transfer coefficients are also discussed.

Chapter 5 is devoted to analysis of the solutions obtained with the help of the integral method developed by the author for the case of disk rotation in a fluid rotating

as a solid body without imposed radial flow, and also for accelerating radial flow (due to its orthogonal impingement) without imposed external rotation.

In Chap. 6, hydrodynamics and heat transfer are modelled for outward under-swirled and overswirled radial flow between parallel co-rotating disks (the integral method), and also aerodynamics and heat transfer in a rotating-disk air cleaner (with the help of CFD).

In Chap. 7, a self-similar solution of a problem of laminar heat transfer in a gap between a rotating disk and/or a cone, as well as that for outward swirling flow in a stationary conical diffuser is presented.

Chapter 8 contains analysis and generalization of the data of different authors for problems of convective heat and mass transfer at Prandtl and Schmidt numbers exceeding unity. Recommendations as applied to the technique of experimental measurement of mass transfer rate for naphthalene sublimation in air are developed. In the integral method developed by the author, effects of large Prandtl and Schmidt numbers are taken into account.

The author deeply acknowledges financial support of Alexander von Humboldt Foundation (Germany) in the form of a Research Fellowship taken by the author at Technische Universität Dresden in 2003–2005, which enabled him to prepare the present book. For the three years that passed since then, the author has refined Chap. 8 and introduced some editing to other chapters in view of the new publications, which have been published for this time. The author would like to thank all the colleagues, whom he has collaborated with during the time of performing the research that laid foundation of the book, for their contribution, useful advices and fruitful discussions.

Stuttgart, Germany

Igor V. Shevchuk

<http://www.springer.com/978-3-642-00717-0>

Convective Heat and Mass Transfer in Rotating Disk
Systems

Shevchuk, I.V.

2009, XIX, 236 p. 116 illus., Hardcover

ISBN: 978-3-642-00717-0