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II. The turbulence modeling group

The turbulence modeling effort was carried out by three separate teams. Aupoix, Blaisdell, Reynolds, and Zeman used Blaisdell's simulations of homogeneous compressible isotropic turbulence and homogeneous compressible shear flow to examine various aspects of modeling the energy equation in these flows. Bradshaw and Sendstad used simulations of channel flow with a spanwise pressure gradient and a 3-D boundary layer to study aspects of three-dimensional turbulent boundary layers. Rodi and Mansour used simulations of channel flow to evaluate various aspects of $k-\epsilon$ modeling in the near-wall region, producing two contributions to this volume. These studies again demonstrate the powerful uses that can be made of simulation databases in guiding the development of turbulence modeling.

Aupoix *et al.* showed that the dilatation dissipation and pressure-dilatation terms are important in the kinetic energy equation and should not be neglected in turbulence models. In decaying isotropic turbulence, these terms depend critically on the initial conditions, specifically on the strength of the initial density fluctuations. However, in homogeneous shear flow, these terms approach limiting behavior that is independent of the initial conditions. The simulations show that the limiting value of the ratio of dilatational dissipation to solenoidal dissipation is about 0.1 and hint that there may be a limiting turbulent Mach number of approximately 0.7. Models for evolution of the *rms* pressure fluctuation and for key terms in the transport equation for pressure-velocity gradient term were also explored.

Bradshaw and Sendstad studied the simulation of channel flow with a suddenly-imposed cross-stream pressure gradient. They showed that the main effects occur in the viscous region and found some support for ideas about toppling suggested earlier by Bradshaw and Pontikos. They initiated a three-dimensional spatially-developing boundary layer calculation similar to an earlier Bradshaw experiment and show some preliminary results from calculations not yet well-developed. These preliminary results indicate that the shear stress vector and velocity gradient vector are not aligned in the outer region of the boundary layer. More detailed conclusions must await the completed calculation.

Rodi and Mansour's first paper on low Reynolds number (near-wall) modeling of the $k-\epsilon$ equation concentrated on the evaluation of various "damping function" models. They show that the treatment of the eddy viscosity coefficient C_μ as a constant (0.09) is at best a rough approximation, and significant tempering of that coefficient as a function of the production/dissipation ratio is required. They proposed improved damping functions for use in standard models. Perhaps the most significant result came from their investigation of Durbin's suggestion for use of $\overline{v'^2}$ instead of k to set the velocity scale. They showed that with this change it is not necessary to use empirical damping functions; hence, this approach gives a cleaner and more physical model. They made a detailed study of the various terms in the ϵ budget, using the results to make a careful assessment of existing models. They identified areas of weakness in the models and proposed new models for the important terms in the ϵ equation, parameterized by the local non-dimensional strain rate and Reynolds number. Their new model is clearly an improvement in the case of channel flow. Subsequent work will test these models in more general situations.

Rodi and Mansour's second paper focuses on one-equation modeling, especially Durbin's ideas on the use of $\overline{v'^2}$ instead of k to give the velocity scale. As noted above, this model does not require damping functions used in existing near-wall models. When used in a one-equation model it requires a correlation for $\overline{u'v'}/\overline{v'^2}$ and $\overline{v'^2}/k$, for which they provide models based on the channel flow simulations. Together with simple linear length scale prescriptions and the k equation, these correlations provide a simple one-equation approach very deserving of further evaluation in more complex flows.

During the summer school, this author gave an informal workshop in which a new type of turbulence model based on a one-point "eddy structure tensor" that contains two-point information was described. This model has since been shown to do remarkably well in predicting the rapid distortion behavior of a very wide variety of homogeneous turbulent flows and a good job in homogeneous shear flow with either weak or strong shear. Working notes giving the current status of this model are available upon request to the author.

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