



*Coupling AcuSolve with
MD-Nastran:
Fluid Structure Interaction*



Farzin Shakib

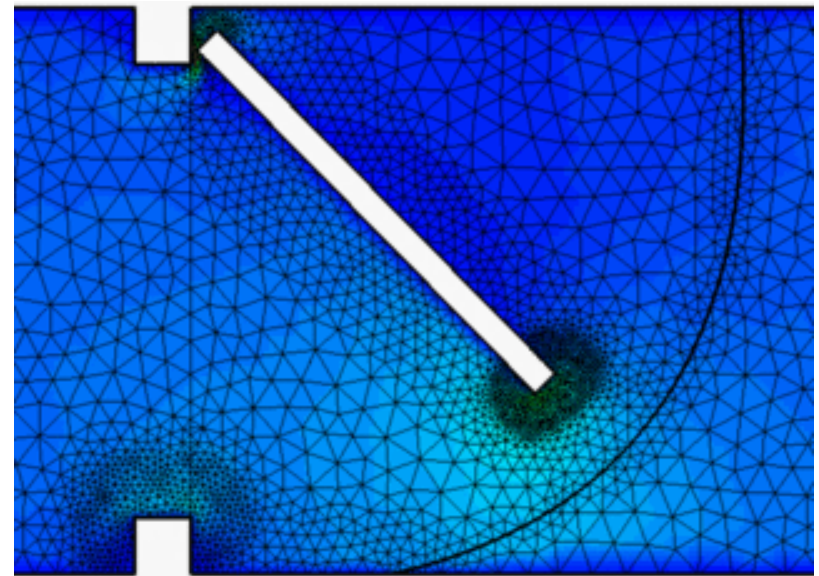
April 21, 2009

ACUSIM Software Inc., 2685 Marine Way, Suite 1421, Mountain View, California 94043
Tel: (650) 988-9700 Fax: (650) 988-9770 info@acusim.com <http://www.acusim.com>

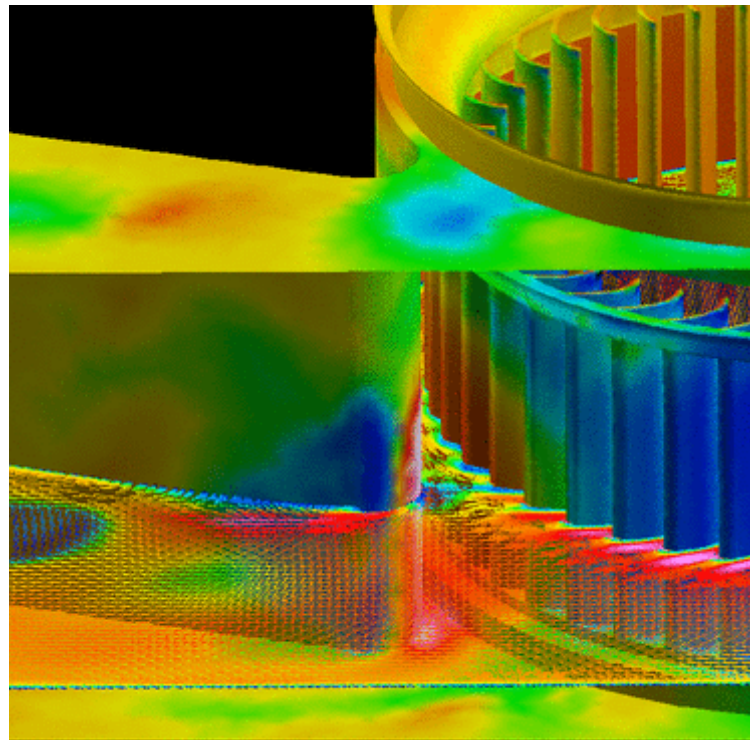
Acusim Software Inc. Proprietary Information

Outline

- Product Overview
- Fluid Structure Interaction (FSI)
 - Practical FSI: Linear Solid/Structural Analysis
 - Direct-Coupling FSI: Nonlinear Solid/Structural Analysis
 - Advance FSI Features
- Conclusion

