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BOOK REVIEWS

R. ARIS, **Mathematical Theory of Diffusion Phenomena and Reactions in Porous Catalysts.** Oxford University Press, Oxford (1974).

EVEN a cursory reading of the book by R. Aris reveals the radical changes which have occurred in chemistry in the last years. These changes consist of the spread of computational-theoretical methods into the science of chemistry. It is noteworthy that this occurs in an equal degree in pure chemistry, which one can no longer imagine without quantum-mechanical calculations, and in applied chemistry. Nowadays, computational-theoretical methods play as large a role in chemical technology as in nuclear technology. The University of Minnesota has played a noteworthy part in the "mathematization" of chemical technology; and one of the leading representatives of this school is R. Aris.

Many processes of chemical technology take place with the acid of porous catalysts, which influence the speeds and selectivity of chemical transformation. At the present time, the old empirical methods of optimal organization of these catalytic processes are significantly supplemented by computational methods.

The monograph under review, despite its large volume, is devoted to a rather narrow range of questions. The author touches neither on the attempts which have been made in the literature to discover the physical theory of the mechanism of catalytic action, nor on the purely chemical aspects of the phenomena. Equally neglected is the theory of absorption and non-catalytic heterogeneous reaction and the macro-kinetics of moving media.

The author indicates that he has tried to summarise the results of the theory, so as to attract the attention of mathematicians to problems which are both of practical importance and of mathematical interest. In the last twenty-five years, an enormous number of computational investigations of catalytic processes have been carried out. It is clear, however, that the greatest interest belongs to: conclusive deductions obtained from model calculations; approximate methods and means of estimation; methods of calculation with the aid of computers; and estimates of the optimal working regimes, and the stability, of catalyst systems. Strict mathematical proofs, despite the indeed surprising growth of mathematical education among chemists in recent years, still lie well away from the fundamental line of their interests. On the other hand, mathematicians and theoretical physicists not only prefer strict analysis, but are also interested in the examination of problems which still await solution.

These two categories of readers deserve, in my opinion, different kinds of monograph, neither of which is easy to write. The attempt to combine both in one, is scarcely realistic. The present monograph appears to me to be open to this criticism.

The main merits of the monograph are its depth of approach, and clarity of the presentation of a series of complex mathematical problems, and the breadth of illumination which is cast over the subject as a whole.

The first chapter deals briefly with models of porous media. The second chapter is devoted to a general formulation of the equations of exchange of matter and heat, and the initial and boundary conditions appropriate to the presence of chemical reaction in quasi-homogeneous media.

All further analysis are based upon the assumption of quasi-homogeneous. The author provides a clear discussion of the question of the possibility of introducing an effective coefficient of diffusion in porous media.

The main part of the text begins with Chapters 3 and 4, which are devoted to a detailed and many-sided discussion of stationary solutions of the equations of diffusion, with presence of a single reaction, in isothermal and non-isothermal circumstances.

While carrying out a detailed solution of examples of gradually increasing complexity, the author discusses the solutions of nonlinear problems, and the substantial complications which arise in simultaneously solving the equations of diffusion and thermal conduction. In these two chapters, the reader will find many instructive details and will understand how the behaviour of the solutions of boundary problems alters with changing principal parameters in the relevant equations.

The theory is exposed more concisely for the case of steady-state regime with simultaneous reactions. This case of fundamental interest in engineering practice is very complex. Qualitative estimates, and also direct numerical calculations by means of computers, are rather more useful here than analytical methods, to which the monograph is essentially devoted.

However, the analytical solutions and qualitative investigations of nonlinear problems have an importance which has been by no means diminished by the availability of digital computers. It is very important to have a notion of the qualitative behaviour of the solution even when solving the problem numerically and choosing the optimum regime.

Chapters 6, 7 and 8, in the second volume, are of special interest. They are devoted to the problems of uniqueness of the solutions and stability of steady states of systems.

The problem of uniqueness of the solutions is closely related to the problems of their stability; and, stability of the regimes is, obviously, of a very practical importance. A thorough consideration of the dependence of stability upon the values of parameters is illustrated by many examples, the case of an irreversible reaction of the first order being given as characteristic. Dependence of stability upon Lewis number has been investigated in this example, and it has been found that, at small values of this parameter, an abrupt transition can take place from stationary to unstable behaviour.

The discussion of unsteady and transient regimes (Chapters 7 and 8) has been expertly performed by the author. The book is also enriched by the examples taken from related areas of science, notably, those from biophysics, very often complicated by absorption or chemical transformations.

The author gives an enormous list or references (about 1100) titles, containing all the principal works in the field. Professor Aris also gives a valuable historic survey of the field, which is objectively composed.

The reviewer would like to point out some minor shortcomings of the book, namely, that in trying to give a strict mathematical form to the style of the exposition, the author writes equations of diffusion and boundary conditions at the beginning of practically every paragraph and each example. This is convenient if the book is used as a handbook, but, in systematic reading, it seems to be superfluous, and even tedious. Placing of the notations at the ends of chapters also makes systematic reading of the book somewhat difficult.

However, in the light of all written above, and notwithstanding the shortcomings mentioned, Professor Aris' book represents a fundamental and valuable effort which, I am sure, will be held in high esteem by the readers.

