FIDAP™ 8.5

FIDAP 8.5 is the CFD solver of choice for a wide variety of laminar and turbulent flows that arise in the polymer processing, thin film coating, biomedical, semiconductor crystal growth, metallurgy and glass processing industries, among others. Based on the finite element method, FIDAP delivers accurate and efficient solutions for problems involving fluid flow, heat transfer, mass transfer, dispersed phase flow, free surfaces, solid/liquid phase change and fluid-structure interaction. Fully-coupled and segregated/iterative solution methods are available using completely unstructured meshes. A comprehensive set of physical models is provided for modeling non-Newtonian rheology, radiation heat transfer, flows in porous media, chemical reactions and other complex phenomena.

General Modeling Capabilities

- 2-D planar, 2-D axisymmetric, 2-D axisymmetric with swirl, and 3-D flows
- Steady-state or transient analysis
- Creeping flow, incompressible, and mildly compressible flow regimes
- Laminar, transitional, and turbulent flow
- Newtonian or non-Newtonian flow
- Heat transfer including natural convection, forced or mixed convection, conjugate (fluid/solid) heat transfer, and radiation
- Chemical species mixing and reaction, including combustion submodels and surface reactions
- Free surface flows (both fixed mesh and deforming mesh models)
- Linear and non-linear elastic deformations in solids, including thermoelastic effects, can be solved simultaneously with the fluid flow (fluid-structure interaction)
- Lagrangian trajectory calculation for dispersed phase (particles/droplets/bubbles) including coupling with continuous phase
- Phase change models for melting/freezing applications (both fixed mesh and deforming mesh)
- Transport of charged species in electric fields
- Porous media with non-isotropic permeability, inertial resistance
- Lumped parameter models for fans, vents
- Inertial (stationary) or non-inertial (rotating or accelerating) reference frames
- Volumetric sources of heat, mass, momentum, and chemical species

Mesh Capabilities

- Quadrilateral, triangle, hexahedral (brick), tetrahedral, wedge (prism) and mixed element meshes
- Linear and quadratic interpolations
- Penalty function approximation and discretized pressure (mixed formulation)
  - For mixed formulation, both continuous and discontinuous pressure models are available
- Unequal and equal-order discretizations
- Import of meshes from I-DEAS and PATRAN
- Mesh-to-mesh interpolation of solution data

Numerical Methods

- FIDAP offers two main choices for solver options. All the solvers in FIDAP are:
  - Based on the finite element method and utilize fully unstructured meshes
  - Valid for all speed regimes
  - Available with dynamic memory allocation
- The fully-coupled solver computes all degrees of freedom simultaneously. It has three different variations:
  - Newton-Raphson
  - Modified-Newton
  - Quasi-Newton, Broyden's update
- To solve the linear set of equations that arises with each of the above techniques, direct Gaussian elimination is used
- The segregated solution algorithm computes each degree of freedom individually in sequential fashion. It has the following features:
  - Jacobi variant that allows constructing the coefficient matrix of more than one degree of freedom during a single element pass
  - Vectorization of element pass
  - Single point quadrature with hourglass correction
  - Reduced stencil scheme which decreases the size of the non-symmetric global coefficient matrices
  - Single- or double-precision storage of global coefficient matrices
- To solve the linear set of equations, the segregated solver uses direct Gaussian elimination or the following iterative methods:
  - GMRES or conjugate gradient squared for non-symmetric systems
  - Conjugate residual or conjugate gradient for symmetric (pressure) systems

Transient Solution Algorithms

- Explicit and implicit time integrators available
- For the implicit time stepping approach:
  - First-order accurate (backward Euler) or second-order accurate (trapezoidal rule)
  - Automatic time step increment controlled by local truncation error
- Fixed time step option also available

Free Surface Modeling

- Two free surface models are available: deforming mesh, fixed mesh

Deforming mesh capabilities

- Suitable for modeling external free surfaces, internal fluid/fluid interfaces, boundaries with specified motion, and melting/freezing of pure materials
- Arbitrary Lagrangian Eulerian (ALE) description
- Surface tension can be included
- Static and dynamic contact lines
- 2-D, 2-D axisymmetric, and 3-D free surfaces