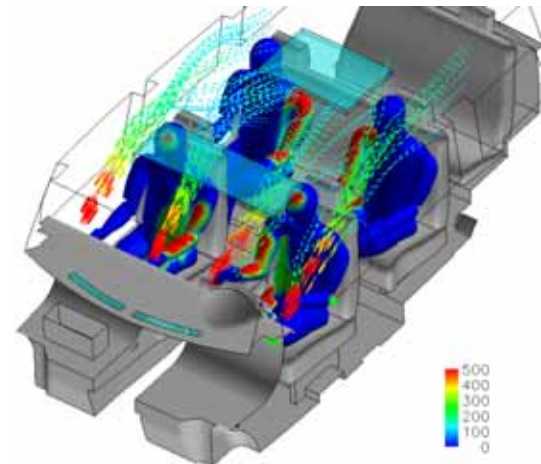


Product Overview



AcuSolve

- A powerful general-purpose finite element flow solver
- *AcuSolve's* differentiation:
 - **Robustness** Most problems solved on the first attempt
 - **Speed** Coupled solver on distributed parallel machines
 - **Accuracy** Highly accurate in space and time while globally and locally conservative
 - **Features** Rich set of functionality; continuously growing
- An ideal enabling technology for integrated engineering and scientific applications



Main Features

■ Physics:

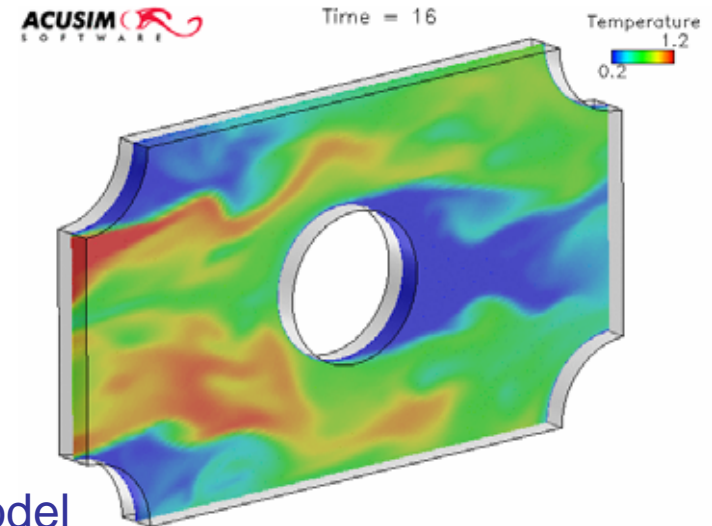
- Incompressible & weakly compressible Navier-Stokes
- Thermal analysis
 - Conjugate heat transfer
 - Multi-layered thermal shell
 - Enclosure radiation – View factors
 - Solar radiation
- Multi-species transport equations

■ Turbulence:

- One-equation Spalart-Allmaras RANS model
- Smagorinsky and dynamic subgrid LES models
- Hybrid RANS/LES (DES) model & (DDES)

