ANSYS CFX Technical Specifications

Overview of Modeling Capabilities
- Laminar and turbulent
- Steady-state and transient
- Incompressible to fully compressible (subsonic, transonic, supersonic)
- Ideal and real gases
- Newtonian and non-Newtonian fluids
- Heat transfer
- Radiation
- Rotating and stationary
- Eulerian multiphase
- Free surfaces (VoF)
- Lagrangian particle tracking
- Chemical reactions and combustion
- Mesh motion and remeshing
- Immersed solids
- Fluid structure interaction

Detailed Outline of Modeling Capabilities

Boundary Conditions
- Inlets
  - Subsonic, supersonic and mixed (combined subsonic and supersonic)
  - Velocity, mass flow and flow direction, static pressure and direction, total pressure and direction, velocity and static or total pressure (supersonic), static pressure and total pressure and direction (supersonic), zero gradient
  - Total temperature, total enthalpy, static temperature
- Outlets
  - Subsonic and supersonic
  - Mass flow (with pressure profile or circumferential average pressure profile), velocity, uniform static pressure, average static pressure, radial equilibrium pressure distribution, circumferential average static pressure, degassing condition, meridional pressure profile, supercritical, zero gradient
- Opening (mixed inflow/outflow)
  - velocity, total (in)/static (out) pressure and direction, static (in)/static (out) pressure and direction, local flow direction or entrainment
- Wall
  - No slip, free slip, finite slip, specified wall shear, smooth, rough, moving, adiabatic, temperature specified, heat flux specified, heat transfer coefficient and reference temperature specified, opaque, black body, radiation intensity
- Symmetry
- Thin surfaces/baffles
- 1-D or 2-D profile specifications for any quantity

General Grid Interfaces
- Connection of multiple meshes from independent sources
- Detailed control of boundary conditions at non-overlapping portions of connections
- Rasterized or direct mesh intersection algorithms

Multi-Domain and Domain Interface Models
- Translational and rotational periodic connections
- Translational periodic connections with pressure change or mass flow rate
- Fluid–solid interfaces with pitch and shape change
- Porous domains with conservative algebraic fluid-porous interfaces
- Thin surfaces between fluid and solid domains for modeling conduction, thermal contact resistance and coatings, and additional variables transfer
- Stationary and rotating frames of reference
- Alternate rotation velocity advection model
- Multiple frames of reference interface models ▲
  - Stage interface model
  - Frozen rotor interface model
  - Transient rotor/stator interface model
- Profile Transformation model for transient blade row simulations with pitch change▲

Turbulence
- Zero- and one-equation models
- Two-equation models: k-ε, RNG k-ε, k-ω, BSL, SST
- Reynolds stress transport models (second-moment closure): LRR, SSG, QI, ω, BSL
- Explicit algebraic Reynolds stress models (EARSMs): k-ε, BSL
- Large eddy simulation (LES): Smagorinsky, dynamic, WALE
- Scalable wall functions and automatic near-wall treatment with integration to the wall
- User-defined turbulent wall functions and heat transfer
- Rough wall treatment for ω-based models, including with transition
- Curvature correction for swirling flow for two-equation models
- Detached eddy simulation (DES)▲
- Scale adaptive simulation (SAS)▲
- Predictive Menter-Langtry γ–θ laminar-turbulent transition model™▲

Heat Transfer and Radiation
- Thermal energy and total energy
- Natural convection (buoyancy)
- Viscous heating
- Conjugate heat transfer (CHT) solids
- Porous CHT domains
- Advection in rotating and translating CHT solids
- Gray, multi-band, and multi-gray (weighted sum of gray gases) spectral models
- Spectral material property dependencies
- Radiation scattering

- Radiation models
  - P1 (diffuse)
  - Rosseland
  - Discrete transfer for participating media and surface-to-surface radiation
  - Monte Carlo for participating media and surface-to-surface radiation▲

