Transport Phenomena

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PA link between chaos and vortex dynamics in a transitional boundary layer

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A model of the dynamic physical processes that occur in a transitional boundary layer flow is described. The CS-solitons, the closed vortex, the secondary closed vortex and the chain of ring-like vortices are postulated to be the basic flow structures of the transitional boundary layer as well as the turbulent boundary layer. It is argued that the central features of the transitional and developed turbulent boundary layer flows can be explained in terms of how the series vortices interact with each other, and with the CS-solitons. The physical process that leads to the regeneration of the new closed vortex along the border of the CS-soliton is described, as well as the processes of the evolution and the interaction of the vortices to high frequency vortices. The model is supported by recent important developments in the theory of unsteady surface layer separation and a number of kernel experiments which serves to both transitional and developed turbulent boundary layer. An important aspect of the model is that it has been formulated to be consistent with accepted rational mechanics concepts that are known to provide a proper physical description of other flows. By the way, a link between chaos and the transitional dynamic system is established. The result shows that fractal dimensions can be used to describe all the transitional processes as a necessary factor such as Reynolds number.

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A critical review of turbulence modelling: physical constraints and physics-preserving models

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The present review, which includes some new material, consists of two parts: physical constraints in turbulence modelling and physics-preserving turbulent closure models that preserve the frame indifference and satisfy both the principle of material frame indifference (PMFI) and the second law of thermodynamics. The former commences with careful definition of the average operation, the Reynolds stress, the turbulent heat flux and the turbulent mass flux. The remainder of this part is on the developments, to date, of three physical constraints imposed by the invariance, the realizability and the PMFI. In particular, two sufficient conditions are discussed for the Reynolds stress tensor and the turbulent heat/mass flux vector to be frame indifferent. The application of the second law of thermodynamics to a thermally isolated system and an irreversible process concludes that realizability inequalities in turbulent flows follow logically from the second law of thermodynamics. How system rotations affect flow fields is critically examined from a basic theoretical standpoint. Also critically reviewed is the literature on the range of validity of the PMFI to the turbulence modelling. The latter is devoted to the progress, to date, of physics-preserving closure models of the Reynolds stress and the turbulent heat/mass flux. In particular, both necessary and sufficient conditions are developed in a systematic, rigorous way for turbulent closure models to satisfy the three constraints reviewed in the first part. The results have either confirmed some intuitive arguments or offered new insights into turbulence modelling, and are of significance in clarifying some controversies in the literature, examining how well existing models preserve the physics, and developing new models. Also developed are a linear theory, a quadratic theory and a flow decomposition theorem to simplify and guide the work of developing specific physics-preserving models. This part ends with a further constraint on the physics-preserving models by the disappearance of Reynolds stress and turbulent heat/mass flux at a vanishing value of the mean velocity. Most methods and results in the present review are also valid for the higher-order correlations and the subgrid-scale (SGS) modelling in the large eddy simulation (LES).

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Burgers' Weak Turbulence by Dynamical Systems Approach

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In the present work, the Green's function of the one-dimensional heat conduction equation is employed to convert Burgers' equation into the infinite dynamical system described by an integration equation system with respect to the time variable. The infinite dimensional system is truncated to finite dimensional dynamical systems. These systems are solved by a numerical method proposed in the present paper. The calculated results not only describe the scenario of the route to the Burgers' turbulence, but also reveal a new explanation for the mechanism of the occurrence of the intermittence in the turbulence. In addition, these results demonstrate a similar behavior for the dynamical systems with dimensions ranging from 30 to 450 that are utilized to approximate the Burgers' equation. This shows some validity of using finite dynamical systems to approach the transition process from laminar flow to the turbulence.

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Solution filtering technique for solving Burgers' equation

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Burgers' equation is a one-dimensional (1-D) analogue of the Navier-Stokes (N.–S.) equations; it embodies all the main mathematical features of the N.–S. equations. In the present study, we test the solution filtering technique by solving Burgers' equation numerically. The solution filtering technique is a new approach proposed for dealing with aliasing of underresolved solution as arise in large eddy simulation (LES) of turbulence. The idea underlying the solution filtering technique is that filtering aliased solutions is far simpler than dealing with the consequences of filtering nonlinear differential equations. The basic approach of the solution filtering technique is that the governing equations (Navier–Stokes equations) are not filtered and are solved directly on a grid system that is much coarser than required by direct numerical simulation; then the solution at each time step is filtered. Our present studies show that such an approach works quite well for Burgers' equation. In spite of the fact that the research carried out in the present studies employs Burgers' equation rather than the full N.–S. equations, from previous studies we believe that the results obtained from Burgers' equation will apply to the N.–S. equations, at least in a general way. Therefore, it is expected that the solution filtering technique will possess significant potential in solving the practical turbulent problem governed by the three-dimensional (3-D) N.–S. equations.

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