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Recent Advances in Fluid Mechanics: Feature Papers

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This Special Issue is a collection of top-quality papers from some of the Editorial Board Members of Fluids, Guest Editors, and leading researchers discussing new knowledge or new cutting-edge developments on all aspects of fluid mechanics. Research in Turbulence continues to be one of the active areas; other papers focus on mixing , multiphase flows and porous media , slow (creeping) flows, potential flows, non-Newtonian fluids, fluid-structure interaction, and numerical methods.

With the latest developments in turbulence modeling, Klein and Germano [1] indicate that the Large Eddy Simulation (LES) technique will be used more often in the future. By performing a multiscale dynamic analysis of the commutation error, based on the filtering approach, they illustrate the flexibility of their method, showing that, in all the cases that they considered, the commutation error was smaller than the error obtained by neglecting the commutation error.

To assess the effects of continuous transition on mixing performance, Ryu and Cookson [2] use a modified blinking vortex system with a varying degree of continuous transition; their results indicate that mixing systems, such as continuous pipe flow-based devices, might benefit from the presence of a small degree of continuous transition between discrete states.

To study gas dispersal in urban places or hilly grounds, one usually uses the two-phase flow approach or the Navier–Stokes equations. Among simpler approaches are the two-layer shallow water models for large-scale dispersions. Based on their previous studies, Chiapolino et al. [3] propose a new model and show that this new model which uses a more appropriate drag force correlation, accurately reproduces the experimental results for the case of heavy gas dispersal in quiescent air.

Koleski and Bickel [4] study the creeping flow of a Newtonian fluid in a hemispherical region. The original solution given by Lamb is not complete when the flow is restricted to a semi-infinite space. The authors also discuss the solutions of Marangoni flows due to a local source at the liquid–air interface.

Baddoo [5] presents a method for computing potential flows in planar domains; this study is based on a new class of techniques, known as "lightning solvers", particularly suitable for flows in domains with corners. The method is then applied to a range of classical problems, including steady potential flows, vortex dynamics, and free-streamline flows.

It has been known that polymeric additives can reduce the frictional drag in turbulent flows. Rajappan and McKinley [6], through experimental measurements in a turbulent Taylor–Couette flow, show that both polymer additives and superhydrophobic walls can be used to reduce the frictional drag in wall-bounded turbulence.

Jiang et al. [7] provide a brief review of some of the recent developments in the mathematical foundations of eddy viscosity (EV) models of turbulence. After reviewing the Boussinesq conjecture, the authors suggest methods to adapt EV models to non-statistically stationary turbulence without encountering numerical instabilities such as the negative eddy viscosities. By reinterpreting the turbulence length scale, they can obtain model simplification and a stronger connection between the model and the Navier–Stokes equation.

High-rise buildings with semi-enclosed landscaped spaces are open to outdoor airflow. Mohammadi et al. [8] studied the effects of three common wind buffers (railing, hedges,

and trees) on the performance of such skygardens by performing computational fluid dynamics (CFD) simulations using the realizable k-ε method. Their results indicate that by using the right combination and right dimension of these elements, aero-thermal comfort across the skygardens can be achieved.

Dostalík et al. [9] use some of the classical models in dilute polymeric fluids and show that they can obtain thermodynamically consistent models for non-isothermal flows of these fluids. They also look at the finite amplitude (nonlinear) stability of a stationary, spatially homogeneous state in a thermodynamically isolated system.

Zhang and Agarwal [10] use the incompressible Reynolds-Averaged Navier–Stokes (RANS) equations with realizable k-ε and WA (Wray–Agarwal) turbulence model in their numerical simulations with ANSYS Fluent to study the flow of a fountain formed by twin-jet impingement on the ground. Their results indicate that, for different Reynolds numbers, a fountain that inclines toward the jet with a smaller Reynolds number can be observed. To compensate for alterations of the turbulence structure due to the numerical treatment, Tangermann and Klein [11] use a method based on local volume forces with a control loop; they present their results for the flow around an airfoil at a high angle of attack and with massive flow separation. Obeid et al. [12] present a closed-loop control algorithm for the reduction of turbulent flow separation over NACA 0015 airfoil. The authors also perform numerical simulations using the URANS equations for various airfoil incidences with and without closed-loop control.

