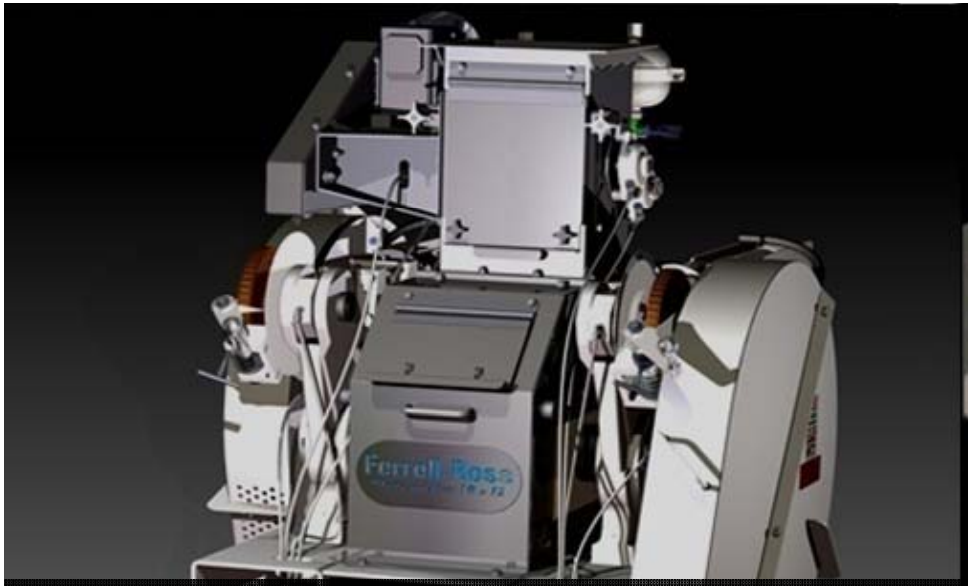
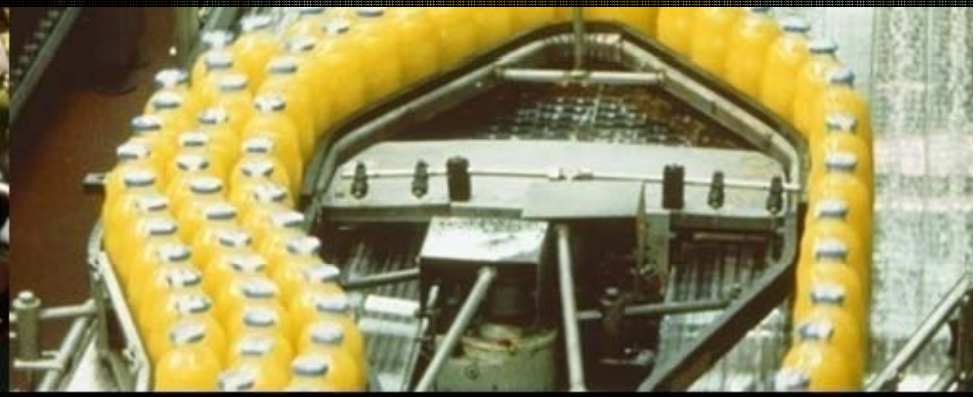
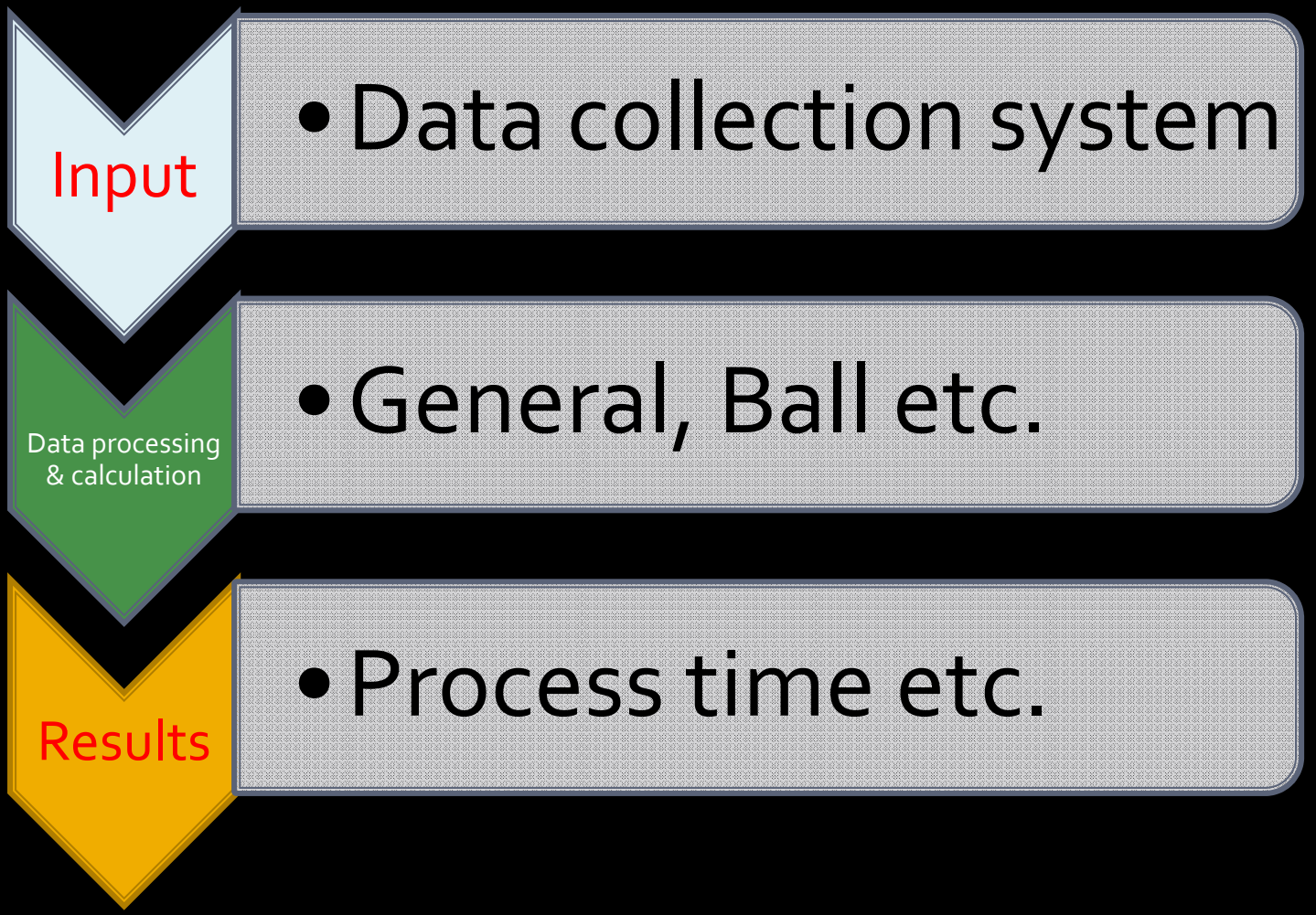


