III. Compressible flow and modeling

A long-term objective of the CTR is to advance the state of turbulence modeling, particularly for compressible flows. The six papers in this section provide several important new ideas towards this end.

Cambon, Coleman, and Mansour used the DNS database for one-dimensional axial compression to guide the development of a rapid distortion theory (RDT) for compressible flows subjected to compressions. They showed that the controlling parameter for compressibility effects is the ratio of the distortion time scale to the acoustic time scale. In the case where the acoustic time scale is slow compared to the distortion time scale, "pressure released RDT" applies, in which the pressure fluctuations can be neglected. In this regime, the growth rate of the turbulent kinetic energy can be higher than the rate when the flow is nearly incompressible. This is different from the homogeneous shear case where compressibility effects are found to reduce the energy growth rate. Finally, they used the RDT and DNS results to suggest improvements in turbulence models for compressible flows.

Blaisdell and Zeman used Blaisdell's DNS for homogeneous turbulence to make further examinations of Zeman's model for the extra rate of turbulent energy dissipation due to turbulent dilatations arising from regions containing eddy shocklets. They show how acoustic waves can be focused in the turbulence to form such shocklets and that the Zeman model works well for turbulent Mach numbers less than 0.3. Their work raises unanswered questions about the model at higher Mach numbers, suggesting need for further study.

Vandromme and Zeman explored the applicability to boundary layer flows of a model for the pressure dilatational term developed by Zeman and Coleman by reference to DNS for rapid axial compressions. The flow considered was a supersonic compression corner flow with an extended separated region, where a considerable improvement over standard k-ϵ modeling was obtained.

Papamoschou and Lele studied the pressure field induced by a small isolated vortex in a compressible shear layer using DNS in a convected frame tied to the disturbance vortex. The idea was to examine the zone of influence of the disturbance with increasing convective Mach number M_c. They showed that this influence extends to the edges of the shear layer, although the zone of influence in the streamwise direction is strongly reduced with increasing M_c.

Kevlahan, Mahesh, and Lee used DNS to study the interaction of a weak shock front with strong isotropic turbulence. This included solving the equation for a propagating surface (the shock wave) and comparisons of the results with the DNS predictions. For 2D turbulence, the agreement was very good. In 3D turbulence, the alignment of the vorticity vector with the intermediate eigenvector of the strain-rate tensor, found in other DNS, occurred upstream of the shock and was strongly intensified by the shock. In addition, they found a more significant tendency for velocity to align with vorticity than has been observed in incompressible DNS.

Durbin and Yang studied a proposed transport equation for the eddy viscosity in wall bounded flows. The relatively simple model, which does not incorporate wall-proximity damping functions, is intended for use in complex turbulent flows. Comparisons with DNS and experiments for various boundary layer flows show good agreement. The model eliminates several of the problems of standard k-ϵ models and shows considerable promise for use in generalized practical engineering calculations.

Together these six contributions include a number of important new ideas that their authors and others at Stanford and NASA/Ames are working to include in operational turbulence models. Thus, these contributions will be extremely helpful in CTR's development of improved turbulence models for compressible flows.

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