

## Preface

Our dedication to the pioneers of the use of Monte Carlo methods in mechanics of fluid and gas in Russia Vladimir Alexandrovich Perepukhov and Vitaliy Evgenjevich Yanitskii.

The beginning of the third millennium is characterized by the global uniqueness of the human civilization. The possibilities of humanity in energetic properties of the industrial processes and of the armament systems became to be comparable with similar properties of the natural processes. It concerns even such energy-consuming processes, as the natural cataclysms. On the one hand, this fact appears as the evidence of the general progress in the development of humanity. On the other hand, this peculiarity evokes a serious misgiving, since it is threatening just the possibility of the further existence of a human civilization. And such a misgiving is connected not only with a possibility of the global thermonuclear wars with unpredictable consequences, but also with the everyday activity on the security of a public life. For example, one of the important factors is the hypothetical global state of climate of Earth. It is assumed that in the result of the large quantities of smoke and soot, which are carried out into the stratosphere through the spacious fires by the explosion of 30–40% of nuclear war-charges, accumulated in the world, the temperature throughout the whole planet will be lowered down to the Arctic values, as a result of the essential increase of the quantity of reflected solar rays. The possibility of appearance of a nuclear winter was forecasted by Charles Sagan in the USA and confirmed in Russia by the computations of V.V. Alexandrov.

The everyday activity on the security of a public life leads both to the accidental large-scale ecological catastrophes, and to the gradually accumulating pollution of the environment (V.P. Dymnikov). Considered in the present monograph are some fundamental problems connected with these subjects. Presented here are the statistical methods of mathematical modeling for various models of the flow of fluid and gas, within the wide range of the characteristic parameters. The models of flow are ranging from the hypersonic flows of strongly rarefied gases (gaseous flows near the Earth's satellites at the orbits and near the apparatuses descending from the orbit), which are influencing the ecological state of the nearest

space, and up to the turbulent flows modeling both the atmospheric phenomena and the processes of flow about the modern flying machines. Described are the modern effective numerical methods, developed both by the authors themselves and by other specialists and intended for the computer realization of these models. The problems considered belong to the classes of three-dimensional evolutionary problems, based on the equations of mathematical physics, for the overwhelming majority of which are not proved even such a fundamental mathematical motions, as the theorems of existence and uniqueness, even in the considerably simplified formulations. The study of such problems, at the present stage of the development of science, when the traditional analytical methods of investigation have, in a certain degree, exhausted themselves, is carried out, mainly, with the help of a computational experiment.

The revelation of the methods of statistical modeling (Monte Carlo) in various areas of the applied mathematics is connected, as a rule, with the necessity of solution of the qualitatively new problems, arising from the needs of practice. Such a situation appeared by the creation of the atomic weapon, at the initial stage of a mastering of space, by the investigation of the phenomena of atmospheric optics, of the physical chemistry, and of the modeling of turbulence (G. von Neumann, Metropolis N., Unlam S., Vladimirov V.S., Sobol I.M., MArchuk G.I., Ermakov S.M., Mikhailov G.A., Bird G.A., Haviland J.K., Lavin M.D., Pullin D.I., Kogan M.N., Perepukhov V.A., Beloserkovskii O.M., Yanitskii V.E., Ivanov M.S., and Eropheev A.I.).

As one of the more or less successful definitions of the Monte Carlo methods, it would be possible to present the following one:

The Monte Carlo methods present in themselves the numerical methods of solution of the mathematical problems (sets of the algebraic, differential, or integral equations) and the direct statistical modeling of the processes (physical, chemical, biological, economical, and social) with the help of obtainment (generation) of the accidental numbers and the transformation of those.

The book contains, in the reasonable proportions, those formulations and solutions, which already proved to be classical ones, as well as the results which have endured the time control and were somewhat extended and supplemented in the light of the last achievements in the corresponding areas of science. And, finally, this book fills in, by quite a natural way, the peculiar gap in the structure of computational aerodynamics, connected with a statistical modeling.

The book was carried out within the frame of a scientific project "POISK" ("Search"), elaborated at the Department of Aeromechanics and Flying Technique of the Moscow Physico-Technical Institute (MPTI). The essence of this project consists in the following. All around the world the tremendous number of researches

is working on the solution of fundamental and applied problems, connected with turbulence, especially with nonuniform and anisotropic one. Accumulated is the tremendous volume of factual material, and as rather actual point became that of preparation of a guide-book for orientation in that boundless sea of the theoretical, experimental, and numerical results. At the above-mentioned Department of MPTI was developed the project for such a guide-book and accompanying materials. The project's structure presents in itself the creation of books, containing the analysis of experimental results, of the theoretical and computer-based methods. This project is already partly realized.

In particular, published is the book surveying the contemporary experimental research on the dynamical structures within the turbulent boundary layer:

- (1) Yu.I. Khlopkov, V.A. Zharov, S.L. Gorelov, *Coherent Structures in the Turbulent Boundary Layer*. M., MPTI, 2002.

Presented in this book, containing over 400 references, are the principles of physics of the dynamical processes in turbulent boundary layer, such as the phenomenon of bursting, the formation of streaks, and the processes of transfer of momentum and energy from the outer boundary of layer to that of the flow itself. Moreover, presented is the critical analysis of the foreign experimental works, formulated are the actual problems. As it was found, the analysis of experimental investigations, conducted during a prolonged period (over 40 years), revealed those essential features of the flows of fluid and gas, which might be used by the construction of a general theory of the processes involved. The theoretical studies of turbulent flows are carried out during a long time, too. The considerable part of that time was devoted to the search of the most effective methods of problem's solution. In the survey book,

- (2) Yu.I. Khlopkov, V.A. Zharov, S.L. Gorelov, *Lectures on the Theoretical Methods of Study of Turbulence*. M., MPTI, 2005, are summed the results of these studies, and presented is the criticism of various methods, used at the earlier stage of the development of a theory. Thus, the reader is permitted to orientate himself in the contemporary directions of study.

The publishing house of MPTI has published also the survey book,

- (3) Yu.I. Khlopkov, V.A. Zharov, S.L. Gorelov, *Renormgroup Methods of the Description of Turbulent Motions of Incompressible Fluid*. M., MPTI, 2006.

Presented in this book is the survey of results of elaboration and application of the number of methods, named as renormgroup methods, for the construction of models of turbulent flows of the incompressible fluid, both in the uniform and isotropic case, and in the case of a strong anisotropy and nonuniformity. The book is based on the studying of about 1000 of the original works, selected

from the totality of which were the most actual ones, according to the authors opinion. The largest part of contents is devoted to the three sub-network models of turbulence, which are widely used in the contemporary practical activity of various specialists in aerodynamics. The book is published as a textbook for students, though it demands the considerable efforts for its understanding and is intended, actually, for the professors and postgraduates. At the present moment is prepared for publication “The Lecture Course on the Theory of Turbulence”, which was presented at the Department of Aeromechanics and Flying Technique by the Professor V.N. Zhigulev and is devoted to the studies on that problem on the kinetical level. Further on, it is planned to carry out the survey and analysis of modern numerical methods, used by the modeling of complicated unsteady flows of fluid and gas. The authors are expressing their deepest gratitude to the Russian Foundation of Fundamental Research, which is supporting this project, especially useful for the young generation.

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