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The prospects of statistical modeling of turbulent flows

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Abstract

The problems and prospects of statistical modeling of energy containing structure of developed turbulent flows are shown. It is shown that the method of RANS can not provide high quality of such models due to unconditional averaging of Navier-Stokes equations. Also, it is shown that high quality of mathematical models can be achieved using the method of autonomous statistical modeling of turbulence ASMTurb, distinctive feature of which is conditional averaging of Navier-Stokes equations over a turbulent and non-turbulent fluid of a turbulent flow.

Keywords: turbulent flows, statistical modeling, intermittency.

1. Introduction

Development of an effective physical-mathematical model which would provide high accuracy and speed of calculation of averaged hydrodynamic values of a developed turbulent flow is still a key problem of statistical hydrodynamics. To solve this problem, it is first of all necessary to determine the type of statistical characteristics most suitable for mathematical modeling. In the classical RANS method, such characteristics are unconditional statistical momenta ("average" and "pulsation" values of hydrodynamic quantities); in the method of autonomous statistical modeling of turbulent flows ASMTurb [1] which takes into account the effect of hydrodynamic intermittency [2] they are conditional statistical momenta for each of the intermittent media with a turbulent and non-turbulent flow. [3, 4, 5, 6].

At present, the method of RANS is being intensively used for mathematical modeling of all possible processes of turbulence (for example, processes in case of turbulent combustion). Such stable attention to the RANS method is explained by a high speed of predicting the structure of a turbulent flow in comparison with the methods DNS and LES, i.e. a high calculation speed of hydrodynamic characteristics of the turbulent flow under study. At the same time, the practice showed that for more than a century-long history of using the method of RANS the attempts to construct a mathematical model of high quality had failed.

The aim of this work is to reveal the problems of the RANS method and determine the prospects of increasing the quality of statistical modeling of developed turbulent flows. For this, it is necessary to answer the following questions: for what reason the method of RANS does not allow building physical-mathematical models of high quality; which of statistical characteristics of a turbulent flow are most suitable for modeling; what approach in statistical modeling of turbulence processes is the most effective?

We will start solving the set up questions with discussion of the problems and peculiarities of statistical modeling of turbulent flows, to be more exact, large scale (energy containing) structure of developed turbulent flows with transverse shear.

2. Problems and peculiarities of statistical modeling of turbulent flows

The problems of the RANS method are well-known – mathematical models built according to this method can not provide a high accuracy of calculation of average and pulsation characteristics of turbulent flows. This especially refers to correlations of pulsation hydrodynamic quantities. At the same time, a recently developed method of autonomous modeling of turbulent flows ASMTurb, the peculiarity of which is consideration of intermittence effect, has shown that models built according to this method give a "surprisingly" good agreement of calculations with the known experimental data [3,4].