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Translated by
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S. N. B. MURTHY (Editor), **Turbulence in Internal Flows: Turbomachinery and Other Engineering Applications.** Hemisphere, Washington (1977).

THIS Proceedings of a Project Squid workshop held in mid-1976 will be a most welcome addition to the library of the active researcher in turbulence phenomena. Such readers will be grateful to the participants, the editor and the publisher for a set of papers that are mostly of a high standard, a number of papers that review major directions of work by particular research groups, a presentation of the work that contains few errors in equations or figures and a prompt publication of the proceedings. The book conveys a fairly accurate sense of the state of the art of turbulence experiment and theory. The active worker can scarcely avoid finding several fascinating papers in this volume, the particular papers depending somewhat on his interests.

Conversely, the design engineer is likely to be disappointed in this book, for it provides him very little concrete assistance. Such a reader may well wish to avoid this book, unless he is able to take a very generalized view of what is relevant reading material. Developments based on the digital computer will eventually offer the designer practical prediction procedures for the more complex flows met with in applications. The rate at which particular applications have yielded rather suddenly, at least in part, to the predictive approach (e.g. the optical output of CW gas lasers, the internal flow of a centrifuge, the performance of a liquid propellant gun, aspects of the internal combustion engine, multi-phase flows in nuclear reactor safety studies) makes it possible to hope that many further significant applications will become accessible to computation within years, rather than decades.

The twenty-one papers and the ensuing discussions of this volume are grouped into three sections: Fundamental Problems, Modelling Procedures and Turbomachinery Applications. A fourth section includes a panel discussion on research in this field and a summary of the conference. The opening pages review the state of the art at the last major conference dealing with "Turbulence in Internal Flows" in 1965, provide a very useful bibliography of significant and relevant developments since that time, and list the project SQUID workshops held on selected subtopics since the 1965 conference.

This schedule of conferences suggests that the organizers may have hoped that the present conference would be the place where the experimental and theoretical developments in the numerous relevant disciplines would be synthesized into a coherent program for research and for design calculations. However, the field simply is not ready for that. Instead, one must be content with a first-rate state of the art report.

These proceedings are not a review paper. Each author deals partially, and from his own point of view, with one or several extremely complex fluid flow phenomena. When preceding developments are summarized and put into perspective, it is usually the author's own research program that is given systematic review. Thus the conference was a hard one to summarize. The papers, which are highly rewarding upon careful study, do not readily yield to a casual reader a systematic view of what measurements have been done, and which are needed, to understand particular complex flows, nor do they easily reveal which flows are subject to theoretical analysis with current methodology and by which methods, at what accuracy and at what cost. Any such synthesizing views must be contributed by the reader, and can only arise from considerable expertise in turbulence research.

The two papers making the strongest impression on the conference participants were probably those by S. Corrsin and W. Kollman and by J. L. Kerrebrock. Corrsin represented the velocity field as a static uniform shear plus a fluctuating field expanded in three dimensional series in space and power series in time, averaged over a periodicity cell to represent ensemble averaging and solved for an initial condition of a uniform shear plus a Taylor Green vortex cell. The results were good enough to indicate qualitative agreement with experiment and to indicate that the evolving turbulent flow field resulted largely from stagnation points with the "right" direction of energy transfer, while those with the "wrong" direction of energy transfer were damped structures. Kerrebrock reported on detailed space and time resolved measurements of flow angles, entropy rise, and flow Mach numbers, as well as a harmonic analysis of the pressure fields, at stations upstream and downstream of a high-pressure ratio transsonic axial compressor rotor. The flow is dominated by a single periodicity which changes with position downstream and is associated with the evolution of the highly swirling flow shed by the rotor blades. The truly turbulent features of the flow are comparatively minor. The origin of the periodic flow is not fully explained, but might be accounted for by the eigenmodes of a perturbation theory.

The remaining papers, including many of high quality, dealt with numerous additional features of turbulence that distinguish "complex" flows from "simple" ones. Flow configurations were emphasized that resemble those arising in turbomachinery and aircraft flight. Phenomena dealt with include flow deformations (1) in a curved duct and (2) at the junction of a wing and an aircraft body, flow interactions between (1) freestream turbulence and/or initial boundary layers and the plane mixing layer, (2) turbulent shear flow and a turbulent boundary layer, (3) two wakes, and (4) cascade flows and freestream turbulence, as well as rotational effects of (1) coaxial jets with swirl and (2) flow manipulators for swirling flows. Considerable attention was given to a variety of prediction methods applied to a number of flow configurations of interest, though without much systematic comparison between methods.

An evolving view on turbulence modeling, based on LASL experience, is that the Reynolds stress transport equations with appropriate closures offer the best practical, long-range chances for a detailed and computable description of the many types of turbulent flows of applied interest, but that a systematic treatment of closure models, in which all terms permitted by general modeling rules would be considered and coefficients determined by experiments and numerical simulations of high accuracy, is badly needed. Computational costs will remain a major limitation for this approach.

However, for truly complex flows, in which chemical reactions or multiphase flow, as well as turbulence and complicated geometries need to be taken into account, the present view suggests the importance of calculations run with the simplest models of the important physical processes in order to discover which phenomena influence the performance of the device most strongly. These latter phenomena are those that one spends the most care (and computer time) on to model accurately. The most influential phenomenon is not always turbulence. For example, in calculations of combustion of premixed fuels it