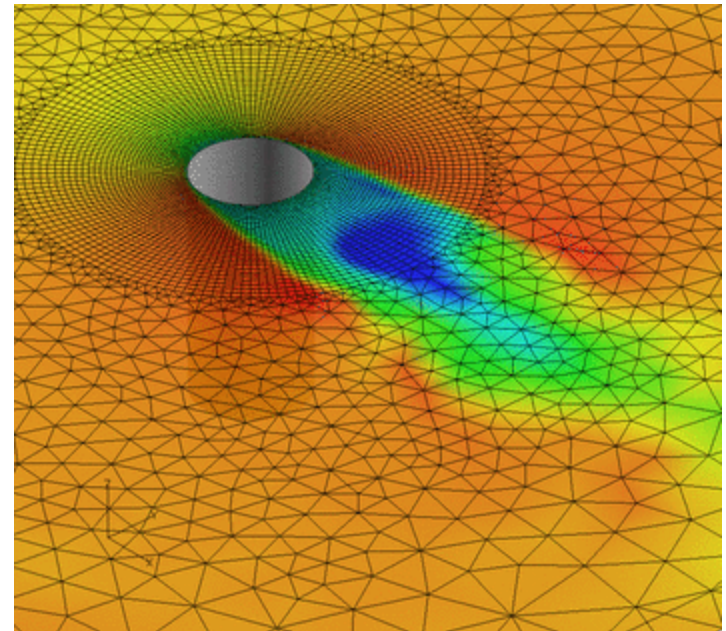
■ Time accurate transient simulation

- Coupled with control systems



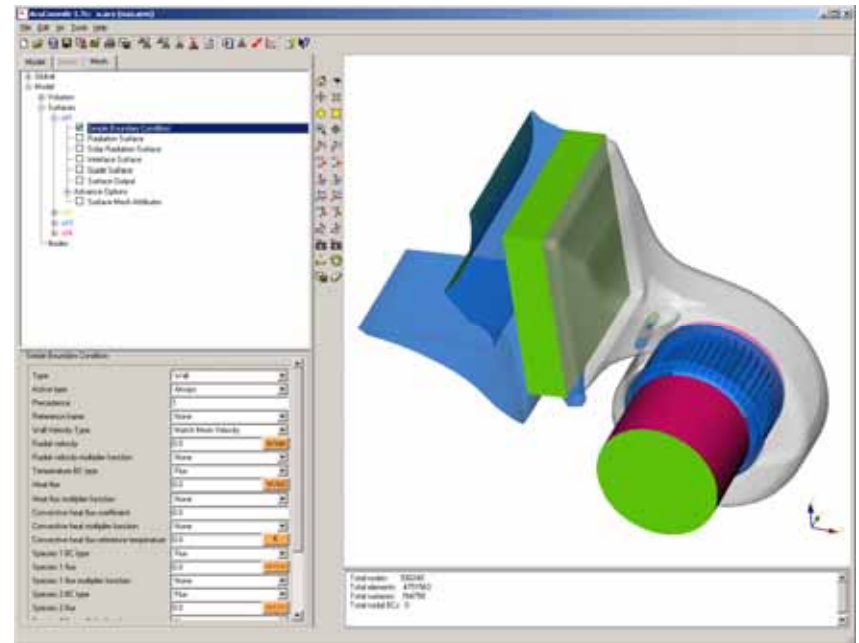
Main Features (cont)

- Arbitrary Eulerian Lagrangian Formulation
 - Flexible mesh motion
 - Free surface
 - Guide surface
 - Sliding mesh
- Fluid/Structure Interactions
 - Practical FSI (P-FSI)
 - Direct Coupling FSI (DC-FSI)
 - Rigid body & flow coupling
- Support for Computational Aero Acoustics (CAA) simulations
- GUI-based Preprocessor
 - Auto tet mesher with boundary layer
 - CAE automation
- and many more ...

