Turbulence Models in ANSYS® Fluent CFD

Reynolds Time-Averaged Navier–Stokes Equations (**RANS**)

Linear **Eddy Viscosity** Modeling

One-equation models typically include a viscosity-like variable $\tilde{\nu}$ as another equation.

Spalart–Allmaras	$\tilde{\nu}$—pseudoviscosity
no wall functions and smaller near-wall gradients low memory requirements stable less sensitive to numerical error from non-layered mesh near wall shows good convergence	inaccurate for shear flow, separated flow, or decaying turbulence

Two-equation models account for history effects like convection and diffusion of turbulent energy. No current two-equation approach can handle buffer layer flow well, in which both Reynolds and viscous stresses are prominent.

k–ε	k—turbulent kinetic energy ε—rate of dissipation of kinetic energy
best for free-shear layer flows with small P gradients wall functions (buffer region flow not simulated) low memory requirements shows good convergence	inaccurate for adverse pressure gradients, strong curvature, and jet flow valid *only* for fully turbulent flow

RNG k–ε (renormalization group)	k—turbulent kinetic energy ε—rate of dissipation of kinetic energy
generally more accurate and reliable than k–ε: especially for rotating flows (incl. time-dependent turbulent vortex shedding) favorable for indoor air simulations formula for turbulent Pr number	inaccurate for vortex evolution unstable in steady-state solutions 10–15% more CPU time

Realizable k–ε	k—turbulent kinetic energy ε—rate of dissipation of kinetic energy
better for rotation, strong adverse pressure gradients, recirculation, mixing, channel and BL flows predicts spreading rate around planar and round jets	produces nonphysical turbluent viscosity in situations with both rotating and stationary fluid zones (multiple reference frame systems)

k–ω	k—turbulent kinetic energy ω—specific dissipation rate
no wall functions low memory requirements often accurate where k–ε model fails	inaccurate for adverse pressure gradients, strong curvature, and jet flow oversensitive to inlet free-stream turbulence properties sensitive to initial guess

SST k–ω (shear stress transport)	k—turbulent kinetic energy ω—rate of dissipation of kinetic energy
no wall functions accurate near wall	overestimates turbulence in regions with large normal strain (better than k–ε, however) converges slowly (use other model for initial guess)

Nonlinear **Eddy Viscosity** Modeling

v^2–f model	$\overline{v^2}$—velocity scale f—relaxation function
similar to k–ε but includes near-wall anisotropy and nonlocal pressure–strain effects good for attached or separated BL flows, as well as damping of turbulent transport near wall no wall functions	cannot solve eulerian multiphase problems

Reynolds Stress Transport Model

RSM (Reynolds stress transport model)	k—turbulent kinetic energy ω—rate of dissipation of kinetic energy
good for anisotropic turbulence (highly swirling flows; stress-driven secondary flows)	moderately computationally expensive (50–60% more CPU time; 15–20% more memory over k–ε) converges slowly

Large Eddy Simulation (**LES**)

RNG–LES	C_S—Smagorinsky constant
resolves large scales in flow field models small scales (so faster than DNS)	C_S not universal computationally expensive

Detached Eddy Simulation (**DES**)

DES (Detached Eddy Simulation)	
hybrid treatment using RANS approach near wall and LES approach in bulk flow (typically Spalart–Allmaras for RANS)	complicated grid generation

Comparative Summary of Turbulence Models in Commercial & Open-Source CFD Packages (as of Oct. 2015)

Several packages also support transitional flow models as well.

COMSOL	Spalart–Allmaras, k–ε, k–ω, SST k-omega, low-Re k-epsilon
CFX	Zero–eqn; k–ε, RNG, EVT(1E); Wilcox, BSL, SST k–ω; v^2–f; RSM, omega/BSL RSM, EARSM; transition model; LES (Smagorinsky, wall-damping/WALE, S–Lilly); DES (SST–DES); Scale-Adaptive Simulation Theory (SAS)
Fluent	Spalart–Allmaras; all three k–ε; std and SST k–ω; v^2–f; RSM; DES; LES
StarCCM+	Spalart–Allmaras, k–ε; realizable k–ε; k–ω SST; RSM; DES, DDES; LES, transition
OpenFOAM:	Reynolds-average simulation (RAS) k–ε; k–ω SST, RNG k–ε, realizable k–ε, Spalart, LES; DES; DNS

This document strives to be complete, but naturally will have omissions; if you discover any, please contact training@cse.illinois.edu.