Finite Element Analysis

Esmaeil Riahi: ConAgra Foods
Michael Fiedler: Autodesk
March, 2010



Thermal process calculation:



Material properties needed for thermal analysis in FEA:

- Mass density
- Specific heat
- Thermal conductivity

Specific heat is the quantity of heat is gained or lost by a unit mass of product to accomplish a unit change in temperature without change in the state.

$Cp=Q/m(\Delta T)$, kj/(kg°C)

$Cp=0.837+3.349\ Xw$ (Siebel 1892)

$Cp=2.093Xf+1.256Xs+4.187Xw$ (Charm, 1978)

$Cp=1.424Xh+1.549Xp+1.675Xf+0.837Xa+4.187Xw$

Thermal conductivity (k):

K is the amount of heat that will be conducted per unit time through a unit thickness of a material if a unit temperature gradient exists across the thickness.

K=J/s.m.C=W/m.C

Metal: 50-400 W/m.C
Alloys: 10-120 W/m.C
Water: 0.597 W/m.C
Air: 0.0251 W/m.C
Insulating material: 0.035-0.173 W/m.C

K=0.148+0.493Xw (Sweat, 1974)
K=0.08+0.52Xw (Sweat, 1975)
K=0.25Xh+0.155Xp+0.16Xf+0.135Xa+0.58Xw (Heldman & Singh, 1981)

What is FEA?