Combustion▲
- User-defined reactions and pre-supplied database of reactions
- Single- and multi-step eddy dissipation model (EDM)
- Finite rate chemistry model
- Combined EDM/finite rate chemistry, single- and multi-step
- EDM maximum flame temperature model
- Flame extinction model
- Spark and auto-ignition (knock and ignition delay) models
- Laminar flamelet with presumed PDF model for diffusion flames
- Premixed/partially premixed combustion (coupled with flamelet PDF for post-flame front mixing and reaction)
  - Burning velocity model (BVM)
  - Extended coherent flame model (ECFM), including wall quenching model
- Exhaust gas recirculation (EGR) model
- Weighted reaction progress model for partially premixed combustion
- Choice of predefined or user-defined turbulent and laminar burning velocity correlations
- NOx models
- Magnusson soot model
- Single- or multi-phase combustion
- Coal combustion with proximate/ultimate hydrocarbon fuel analysis
- Chemistry (for example NOx) post-processing mode
- Real gas combustion
- Component-dependent turbulent Schmidt numbers
- User-definable turbulent Schmidt and Prandtl numbers

Additional User-Defined Transport Equations
- Scalar and vector additional variables
- Advective and diffusive transport
- Purely diffusive transport
- Poisson equation
- User-defined algebraic equation
- Conjugate additional variables and additional variables in solid domains

Material Properties
- User-defined materials and pre-supplied database of materials
- Equation of state
  - Ideal gas
  - Standard Redlich–Kwong
  - Aungier Redlich–Kwong
  - Soave Redlich-Kwong
  - Peng-Robinson
  - IAPWS IF-97 (water)
  - User defined
- Specific heat capacity
  - Constant
  - NASA format
  - Fourth-order polynomials
  - User defined
- Conductivity
  - Sutherlands formula
  - Modified Eucken kinetic theory model
  - User defined
- Viscosity
  - Sutherlands formula
  - Rigid non-interacting sphere kinetic theory model
  - Rigid interacting sphere kinetic theory model
  - User defined
- Non-Newtonian viscosity models
  - Bingham
  - Bird-Carreau
  - Carreau-Yasuda
  - Casson, Cross
  - Hershel-Buckley
  - Ostwald-de Waele
  - User defined
- Antoine equation for vapor pressure curves of pure substances
- Multi-component mixtures
- Electro-magnetic properties
  - Electrical conductivity
  - Magnetic permeability

Eulerian Multiphase Models▲
- Homogeneous or fluid-dependent mass and momentum equations
- Homogeneous or fluid-dependent turbulence equations
- Homogeneous or fluid-dependent energy equations
- Unlimited number of phases
- Drag force models
  - Schiller–Naumann, Wen Yu and Gidaspow drag models for solid particles
  - Ishii–Zuber and Grace drag models for drops and bubbles
  - General user-defined drag coefficient
- Non-drag force models
  - Lift force models
  - Turbulent dispersion force model
  - Virtual mass force model
  - Wall lubrication models
  - Solids pressure force model
  - Kinetic theory model
- Interphase heat transfer
  - Specification of interface flux, heat transfer coefficient, Nusselt number, two-resistance model, Hughmark or Ranz–Marshall correlations
- Interphase variable transfer
  - Specification of interface flux, transfer coefficient, Sherwood number, Hughmark or Ranz–Marshall correlations
- Interphase mass transfer
  - Equilibrium phase change mode
  - Thermal phase change model (evaporation, condensation, bulk boiling)
  - Non-equilibrium droplet nucleation and phase change model (evaporation, condensation)
  - Cavitation model (Rayleigh–Plesset)
  - Wall boiling model
- Multiple size group (MUSIG™) model for poly-dispersed with breakup and coalescence
- Algebraic slip multiphase model

Lagrangian Particle Tracking▲
- One-way or fully coupled two-way momentum transfer
- Steady-state or transient
- Moving mesh support
- Detailed control of injection locations, size distributions (6+ distribution functions), etc.
- User-defined and predefined particle drag models

