Information Sciences

Estimating Resolution Lengths of Hybrid Turbulence Models

This is a step toward increasing accuracy and robustness of unsteady-flow simulations.

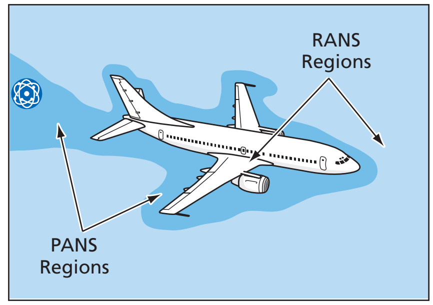
Langley Research Center, Hampton, Virginia

A two-stage procedure has been devised for estimating the spatial resolution achievable in the simulation of a given flow on a given computational grid by a computational fluid dynamics (CFD) code that incorporates a hybrid model of turbulence. The hybrid models to which this procedure is especially relevant are those of the Reynolds-averaged Navier-Stokes (RANS) and the partial-averaged Navier-Stokes (PANS) approaches. This procedure represents the first step toward adding variable-resolution turbulence-modeling capabilities to CFD codes as part of a continuing effort to increase the accuracy and robustness of CFD simulations of unsteady flows.

Some background information is prerequisite to a meaningful summary of the procedure. Among experts in CFD, it is well known that combination of the Reynolds-averaged Navier-Stokes (RANS) approach and eddy-viscosity turbulence models offers limited capability for simulating unsteady and complex flows. The RANS approach includes an assumption that most of the energy in a given flow is modeled through turbulence-transport equations and is resolved in a computational grid used to simulate the flow. RANS also overpredicts eddy viscosity, thereby yielding excessive damping of unsteady motion. The eddy viscosity attains an unphysically large value because of unresolved scales, and suppresses most temporal and spatial fluctuations in the resolved flow field. One approach used to overcome this deficiency is to provide a mechanism for the RANS equations to resolve motion only on the largest scales and to use a hybrid model to represent effects at smaller scales.

The RANS approach involves the use of a standard two-equation turbulence model in which the effect of turbulence is summarized by a viscosity that is a function of (1) the time-averaged kinetic-energy density (k) associated with the local fluctuating (turbulent) component of flow and (2) the time-averaged rate of dissipation of the turbulent-kinetic-energy density (ε). In PANS, which was developed to overcome the grid dependency associated with other hybrid turbulence models (including that of RANS), the standard two-equation turbulence model is replaced by another two-equation model in which one solves for the previously unresolved k and ε, which are now allowed to vary in space and time.

This minimum essential background information having been presented, it is now possible to summarize the two-stage procedure for estimating the achievable spatial resolution. In the first stage, one solves the unsteady or steady RANS equations. From the results of the RANS computation, one calculates a characteristic length scale of turbulence (L_T) and a length-scale ratio $\lambda = L_T/\Delta$, where Δ is the cell width along one of the three spatial coordinate axes. During the second stage, one solves the applicable PANS equations for the case in which λ is fixed in time but allowed to vary in space. The use of λ plus other criteria too complex to describe here makes it possible to determine appropriate spatial resolutions for different regions of the flow (see figure). One can quickly determine whether the grid spacing is appropriate for the resolution needed to simulate the flow by use of PANS or another hybrid model.



Different Regions of a Flow Field are best simulated by use of different models (e.g., RANS or PANS) and different computational-grid spacings, depending on the spatially varying length scale of turbulence.

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Education and Training Module in Alertness Management

An interactive Web-based General Aviation version of the module is now available for FAA WINGS credit.

Ames Research Center, Moffett Field, California

The education and training module (ETM) in alertness management has now been integrated as part of the training regimen of the Pilot Proficiency Awards Program ("WINGS") of the Federal Aviation Administration. Originated and now maintained current by the Fatigue Countermeasures Group at NASA Ames Research Center, the ETM in Alertness Management is designed to give pilots the benefit of the best and most recent research on the basics of sleep physiology, the causes of fatigue, and strategies for managing alertness during flight operations.

The WINGS program is an incentive program that encourages pilots at all licensing levels to participate in recurrent training, upon completion of which distinctive lapel or tie pins (wings) and certificates of completion are awarded. In addition to flight training, all WINGS applicants must attend at least one FAA-sponsored safety seminar, FAA-sanctioned safety seminar, or industry recurrent training program. The Fatigue