- FEA is a mathematical solution to engineering problems where a physical model is divided into discrete components.
- FEA models are defined by nodes and elements (commonly called a mesh).
- Basic engineering equations, such as Hooke's law, are solved at the nodes and elements.
- A matrix equation, including terms from each element, is solved.

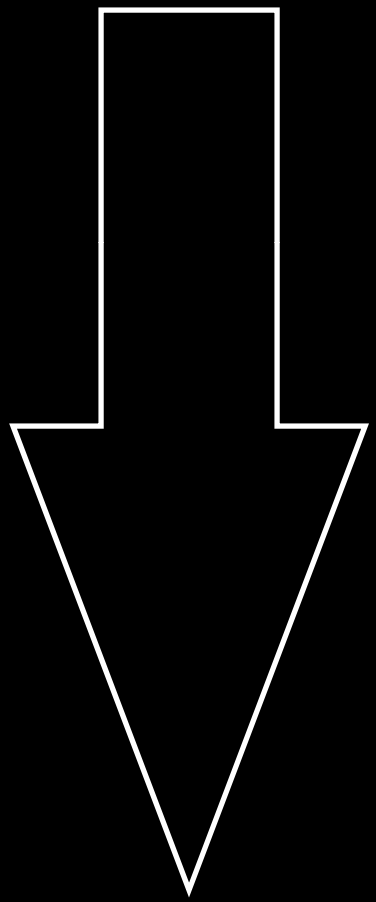
What is FEA?

- Predicts change within the element (for example, deformation and stress).
- The results are plotted on the model using color to show the lowest and highest values.
- Provides a non-destructive means of testing products.
- Faster prototyping for “what if” scenarios.
- Design optimization.
- Speed up time to market by shortening the design cycle.

- FEA requires engineering judgment. In the best case, you should know the approximate answer before you begin.
- Proper selection of elements, materials, loads, constraints and analysis parameters comes from experience.

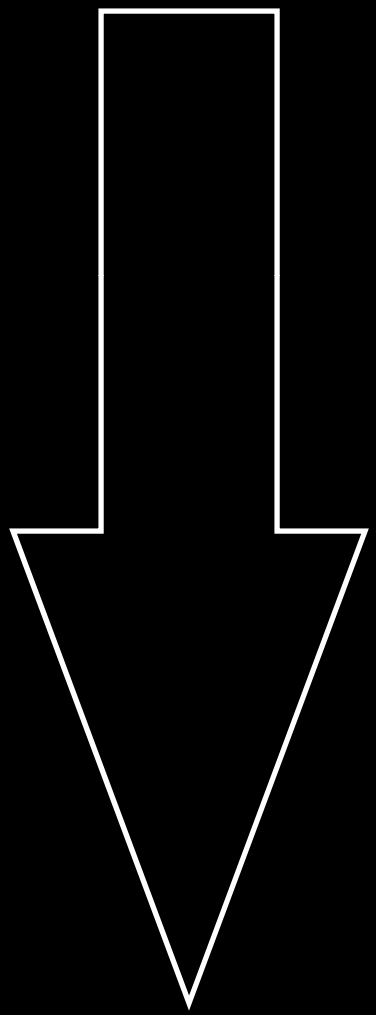
The Basic Steps of FEA

- Build/Mesh a Model
- Define FEA Model –
  Element and Analysis Details
- Define Loads and Constraints
- Analyze Model (Solve)
- Review Results and Create Presentations



Example Using Algor® Simulation

- Create the Mesh within the FEA Editor Environment
- Set up Analysis Type, Element Type/Data, Materials, and Analysis Parameters within the FEA Editor Environment
- Apply Loads and Constraints within the FEA Editor Environment
- Analyze the Model (Solve)
- Review Results within the Results Environment and Create an HTML Report within the Report Environment

