Preface

The book provides an original approach in the research of structural analysis of free developed shear compressible turbulence at high Reynolds number on the base of direct numerical simulation (DNS) and instability evolution for ideal medium (integral conservation laws) with approximate mechanism of dissipation (FLUX dissipative monotone "upwind" difference schemes) and *does not use any explicit sub-grid approximation and semi-empirical models of turbulence*. Convective mixing is considered as a principal part of conservation law. Appropriate hydrodynamic instabilities (free developed shear turbulence) are investigated from unique point of view. It is based on the concept of large vortices with stochastic core of small scale developed turbulence ("turbulent spot"). Decay of "turbulent spot" are simulated by Monte Carlo method. Proposed approach is based on two hypotheses "independence of large ordered structures and small-scale turbulence" and "weak influence of molecular viscosity (or more generally, dissipative mechanism)" on properties of large ordered structures.

Two versions of instabilities, due to Rayleigh–Taylor and Richtmyer–Meshkov are studied in detail by the three-dimensional calculations, extended to the large temporal intervals, up to turbulent stage and investigation turbulent mixing zone (TMZ).

The book covers both the fundamental and practical aspects of turbulence and instability and summarizes the result of numerical experiments conducted over 30 years period with direct participation of the author.

Appreciation of contribution Academician O. M. Belotserkovskii to the world science are given by Academician A. S. Monin (Russia), Prof. Y. Nakamura (Japan, Nagoya University) and Prof. F. Harlow, (USA, Los-Alamos).

OPINION by Academician A. S. Monin (Russia)

Reproduction of coherent structures in turbulent flows by numerical calculation of the hydrodynamic equations — is very complicated problem, especially at high Reynolds number, when the spectrum of turbulent structures with turbulent cores is very wide and it is practically impossible to provide their full resolution from max to min scale even with the help of the modern super computers.

That is why the modeling of the large vortices is needed to be conducted separately from numerical description of small-scale turbulence taking into account molecular viscosity (which at present time is accessible only at $\mathrm{Re} < 1000$). Original approach to the task of estimation LOS is developed in the works of Academician O. M. Belotserkovskii and his school. It consists in *the Direct Numerical Simulation* (DNS) of the hydrodynamic ideal flow. For this task non-stationary Euler equations, evaluating proper conservation laws with *approximate* account of energy dissipation created by small-scale turbulence are used. Turbulent flow is represented as relatively ordered slow movement of coherent structures — weakly unstable large structures, which transfer flow with developed turbulence from one flow area to another. This approach can be used also for description of "residual" coherent structures of bifurcation origin (dynamic structures).

Academician RAS A. S. Monin

["About coherent structures in turbulent flows" in the book. "Sketch about Turbulence" (Moscow, Nauka, 1994) pp. 7–17.]

See also: Investigation of stochastic turbulence, A. S. Monin, A. M. Yaglom, Statistical fluid mechanics, eds. J. Lumiey (MIT Press, Cambridge, MA; Vol. 1, 1971; Vol. 2, 1975).

OPINION by Professor Yoshiaki Nakamura (Japan)

Although the theoretical studies of turbulence have a long history, physical principles of turbulence are still not well clear (for example, what is the source of the energy of chaotic motion). Currently, some experimental data evidently point at the existence of Large-Scale Ordered ("coherent") Structures (LOS), especially in the case of fully developed turbulence, where the basic part of the transferred energy is disposed. The Karman's Lecture of 1976 delivered by Professor Oleg M. Belotserkovskii was one of the turning points in the theoretical study of turbulence (see Appendix A to this book).

Since 1976 the LOS as well as the related hydrodynamic instabilities have been intensively investigated by Russian researchers headed by Professor O. M. Belotserkovskii. "Constructive Modeling of Structural Turbulence and Hydrodynamic Instability" is one of the most influential books on the subject ever to appear. It is devoted to the studies of multi-dimensional developed turbulence and hydrodynamic instability on the basis of structural analysis and numerical calculations with the usage of high performance computers. This monograph puts together the most important works of Professor O. M. Belotserkovskii and his school for more than 30 years. It demonstrates constructive approach to calculation of Large-Scale Ordered Structures (LOS), which transfer energy. And together with the stochastic models such an approach allows to study all phenomena as a whole. One of the most interesting results is that the inner structure of "large vortices" has stochastic character of "Small Turbulence" (ST). Calculations of LOS were made on the base of Integral Conservation Laws (ICL) without taking into consideration for molecular viscosity effect, of which influence on the characteristics of big structures is quite insignificant. Such approach allowed to decrease demands to possibilities of Computers (power and operational memory) and conduct researches of a number of important tasks such as: wakes after moving objects, shear layers, jets and other phenomena. It is important to stress that for LOS calculations one should not use semi-empirical models of turbulence and sub grid approximations. Investigations of ST were carried out on the basis of rational approaches to spectral methods (Navier–Stokes equations) by F. Harlow, Y. Kaneda or at the kinetic level by the Monte Carlo approach (O. Belotserkovskii, Y. Chlopkov, V. Vanitskii).

