Berechnung turbulenter Strömungen mittels Zweisechicht-Turbulenzmodell

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vorgelegt von

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Abstract

The two-dimensional incompressible Navier-Stokes equations including a new low-Reynolds-number \( k-\tau \) two-layer turbulence model are solved by an implicit time-stepping routine, using the method of artificial compressibility. A fifth-order upwind-biased differencing scheme is used to discretise the convective and pressure terms and second-order central differences are employed to the other spatial derivatives. The new \( k-\tau \) two-layer turbulence model uses the transport equation for the turbulent kinetic energy \( k \) and an algebraic relationship for the turbulent time scale \( \tau \) near the wall but reverts to the \( k-\tau \) turbulence model proposed by Speziale et al. in the bulk of the flow away from the wall. The algebraic relationship for the turbulent time scale \( \tau \) and the eddy viscosity damping function \( f^\mu \) are validated by direct numerical simulation data and asymptotic analysis of near-wall turbulence.

The nonlinear equations are solved using the preconditioned GMRES (Generalized Minimal Residual) technique in conjunction with a numerical linearisation. A \( LD^{-1}U \) factorization of the approximate Jacobian matrix is used as preconditioning matrix. The iterative scheme has good vectorization properties and runs at about 160 MFlops on one processor of the Cray-YMP at the ETH Zürich.

A variety of flows are calculated at several Reynolds numbers to test and validate the present scheme. Results for the laminar flow in a square cavity and over the backward-facing step are in good agreement with experimental data and published numerical solutions. To check the turbulence model, the developed turbulent channel flow and the turbulent flow over a backward-facing step in a diverging channel are calculated. The results for the turbulent channel flow are in good agreement with direct numerical-simulation data even in the viscous sublayer. The simulation of the flow over the backward-facing step shows that the reattachment point is very sensitive to adverse pressure gradients. Finally, the turbulent flow of a vertical jet discharging into shallow water is considered.