Numerical experiment in hydrodynamics

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R. Peyret and T. D. Taylor, *Computational Methods for Fluid Flow*, Springer-Verlag, New York, Heidelberg, London, Paris, Tokyo, Hong Kong, Barcelona, 1990, 358 pp (Springer Series in Computational Physics)

It is well known that various instabilities are typical for hydrodynamic flows. These instabilities lead to motion with substantially varying scales. The acquisition of rigorous mathematical results is made difficult here not only in the sense of analytical solutions, but also at the level of existence and uniqueness theorems. In this situation it is very difficult to construct numerical models which reflect sufficiently accurately the characteristic properties of the phenomena under examination and which are at the same time accessible for a computer experiment. The success of numerical modeling of hydrodynamic flows, as shown by many years of experience, depends to a significant degree on a profound understanding of the physical statement of the problem and a successful selection of a numerical method which is suited to the phenomenon to be studied. Thus, the researcher, having decided to turn to a numerical experiment in hydrodynamics, needs a handbook which makes it possible for him to familiarize himself with the varied arsenal of available numerical methods. It is for the beginning reader interested in a fast mastery of these methods that this book is intended. It is well known and has withstood the test of time: this is the third edition (since 1983).

Since the book is intended for rapid entry of the reader into the problem, the exposition of theoretical foundations is reduced to a minimum, and complex proofs and calculations are absent. Application of the methods is illustrated by simple examples, the number of which is near optimal. Actually this is a comprehensive survey of numerical methods with an exposition of their foundations. The book is divided into three parts, 11 chapters (the numbering is straight-through with a set of sections and subsections which makes it easy for the reader to orient himself in the material.

The first part presents basic numerical methods and schemes used in the solution of hydrodynamic problems. It is completely justified that the largest chapter in this section is devoted to differential methods, because they are, on the one hand, the most developed and widely applicable, and on the other hand, they are the most promising from the point of view of use in "ideal" modeling, when, with the necessary amount of inventiveness, one can obtain numerical solutions which coincide in network vertices with the solutions for continual models. There is a less complete analysis of spectral methods, finite elements methods, and specialized methods in particular. Fourteen pages in all are devoted to these methods, which include approaches using Green's functions, characteristics, discrete vortices and particles in cells.

The second part is devoted to the application of methods presented in the first part to the calculation of incompressible flows. Here there is also a discussion of the features of using various pairs of variables, "velocity-pressure," "vorticity-current function," and the boundary condition problems which arise for pressure or vorticity. The inclusion in this part of a description of "professional approaches," for example, the introduction of an artificial compressibility or a pseudo-nonsteady-state condition in the calculation of steady-state flows, gives the beginning reader an idea of the effectiveness and expansion of opportunities of numerical methods provided when one uses nonstandard approaches. It aids in the development of a knack for finding them. A small chapter in this part (14 pages) contains a brief discussion of methods of calculating turbulent flows based on classical schemes of closure equations for turbulence and on subnetwork modeling.

The last part, which is the smallest, is devoted to compressible flows, and touches only on the most characteristic features of the calculation of these flows. It is divided into two chapters in which an attempt is made to divide the most typical approaches to calculations of viscous and nonviscous flows.

It should be noted that not all the chapters are equivalent in the depth and breadth of coverage of the issues examined in them. In particular, chapters which discuss methods based on closure schemes and subnetwork modeling and special methods (like the discrete vortices method) and compressible flows are similar to a somewhat outdated survey (the book has references to work published up to 1982). We add that there are virtually no references to publiclations by Soviet authors. Overall the material is presented in a very skillful and clear fashion at a level accessible to a reader who is encountering the issues addressed in the book for the first time. It is possible that professionals will not find anything new here, but the book may be very useful for undergraduate and graduate students, and instructors at these levels.

Translated by C. Gallant

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