Fluid-solid interactions is a challenging area of research, especially if the solid component is deformable. Silva-Leon and Cioncolini [13] use flexible filaments with a rectangular cross-section and various lengths; they consider air flow at a moderate Reynolds number, corresponding to laminar and mildly turbulent flow conditions, and experimentally study the flexible filaments dynamics using fast video imaging.

By using a DNS database of statistically premixed flames subjected to unburned gas, Brearley et al. [14] show that the turbulent velocity fluctuations within the flame brush remain anisotropic, indicating a tendency toward the trailing edge of the flame brush. Their study indicates that the assumption of homogeneous isotropic turbulence may not be valid for turbulent premixed flames.

In many studies, baffle plates are used as a potential device for dampening the sloshing of propellant in rocket tanks; this may cause larger pressure fluctuations in the tank. To avoid this problem, Furuichi and Tagawa [15] consider the two-phase flow of gaseous oxygen and liquid oxygen in a spherical spacecraft tank in a non-gravitational field, with an imposed impact excitation force. Their computational studies indicate that the sloshing depends to a certain extent on the magnetic flux density at the coil center.

To accurately model transport in porous media, an important parameter is the hydrodynamic dispersion coefficient for particles, which could depend on the properties of the medium, the dispersing compound, and the flow field characteristics. Nguyen and Papavassiliou [16] use the lattice Boltzmann method (LBM) to simulate the flow in porous media and the Lagrangian particle tracking (LPT) to track the movement of individual dispersing particles. They find that the hydrodynamic dispersion coefficient depends on the effective Lagrangian Peclet number for packed beds. Most two-component (two-phase flow) studies assume that the whole mixture has one temperature and only one energy equation is required. Two-temperature theories are rare and difficult to use. Kirwan and Massoudi [17] consider a mixture of two Newtonian fluids which are at different temperatures and use standard principles, such as frame indifference, in continuum mechanics; they look at the constraints due to the Clausius–Duhem inequality and obtain inequalities involving the principal and the cross flux coefficients appearing in the constitutive relations.

Su et al. [18] develop a novel flapping mode, named partial advanced mode (PAM), which can generate a high lift force. Their numerical simulations indicate that the period-averaged lift coefficient, CL, increases up to 16% when compared to the traditional symmetrical mode.

One of the approaches used to study flow in fractured porous media is the complex variable formulations. Weijermars and Khanal [19] present a modified solution, using complex analysis methods (CAM). They show that the new approach corrects the physically unfeasible refraction of streamlines across high-permeability bands.

Kinetic instabilities of sedimentation and creaming are important issues when studying suspensions and emulsions. Pal [20] provides a brief review of the unhindered and hindered settling/creaming behaviors of conventional suspensions. The results, based on simulations, show the influence of a three-phase contact angle of nanoparticles at the oil/water interface.

Basse [21] considers the streamwise turbulence intensity definitions using smooth- and rough-wall pipe flow measurements; he also presents a procedure to calculate the turbulence intensity based on the bulk Reynolds number.

Vortex methods can be used to solve the incompressible Navier–Stokes equations in their velocity-vorticity formulation. Mimeau and Mortazavi [22] provide an overview of the Vortex Methods, which are based on Lagrangian approaches. They present detailed evaluations and developments of the mathematical framework, and they discuss the strengths and the limitations as well as some references to applications and numerical simulations using these techniques.

To study turbulence-solid surface interactions, the Rapid Distortion Theory on transversely sheared mean flows is sometimes used. Goldstein [23] provides a brief review of the general theory given in recently published papers. He uses a pair of very general conservation laws which can be used to derive upstream boundary conditions.

To study hydrocarbon migration, one can use complex analysis methods (CAM) along with Eulerian particle tracking. Weijermars et al. [24] use CAM, provide pressure field solutions, and compare their results with the independent embedded discrete fracture method (EDFM) solutions. They also provide different examples for the fast optimization of waterflood patterns and the modeling of fluid withdrawal patterns in hydraulically fractured wells.

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