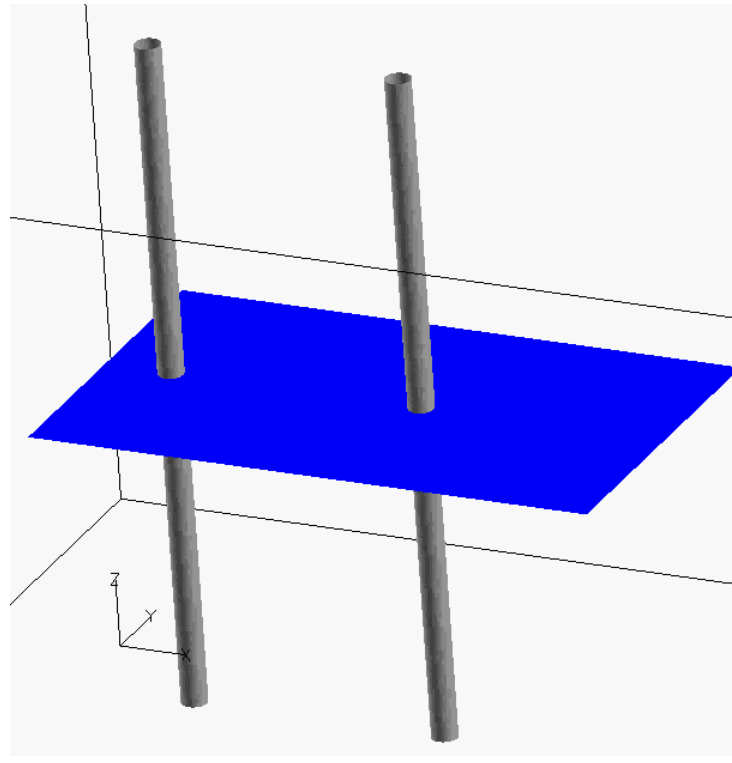


AcuConsole

- GUI-base preprocessor for *AcuSolve*
 - Starts from CAD or MESH
 - ProE, Parasolid, ACIS, Catia V5, Discrete
 - Icem, Harpoon, Hypermesh, GridGen, ...
 - Generate mesh from CAD
 - Automatic tet mesher
 - Boundary layer
 - Full problem specification
 - Global parameters
 - Boundary conditions, etc.
 - Launch solver
 - Monitor progress
 - Customizable for easy deployment



Fluid Structure Interaction



FSI Technology

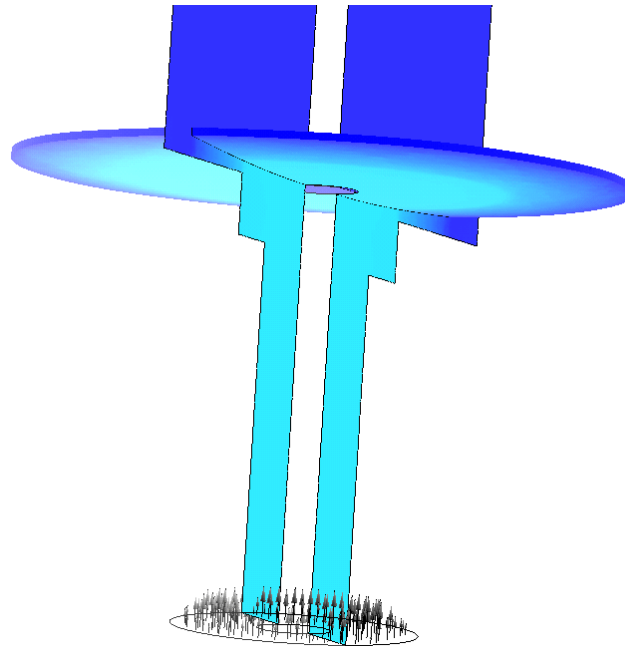
■ Practical FSI

- Modal response of solid/structure given to *AcuSolve*
- *AcuSolve* runs by itself
 - Fast, easy and robust
 - Accommodates linear solid/structure interactions
- Released Q2-2004

■ Direct-Coupling FSI

- Tight coupling of *AcuSolve* & Solid/Structural Code
 - Two codes run in tandem
 - Projection & interpolation performed by *AcuSolve*
 - No intervening middleware
- Released Q2-2007
 - Soon to be released with *MD-Nastran* OpenFSI

Practical FSI: Linear Solid/Structural Analysis



Practical FSI

- Step 1: Solid Model
 - Solve an Eigenvalue problem using *Nastran*
- Step 2: Projection
 - Project the Eigenvectors onto the *AcuSolve* mesh
 - Built-in tools to extract and project directly from OP2 files
- Step 3: Run *AcuSolve*
 - Solve the transient coupled flow and linear deformation
 - At each step, *AcuSolve*
 - Computes fluid forces on the wet surface
 - Projects the forces onto the Eigensystem
 - Advances the modal response
 - Computes the new mesh position
 - Solves the fluid and other equations on the deformed mesh

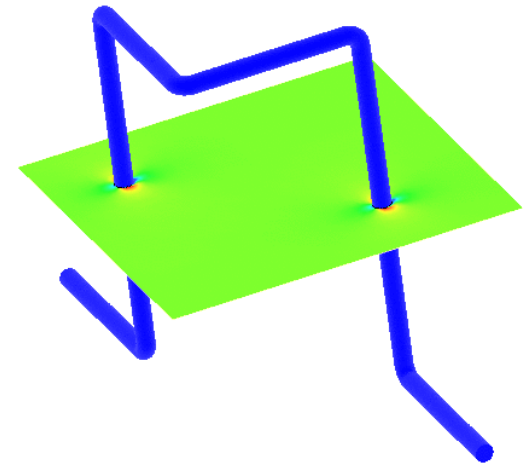
Advantages & Limitations

■ Advantages:

- The fluid and solid codes are run independently and separately
 - No run time coupling is required
 - No fluid mesh size limitation imposed by FSI
- Significantly more stable than alternative approaches
 - Eliminates high wave number modes, yields smooth coupling
- Very efficient
 - Problem setup
 - CPU time

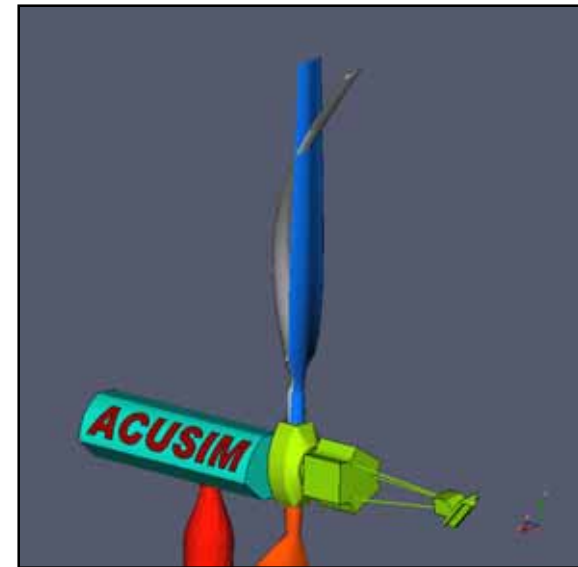
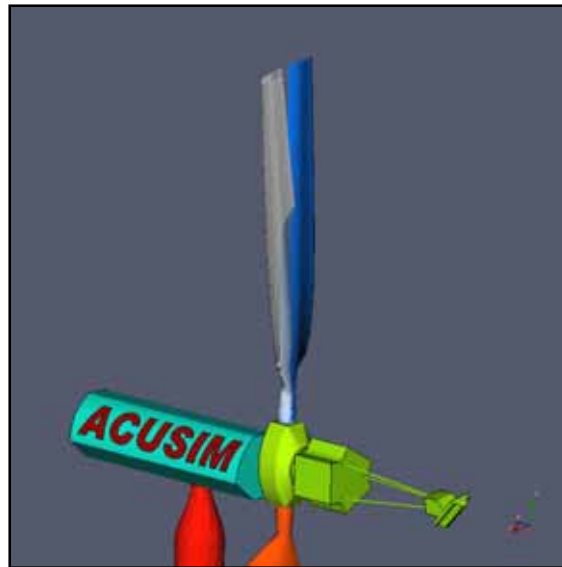
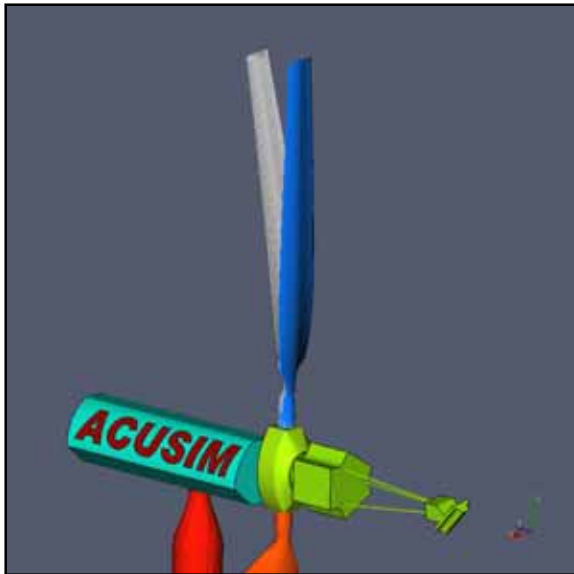
■ Limitations:

- Only linear solid/structural analysis
 - No material or geometric nonlinearities
 - Only simple contacts