- Non-drag forces (virtual mass, pressure gradient and turbulent dispersion)
- Primary breakup models: BLOB, enhanced BLOB, LISA, turbulence-induced atomization
- Secondary breakup models: Reitz and Diwakar, TAB, ETAB, Schmehl, CAB
- Advanced particle-wall interaction
- Virtual wall model for particle reflections at rough walls
- Quasi-static wall film model
- Wall erosion models (user-defined, Finnie, Tabakoff)
- Stochastic particle-particle collision model
- Extensive spray penetration diagnostics
- Convective, latent, and radiative heat transfer
- Evaporating and boiling single- and multi-component liquid droplets
- Coal combustion model with proximate/ultimate hydrocarbon fuel analysis
- Particle track quantities averaged onto fluid mesh
- User Fortran control of particle injection and particle models
- Fully parallelized
- Choice of particle termination criteria: distance, time, composition

Free Surface Modeling
- Single velocity field (VoF)
- Compressive discretization at free surface
- Surface tension
- Zero gradient boundary conditions for volume fractions for automatic height calculation in subcritical free surface flows
- Supercritical flow outlets
- Multiple velocity fields for strong mixing/entrainment with separation▲

Noise Modeling
- Lighthill stress output
- Export of monopole, dipole and rotating dipole sources for acoustics solvers

General Source Term Models
- Isotropic and directional loss models
  - Linear and quadratic resistance models
  - Permeability and loss coefficient models
- User-defined volumetric sources of mass, momentum, energy and species
- User-defined boundary sources of mass, momentum, energy and species

Mesh Motion and Remeshing
- Steady-state and transient
- Diffusion of prescribed surface mesh motion
  - Increased mesh stiffness for small elements and near-wall mesh
- Explicit volume mesh deformation
- Solution-based mesh adaption
- Integrated remeshing control

Six Degree-of-Freedom Rigid Body Solver
- Implicit motion of mesh regions and domains
- Detailed rigid body solution and coupling control
- Expression language access to all rigid body state variables

Immersed Solids
- Capture of motion of solids completely or partially overlapping with fluid domains
  - Unlimited general solid motion without remeshing
- Implicit motion of immersed solids based on rigid body solver solution

Fluid Structure Interaction (FSI)
- One-way FSI coupling with ANSYS structural mechanics solutions for steady-state analysis
- Two-way FSI capability for transient or steady-state analysis with moving/deforming geometry
- Conservative profile-preserving interpolation for fluid dynamic forces and heat flows

Electro-Magnetic Hydrodynamics ▲
- Solution of potential equations for electric and magnetic fields
- Lorentz force in fluid momentum equations
- Resistive (Joule) heating in energy equation
- Conjugate transfer between fluid and solid domains

Problem Setup and User Environment

Physics Pre-Processor
- Intuitive general problem definition environment
- Wizards for quick setup of standard problems and turbomachinery applications (TurboPre™)
- User-defined GUI extensions
- Import of meshes from a wide variety of sources and formats, consisting of any combination of tetrahedral, hexahedral, prism and/or pyramid elements
- Automatic generation of interfaces between physical domains
- Mesh face region creation and editing
- Transformation and connection of multiple meshes
- Flexible material properties editor, including a library of common materials
- Flexible chemical reactions editor, including a library of common reactions
- Expression language for general user-defined functions for pervasive use, including for:
  - Parameterization
  - Boundary conditions and profiles
  - Initial conditions
  - Fluid properties
  - Equation sources
  - Solution monitors
- Visualization of profile and expression boundary conditions
- Executable in batch mode with full access to CFX Command Language™ (CCL) power syntax for advanced/custom applications and macros
- Context-sensitive online user documentation with hyperlinks

User Modeling and Solution Control
- Dynamic tracking of monitor point and boundary flow values
- Dynamic command file reread
- Modify solver parameters and boundary condition values as solution proceeds
- Expression language for user-defined functions for fluid properties, equation sources, boundary condition profiles and initial conditions. A wide range of intrinsic functions are supported including:
  - Dynamic evaluation of boundary values and flows
  - 1-D or 3-D cloud point data interpolation
  - User subroutine interface for fully programmable user function