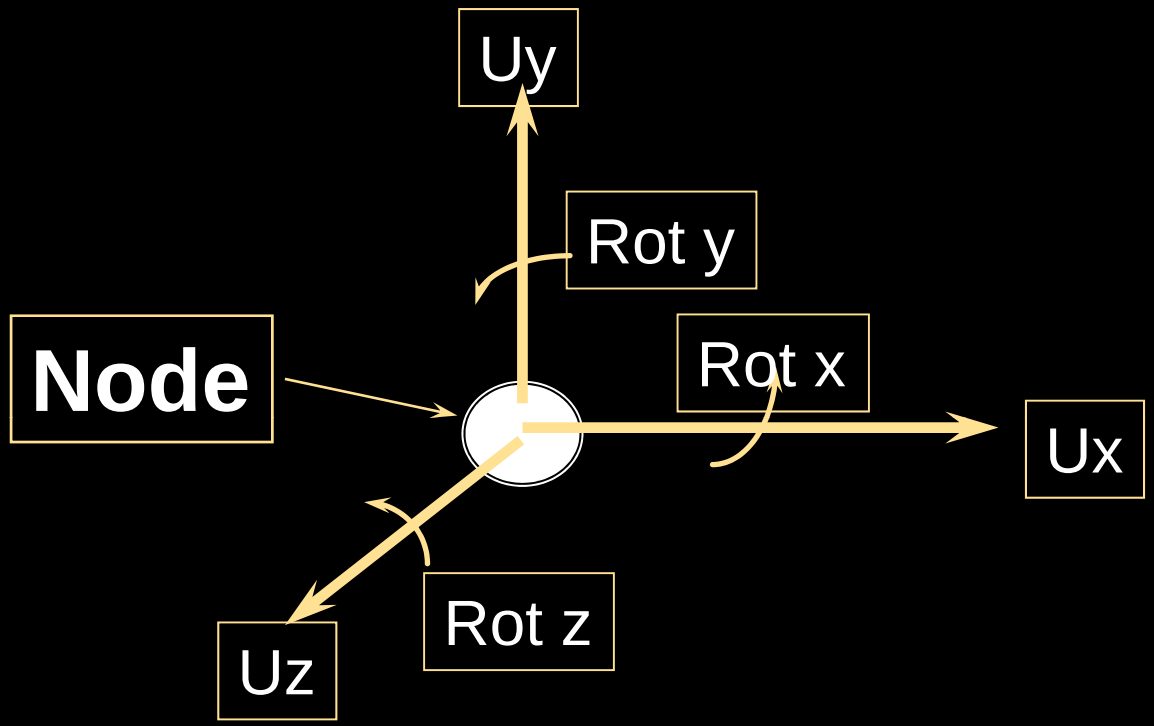


What is a DOF?

- The unknowns in a finite element problem are referred to as degrees of freedom (DOF).
- Degrees of freedom vary by element and analysis type.

DOF Type	Action	Application
Displacement	Force	Structural
Temperature	Heat Flow Rate	Thermal
Velocity	Fluid Flow Rate	Fluid
Voltage	Electromotive Force (EMF)	Electrostatic