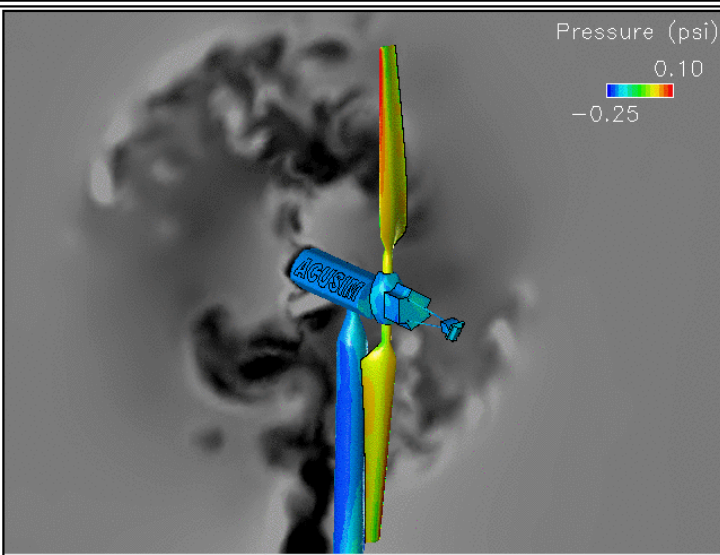
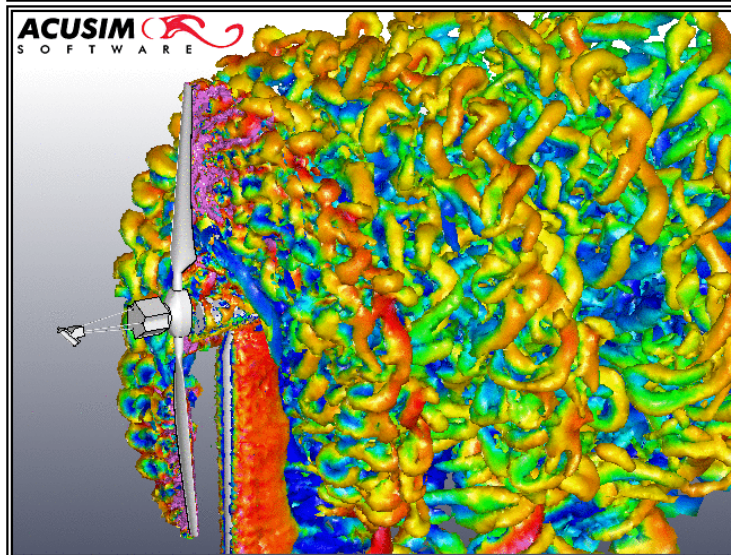
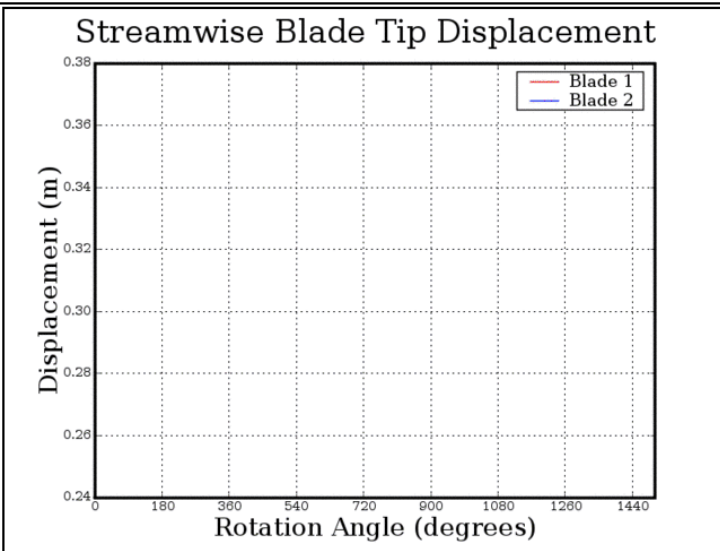
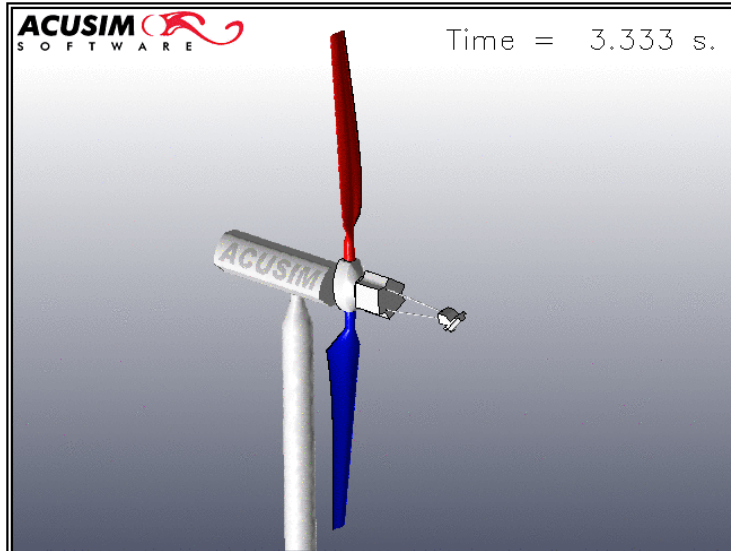