Fixed mesh capabilities

- Volume of fluid (VOF) model
- Single-fluid and two-fluid formulations
- Well-suited for problems involving irregular or large-scale deformations to the free surface (such as filling, sloshing, break-up)
- Surface tension (and Marangoni effect) can be included
- Heat and mass transfer at the interface can be included in single fluid analyses
- VOF model can be combined with boundaries that deform with prescribed motion
- 2-D, 2-D axisymmetric, and 3-D free surfaces

- Free surface problems can be laminar or turbulent

Fluid-Structure Interaction

- The deflection and stress in solid structures can be computed and coupled with the fluid flow, heat and mass transfer analysis
- The structural solver in FIDAP includes the following features:
  - continuum structural elements
  - linear and nonlinear elasticity
  - steady or transient
  - thermoelastic effects (thermal expansion coefficient, temperature dependent properties)
- Boundary conditions for the structure include: stresses/loads, displacement, and mixed (stress is proportional to displacement)
- Remeshing of the deformed structure and fluid domains is accomplished using an elasticity-based remeshing scheme
- Fully-compatible with free surface and VOF models, and parallel processing
- Postprocessing of the deformed structure, stresses, strains and integrated forces is provided

Turbulence Modeling

- Algebraic mixing length model:
  - Automatic mixing length calculation
  - User-defined mixing length calculation
- Multiple choices of k-ε models including standard k-ε, anisotropic k-ε, and RNG k-ε models as well as extended k-ε and RNG k-ε models
- Wilcox low-Reynolds number k-ω model
- Three eddy viscosity models:
  - Boussinesq isotropic eddy viscosity model
  - Speziale anisotropic eddy viscosity model
  - Launder anisotropic eddy viscosity model
- Near-wall elements incorporating special shape functions accurately capture non-equilibrium wall effects
- Surface roughness model

Chemical Reaction and Combustion Modeling

- Formulation based on multispecies transport equations, including diffusion and reaction source terms
- Finite rate chemistry for any number of reactions using:
  - Extended Arrhenius (built-in)
  - User-defined subroutine
- Up to 15 species
- Bulk phase or surface reactions
- Turbulence-chemistry interaction via:
  - Algebraic eddy-breakup model (Spalding)
  - Transport eddy-breakup model (non-equilibrium; transport equation for variances)
  - Eddy-dissipation model (Magnussen)
- Solver enhancements for numerically stiff chemistry
- Thermodiffusion

Radiation Heat Transfer

- Two radiation models are available:
  - Surface-to-surface (non-participating) radiation based on enclosure theory
  - View factors are computed (including shadowing effects) once before the simulation

  - P-1 (participating) radiation model
- Both models can model gray-diffuse and non-gray (wavelength-dependent) surfaces and properties
- Temperature-dependent emissivity
- Non-gray (spectrally dependent) emissivity

Lagrangian Dispersed Phase Modeling

- Trajectory calculation for particles, bubbles, or droplets at low volume fractions (steady flows)
- Momentum, heat, and mass transfer coupling with fluid (continuous) phase
- Built-in polynomial and power-law drag models for non-evaporating particles
- Additional drag model for evaporating droplets
- User can specify initial position, velocity, temperature, size, volatile/humidity content, and chemical composition of particles
- Stochastic model for influence of turbulence on particle trajectories
- Standard-normal and log-normal particle size distributions
- Multiple choice of boundary conditions for particles, including rebound with coefficient of restitution, trapping and escape
- Heat and mass transfer between fluid and dispersed phase
- Evaporation from liquid droplets
- Drying of wet particles
- Detailed reporting of particle position, velocity, temperature, diameter and residence time
- User-defined subroutines to specify the drag coefficient, force, injection position/velocity, boundary conditions, and heat/mass transfer are available

Boundary Conditions

- Multiple inlets/exits with specification of:
  - Inlet velocity in terms of Cartesian or cylindrical components, or local coordinate components
  - Normal and/or tangential stresses
  - Inlet mass fraction or species mass flux for multicomponent flows
  - Inlet fluid static temperature
  - Inlet turbulent kinetic energy and dissipation rate (with optional input of turbulence intensity and length scale)
- Outflow boundaries
- Intake/exhaust fans
- Intake/outlet vents
- Wall boundaries, with specification of:
  - Tangential wall velocity using Cartesian component form or rotational speed
  - Shear stress, including slip conditions (Navier slip, Coulomb friction)
  - Thermal boundary conditions using heat flux, temperature, or external convection, radiation (emissivity), or mixed conditions
  - Shear-stress calculation using specialized wall function for turbulent flow, including wall roughness effects
- Free surface with surface tension
- Surface with specified motion
- Boundary profiles as polynomial functions of x,y,z
- Boundary conditions as time function curve
- Symmetry, rotationally periodic, and translationally periodic boundaries
- Axis boundary conditions