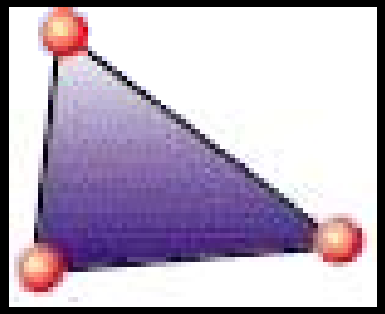
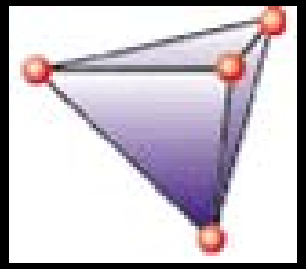
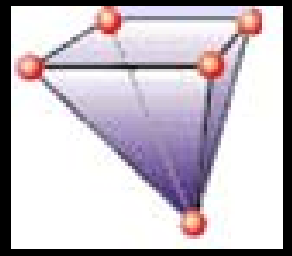
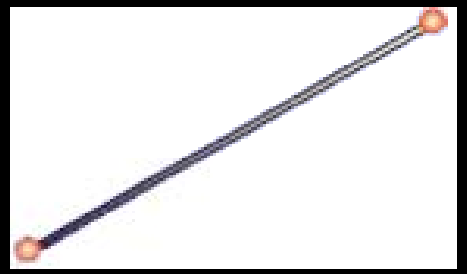
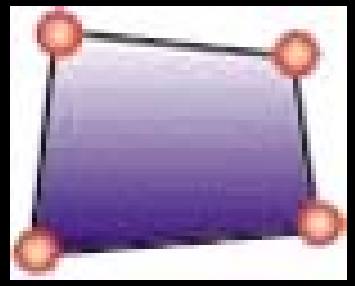
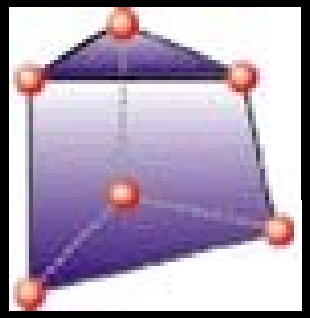
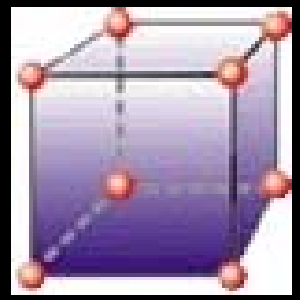
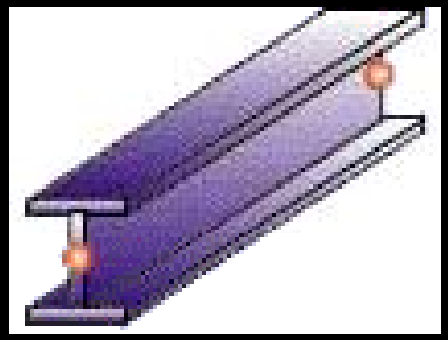
What is a DOF?



A node is a coordinate location in space where the DOF are defined. The DOF of this point represent the possible response at this point due to the loading of the structure

Element

- An element is a mathematical relation that defines how the DOF of a node relate to the next. These elements can be lines (beams), areas (2-D or 3-D plates) or solids (bricks and tetrahedral).

Nodes and Elements

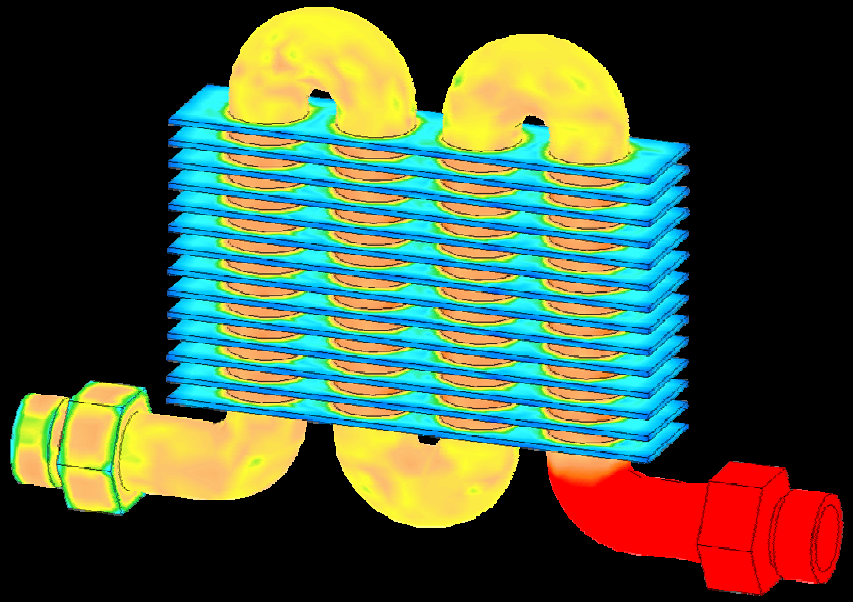
- A node has a given set of DOF, which characterize the response. For structural analyses, these DOF include translations and rotations in the three global directions.
- The type of element being used will also characterize which type of DOF a node will have.
- Some analysis types have only one DOF at a node. Examples of these analysis types are temperature in a heat transfer analysis and velocity in a fluid flow analysis.