Wind Turbine Modeling

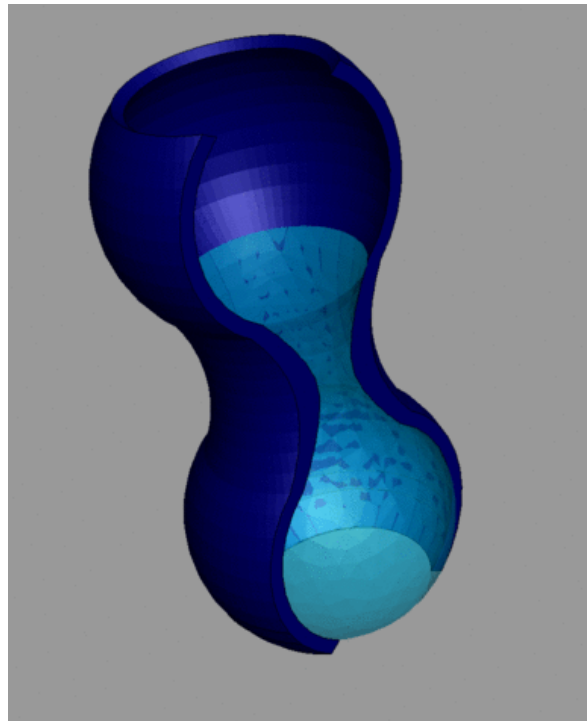
- National Renewable Energy Laboratory (NREL) model
- Transient Sliding Mesh Model - Flexible Blades
 - Total of 20 structural modes were included for this analysis.