Solver Technology

Numerics

- Conservative finite-element-based control volume method
- Implicit, pressure-based algorithm for all flow speeds, incompressible to compressible
- Advection modeling
  - Upwind difference advection scheme
  - First- and second-order blend factor
  - High-resolution bounded advection scheme
- Bounded central difference scheme
- Robust and accurate diffusion discretization scheme
- Conservative first- and second-order transient discretization with adaptive transient time stepping
- High-speed numerics treatment for improved shock capturing

Linear Solver

- Coupled solution of mass and momentum, including for multiphase flows (optionally with volume fraction equation)
- Coupled solution of energy for multiphase flows
- Coupled solution of additional variables for multiphase flows
- Algebraic multi-grid
- Incomplete lower/upper factorization (ILU) smoother
- Linear performance with increasing number of nodes

High-Performance Computing

- Homogeneous or heterogeneous networks of Linux®, UNIX® and/or Windows® platforms
- PVM or MPI parallel communication libraries
- Vendor specific MPI support
- MPI support on Linux for high-speed interconnects (Myrinet, Infiniband, Quadrics) with HP-MPI
- Automated domain partitioning with various algorithms
- Partitioning across or within individual domains
- Highly efficient parallel execution
- Scalable memory usage

Beta Features

ANSYS® CFX® software at the ANSYS 13.0 release includes a number of released (visible) and unreleased (hidden) "beta" features that demonstrate capabilities currently in development within ANSYS CFX. These capabilities are largely untested, unsupported and subject to change in future releases. All released beta features are visible in CFX-Pre if you select to enable them. Unreleased beta features are not generally visible within the product and usually entail activation of custom CCL, user Fortran or activation of CFX solver expert parameters. Hidden beta features can be made available to selected users on demand. Some of the beta features available within ANSYS CFX software at release 13.0 include:

Released (Visible) Beta Features

- Non-reflective acoustic boundary conditions (inlet, outlet and opening conditions supported)
- Independent physics modeling between disconnected domains
- Additional turbulence models including one-equation Spalart–Allmaras model and reattachment modification for SST
- Iteratively implicit pressure averaging at stage interfaces and outlets
- Iteratively implicit stage averaging at stage interfaces
- Inhomogeneous MUSIG Eulerian multiphase model
- Homogeneous and inhomogeneous DQMOM
- Boundary-only additional variables
- Particle user routines for multiphase reactions
- Thermal and turbulence effects for cavitation
- Mesh deformation for CHT solids
- Surface export using CSV format
- Radiation for Eulerian multiphase (bulk- and fluid-dependent)
- Opaque boundary condition for non-walls
- Mesh adaption for porous domains
- Domain-based solver control
- Additional models for transient blade row simulations with pitch change
  - Time transformation
  - Fourier transformation

Unreleased (Hidden) Beta Features

- Stiff chemistry solver
- Non-ideal thermodynamic mixture properties
- Bradley's turbulent burning velocity correlation
- Lindstedt-Vaos combustion model
- ECFM modification for laminar flame limit
- Orthotropic thermal conductivity and diffusivity for additional variables
- Electromagnetic force effects on particles
- Modified CAB droplet secondary breakup model
- Particle fragmentation for particle-wall interaction
- Finite slip velocity for algebraic mass fractions
- Real liquid property support with saturation clipping
- Customizable user interface
- Turbulence forcing for zonal scale-resolving modeling
- Particle injection based on local coordinate frames
- Particle velocity component definition for swirling injection
- Solution-dependent activation of domain interface connections
- Temperature- and pressure-dependent flamelet libraries
- G-equation combustion model
- User-defined spark ignition model
- Wall condensation model
- Wall slip model
- Instantaneous solution field in post processing on transient particle tracks can be dropped in any case

▲ Capability included in ANSYS CFX but not in ANSYS® CFD-Flo™

ANSYS®

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