Material Properties

- Constant or variable fluid properties including temperature dependence (data pair input)
- Fluid density calculation using ideal gas law or polynomial dependence on temperature; optional Boussinesq treatment of density for buoyant flows
- Fluid viscosity calculation using linear function of temperature or species

- Non-Newtonian fluid models, including power law, Bingham and Carreau fluids, or user-defined law; exponential temperature dependence can be included
- Incorporation of normal stress effects via second order fluid model
- Temperature-dependent heat capacity and thermal conductivity in solid regions
- Non-isotropic thermal conductivity
- User-defined property inputs

Phase Change

- FIDAP offers two solid/liquid phase change models:
  - Tracking of a distinct melt interface using a deforming mesh
    - May also track solute concentration and segregation of multiple species at melt interface
    - User-defined feedback loop option for adjusting heat flux based on melt interface position/shape
    - Melt temperature may be a function of temperature, solute (species) concentration
  - Enthalpy/specific heat method using a fixed mesh
    - So-called “mushy” zone represented by change in viscosity as material freezes
    - Turbulent viscosity decay function for turbulent phase change flows

Electrohydrodynamics

- The conservation of charge equation can be solved, accounting for the change in charge distribution due to convection, diffusion, electric field and reactions
- The momentum equation includes the Coulomb or electrophoretic force
- Gauss’ Law can be solved to obtain the voltage field
- Multicomponent systems are allowed

Miscellaneous

- Moving-body constraint allows user-definable constraints on any nodal variable to be applied and released as a function of time, position, and solution
  - Can be used to model the motion of impellers, blades, or other solid bodies through the fluid
- Bar and shell elements allow heat conduction along the axis/plane with no resistance across the thickness
- Contact resistance allows heat transfer between two surfaces without modeling the region between them

User Defined Subroutines

- Compiled user subroutine option
- Specification of volumetric sources in continuity, momentum, energy and species equations
- Surface and volumetric reaction rates
- Definition of custom physical properties
- Customized boundary conditions and initial conditions
- User-defined scalar transport equations
- Creation of custom postprocessing quantities
- User-specified emissivity and external reference temperature functions for radiation modeling
- Body force, drag, and heat/mass source terms for discrete phase modeling

Interface, Graphics, Postprocessing, and Reporting

- Fully interactive graphical and text-based user interface
- Journaling and transcripting
- Journal files may contain user-defined parameters, do-loops, if-then-else statements, and macros for automating parametric studies
- Diagnostics and error trapping
- Automatic checking of entity/property data, element data, boundary conditions, initial conditions, and problem consistency
- Optimal renumbering of mesh nodes
- Summary reports of solver and physical model settings
- Dynamic interrupt and restart of calculations
- Reporting and display of convergence history
- Reporting of fluxes of mass, heat, and chemical species
- Calculation and reporting of mass and volumetric flow rates
- Integration and reporting of mean values over domain or portions of domain
- Transformation of data via pre-defined functions (exponent, log, tanh, and gradient operators)
- Reporting and visualization of derived quantities
- Calculation and reporting of residence time distribution
- Fast Fourier transform (power spectrum vs. frequency)
- Time history plots
- Quantitative XY-plotting of data
- On-screen mouse-based view manipulation (rotation, translation, magnification)
- Hardcopy options

Data Export

- Export of temperature solution data in ANSYS format
- Import/export of FEA data to/from MARC nonlinear structural analysis package

Online Help and Documentation

- Complete HTML-based online documentation
- User guides
- Tutorial guide
- Extensive Examples manual
- Theory manual
- Training manual

Supported Hardware

- Serial and parallel (segregated solver) versions of FIDAP 8.5 are supported on most common UNIX and Windows/NT platforms. Please contact Fluent Inc. for details.

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