Wind Turbine



Direct-Coupling FSI: Nonlinear Solid/Structural Analysis

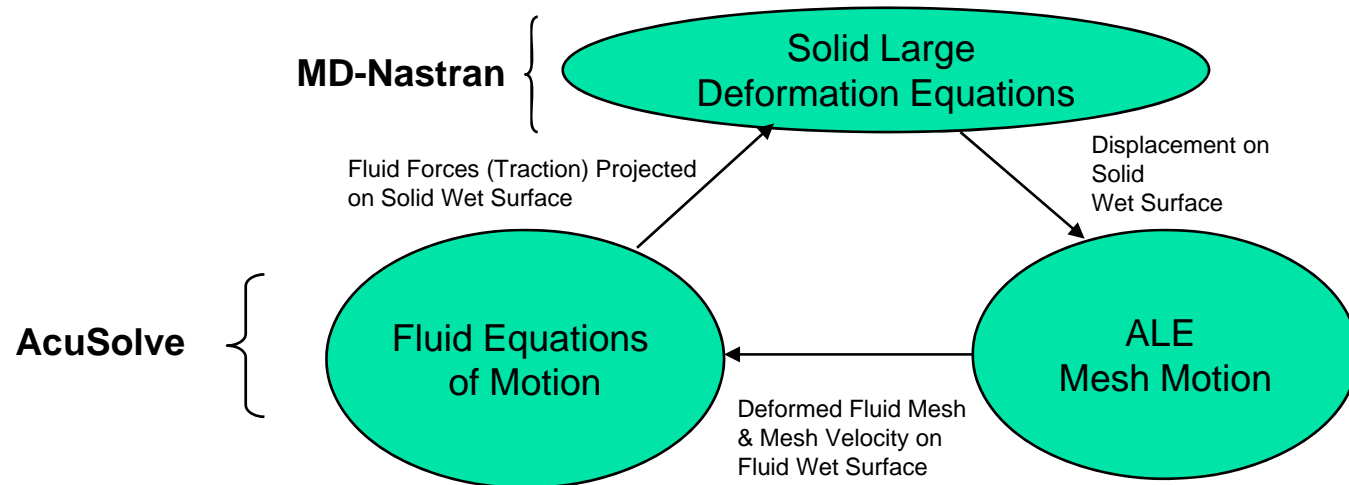


Direct-Coupling FSI

- Step 1: *MD-Nastran* input file
 - Setup an independent solid/structural mesh and input file
 - Identify the solid wet surface
- Step 2: *AcuSolve* input file
 - Setup an independent fluid mesh and input file
 - Identify the fluid wet surface
- Step 3: Run *AcuSolve* and *MD-Nastran*
 - Start *MD-Nastran*
 - SCA Library & Resource Catalog set for OpenFSI/*AcuSolve*
 - Start *AcuSolve*
 - Given host name of running *MD-Nastran*
 - May run in parallel

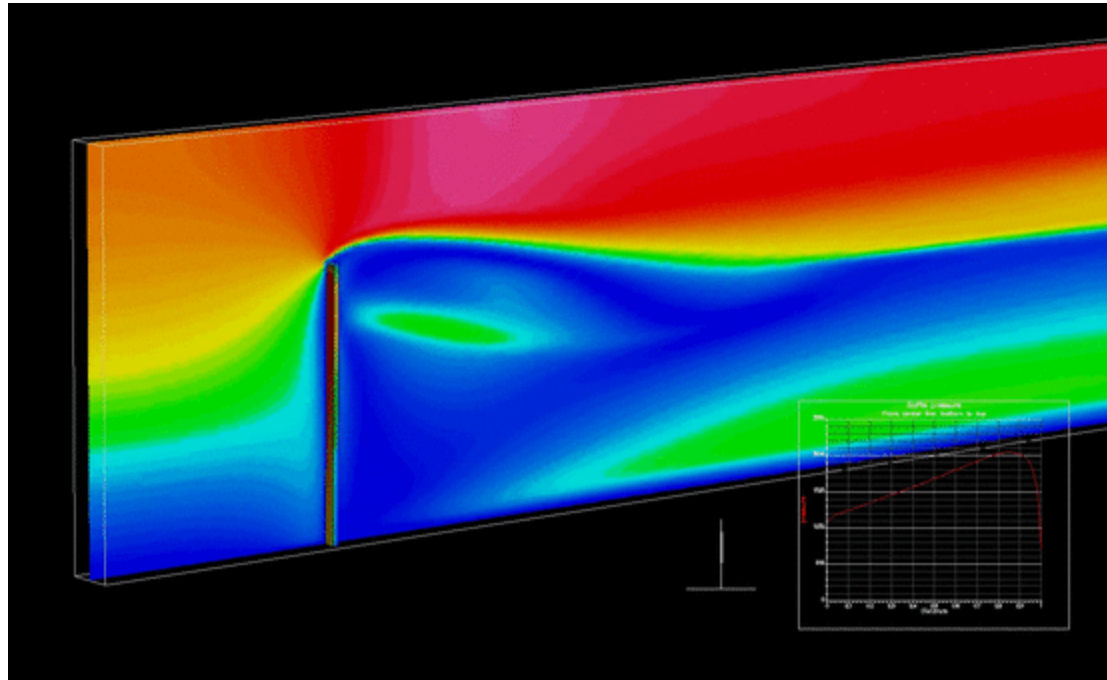
Direct-Coupling FSI (cont)

- At the start of run
 - *MD-Nastran* via *SCA* sends its surface definition to *AcuSolve*
 - *AcuSolve* builds interpolation and projection data structure
- At each time steps
 - *AcuSolve* and *MD-Nastran* exchange nodal forces and displacement on solid wet surface



Vertical Baffle

- First coupling solution of *AcuSolve* and *MD-Nastran*
 - *Explicit OpenFsi*



Conclusions

- *AcuSolve* is a powerful general purpose CFD code
 - The premier commercial finite element based CFD solver
- *AcuSolve* has two FSI capabilities
 - Practical FSI
 - Simple to set up and run
 - Very robust
 - Only linear structural response
 - Direct-Coupling FSI
 - Simple to set up and run
 - Full nonlinear structural response
 - Stable for a wide-range of problems
- Both FSI options are well integrated with *MD-Nastran*

