Burgers Lecture: Flow Instabilities and Turbulence of Visco-Elastic Fluids

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Although engineers have since long been acquainted with the fact that visco-elastic fluids like polymer melts and solutions exhibit many unusual instabilities in industrial processes like extrusion, it is only more recently that scientists have become interested in these types of problems.

The interest in them stems from the realization that while most instabilities in normal fluids are due to inertial effects, many visco-elastic instabilities occur in the small Reynolds number limit, i.e. are noninertial. In polymeric fluids the instabilities are due to the anisotropic elastic forces that result when the polymers get stretched and oriented by the flow itself. Recent experiments on polymer fluids have also given strong evidence for the existence of a regime of elastic noninertial turbulence. In this talk I will review the recent progress in this field, including our own recent nonlinear analysis which predicts that in this limit, Poiseuille flow of a visco-elastic fluid exhibits a nonlinear (subcritical) transition to a dynamical state which is probably weakly turbulent, and experiments aimed at testing this prediction.

From Particle to Kinetic and Hydrodynamic Descriptions of Flocking

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We discuss a particle model for flocking introduced by Cucker & Smale (C-S).

Flocking occurs when pairwise long range interactions are sufficiently strong. We derive a Vlasov-type kinetic model for the C-S particle model and show that it exhibits time-asymptotic flocking behavior for arbitrary compactly supported initial data.

Finally, we introduce a hydrodynamic description of flocking based on the C-S Vlasov-type kinetic model and show flocking behavior without closure of higher moments.

Matchsticks, Scramjets, and Black Holes: Numerical Simulation Faces Reality

Elaine S. Oran
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Naval Research Laboratory

The evolution of the science and art of numerical simulation of complex, complicated fluid flows has made enormous strides in the past forty years.

We have progressed from relatively simplified one-dimensional steady-state results to fully three-dimensional, time-dependent simulations including very complex physics. These advances have been driven by new computational hardware, new algorithms for solving the equations, and the real need for this technology. This presentation emphasizes the broad range of applications that are possible, and describes some of what we can now do, what we have learned, and where we might go with this exciting technology in the future.

Velocity Fluctuations in Laminar Fluid Flow

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We discuss the systematic incorporation of intrinsic thermodynamic noise to the classical planar Couette flow problem, establishing stochastic Orr-Sommerfeld and stochastic Squire equations for the velocity fluctuations around the stationary Couette solution. We then first solve the stochastic Orr-Sommerfeld and Squire equations in bulk, without accounting for boundary conditions in the fluctuating velocity field. In this way it is possible to obtain an exact representation of the spatial spectrum of the thermodynamic fluctuations in the limit of large wave numbers.

Next, we incorporate confinement effects and present an approximate solution for the intensity of velocity fluctuations based on a simple Galerkin projection technique. We shall also discuss how an exact solution for the case of confined geometries can be obtained by an expansion into a set of hydrodynamic modes, conveniently expressed in terms of Airy functions. Then, energy amplification can be simply expressed in terms of the decay rates of these hydrodynamic modes.