The revised approach to the studies of structural turbulence problems and hydrodynamic instability was presented by the author at the lectures and workshops in Belgium at Karman's Lecture, in the USA on lecture in Mathematical Institute of R. Courant, at the work-shops in Los Alamos organized by Dr. F. Harlow and also at numerous seminars in Germany, Poland, Japan, India and other countries. Russian–Japanese cooperation in this area appeared very successful, which found acknowledgement in numerous workshops and joint project "Turbulence and Instability" between Nagoya University, Japan and Institute for Computer-Aided Design, Russian Academy of Sciences.

We can assert that the monograph by Academician O. M. Belotserkovskii is based on the structural analyses of the nature of the investigated phenomena and the achieved results demonstrate it.

In a whole the book is outstandingly interesting and can be useful from both theoretical and practical point of view.

Professor Yoshiaki Nakamura
Department of Aerospace Engineering
Nagoya University

16 May 2008

See also: O. Belotserkovskii, Y. Kaneda, and I. Menshov (eds.), *Investigation of Hydrodynamical Instability and Turbulence in Fundamental and Technological Problems by means of Mathematical Modeling with Supercomputers* (Nagoya-Press, Japan, 2007).

OPINION by Professor F. Harlow and Dr. Hopson (USA, Los Alamos)

Memorandum of understanding

For assumed cooperation between the Institute for Computer Aided Design, Russian Academy of Sciences (ICAD RAS), and Group T-3, Los Alamos National Laboratory (LANL).

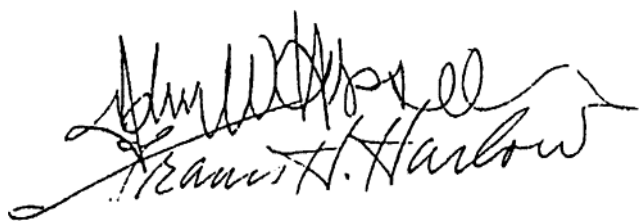
Academician Oleg Belotserkovskiy, Director of the ICAD RAS, visited the Los Alamos National Laboratory, Group T-3, in a consultant position from September 29, 1994, to January 11, 1995. During this time he established various scientific contacts and recognized different scientific and applied directions that represent mutual interest for common activity between ICAD RAS and Group T-3 and with other Divisions of LANL. Academician Oleg Belotserkovskiy presented 14–15 official seminars and lectures representing topics of significant interest to Los Alamos. The main directions of the scientific activity of Oleg Belotserkovskiy were the following:

- direct modeling of turbulence (large ordered structures, turbulent background, transition to chaos);
- instabilities studies: Rayleigh–Taylor, Richtmyer–Meshkov instabilities (multidimensional and multi-mode interactions, nonlinear late-time stages, a sequential transition to turbulence, etc.);
- development and adapting of new algorithms for the calculations of unsteady multi-dimensional (2D-3D) problems (FLUX-method, grid-characteristic approach, and others);

- Monte-Carlo technique;
- difference schemes with positive approximation on unstructures grids;
- practical applications (computational fluid dynamics, solid mechanics plasma physics);
- application of mathematical methods and computers in medicine;
- demonstration diskettes using a color visualization and others.

For the above-mentioned activities Academician Oleg Belotserkovskiy was very highly qualified. Two reports are being prepared for publication by LANL on the mentioned subjects.

The visit of Acad. Belotserkovskiy developed much friendship and was a great pleasure for those of us who had the opportunity for extensive discussions.



For Group T-3, LANL
Dr. John Hopson, Group Leader of T-3
Dr. Frank Harlow, Group T-3
January 6, 1995