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Preface

Symposium on Turbulence Structures and Aerodynamic Heat/Force (STSAHF2018)—Scientific Significance of Turbulence Research

Most fluid flows in nature and engineering applications are in the state of turbulence. Turbulent motions usually exhibit a wide range of spatial and temporal scales, such as the flow of natural gas and oil in pipelines, the wakes of cars and submarines, the boundary layer of an aircraft, the current in the ocean surface, the atmospheric boundary layer, the interstellar gas clouds (gaseous stars), and the Earth's wake in the solar wind. Turbulence can greatly improves the heat and mass transfer efficiency of macroscopic flow. For example, chemical engineers use turbulence to mix up and homogenize fluid components, and to increase chemical reaction rates in liquids or gases. However, turbulence can also lead to the increase of drag, aerodynamic heat, hydrodynamic and aerodynamic noise. For instance, the aerodynamic loading of high-speed aircraft can be significantly increased due to turbulence.

Although mechanics is the most basic form of the study of macroscopic mechanical motion of a substance, and the most classical and "mature" part of the scientific system, it is still impossible to implement effective control over most common and important flows. The reason is that turbulence is the most common form among all kinds of flow patterns. Our current knowledge of turbulence is far from mature, let alone the effective control.

Turbulence is not a property of fluid, but a characteristic of fluid flow. If the turbulent Reynolds number is large enough, most turbulent dynamics is almost the same in all fluids, no matter liquids or gases. The definition of turbulence has been widely divergent. Batchelor [1] suggests that turbulence occurs when the pressure and velocity in the flow change chaotically. Tritton [2] argues that it seems impossible to give a simple and complete definition of turbulence. People usually describe some characteristics of turbulence and make discontinuous summaries rather than give a formal definition. Perhaps the best definition is that turbulence is a state of continuous instability. If one studies turbulence from a statistical point of view, he/she will encounter the problem of identification of turbulence, i.e., the state in which the flow can be called turbulence. Phillips [3] believes that turbulence is essentially the result of convective instability or shear flow instability. It is widely acknowledged that turbulence can be described by the Navier-Stokes equations. However, it is well known that the solution of Navier-Stokes equations is an open mathematical problem. Therefore, there is no general solution to the turbulence problem. As the equations of fluid motions are nonlinear, each individual flow pattern has its own uniqueness related to its initial and boundary conditions.

Turbulence is a highly unstable, multi-scale and multi-structure thermodynamic nonequilibrium state in which the inherent degree of freedom of the fluid is highly excited by inertia-dominated instability at high energies. Turbulence is the most complex fluid movement due to high degree of freedom and dimension, strong nonlinear interaction, and the coexistence of orderliness and randomness among multi-scales. Therefore, its adequate quantitative description is extremely difficult. Although formally investigated for more than a century, great difficulties have been encountered in theoretical analysis, experimental analysis and numerical simulation. Although many famous scholars had been attracted by the turbulence problem, they could not persevere on this endeavor. It is also rare in the history of science that progress has been very slow, despite long-term and strong financial support given by governments of major countries.

The central problem of turbulence research, as well as the key issue of turbulence control, is to understand the evolution law of large-scale space-time geometric structures, i.e., the coherent structures. However, the nonlinear coupling between large-, intermediate- and small-scale degrees of freedom leads to the anisotropy of complex large-scale coherent structures, which is the core difficulty of the turbulence problem. Previously, all the remarkable results in turbulence theory (such as Taylor's turbulence statistical theory and the famous Kolmogorov phenomenological theory) have been achieved for nearly isotropic small-scale structures with approximate universal laws [4]. These theories are based on the fact that under isotropic condition, turbulence has stationary random fields and isomorphic ergodicity, although the turbulence problem itself cannot be closed. Mathematical tools such as Fourier analysis and perturbation approximation are available for isotropic turbulence study. However, Effective mathematical tools for high-dimensional nonlinear and non-Markov stochastic processes are still lacking. In addition, the scale of spatial and temporal resolution required for fine observation of turbulence is astronomical in direct proportion to the cube of the Reynolds number, which poses a continuing challenge to numerical simulation and experimental measurements.

As mentioned previously, although turbulence is observed in nearly all areas of industrial engineering and human life, it remains a challenge for experimental, theoretical and computational studies. In this context, the Symposium on Turbulence Structures and Aerodynamic Heat/ Force (STSAHF2018) was held in Tianjin, China on 7-9 July 2018. The aim of this symposium is to bring together the leading young research scientists, researchers and research scholars from universities, institutes and research laboratories in China to discuss the state-of-the-art theory, modelling, experiment and simulation of incompressible and compressible turbulence in single- and multi-phase flows. Special focuses are on the role played by turbulence structures in the prediction and control of aerodynamic heat and force. There are totally 48 invited oral presentations and 18 student oral presentations in this symposium. The active participation and contributions of all attendees have made the symposium a successful event. In order to celebrate the achievements made in this symposium, 15 selected papers are suggested by the organizing committee for publication in Advances in Applied Mathematics and Mechanics