Thermal Analyses

The following two types of thermal analysis are available:

- Steady-State Heat Transfer
  Determine temperature distribution, heat flow, and heat flux in steady-state conditions.

- Transient Heat Transfer
  Calculate temperature distribution, heat flow, and heat flux when temperature or loads vary over time



Thermal Elements

- Thermal elements are geometrically identical to the corresponding structural elements. The available types are:
  - Rod
  - 2-D
  - Plate
  - Brick

Thermal Nodal Loads

- Initial Temperature
  - Specify the temperature of a node(s) at the beginning of the analysis (transient analysis).
- Applied Temperature
  - Specify a temperature at which a node(s) will be held during the analysis. A stiffness value specifies the amount of thermal energy (heat source or heat sink) available for maintaining the temperature.

Thermal Surface Loads

- Convection
  - Assign a convection coefficient and the ambient temperature.
- Radiation
  - Assign the radiation function and the ambient temperature.
- Heat Flux
  - Assign the amount of heat added or removed per unit area.

Thermal Results

- Temperature
- Heat flux *(energy / time / length^2)*
- Heat rate of face *(energy / time)*

Predict Product Performance

Autodesk Algor Simulation software provides a full set of tools that helps users perform accurate, efficient simulations and collaborate in a multi-CAD environment.

These tools provide static stress analysis, linear dynamic analysis, mechanical event simulation, heat transfer, computational fluid dynamics, and multiphysics to predict product performance.

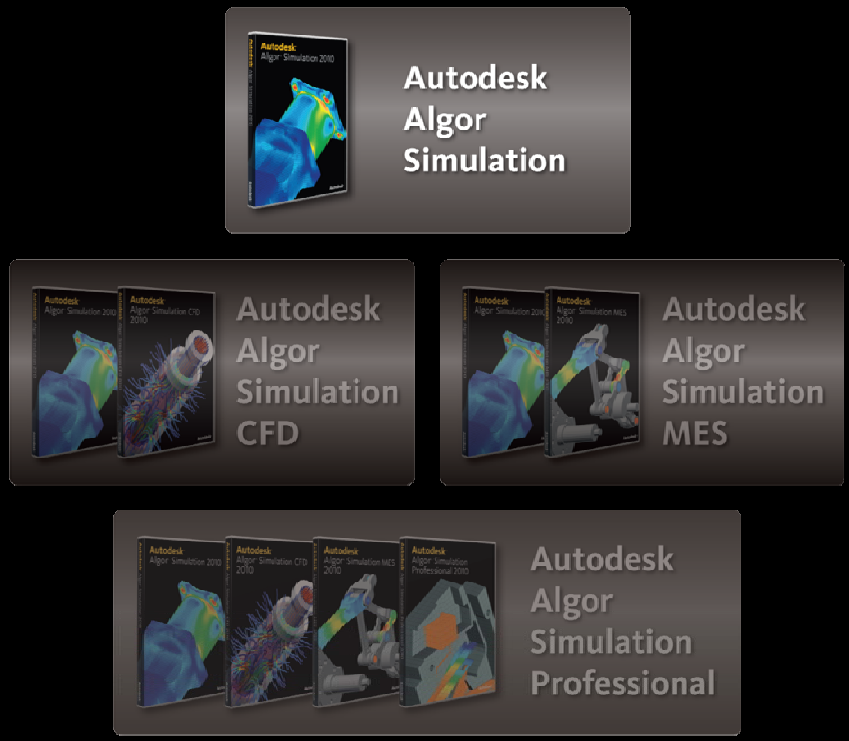
A World Leader in 2D and 3D Design and Engineering Software

- 9+ million users, across 700,000+ companies
- A growing student community of 500,000+ members
- 2+ million students trained each year

Autodesk®

Autodesk Algor Simulation

- Static stress with linear material models
- Linear dynamics
- Critical buckling
- Steady-state and transient heat transfer



Autodesk®

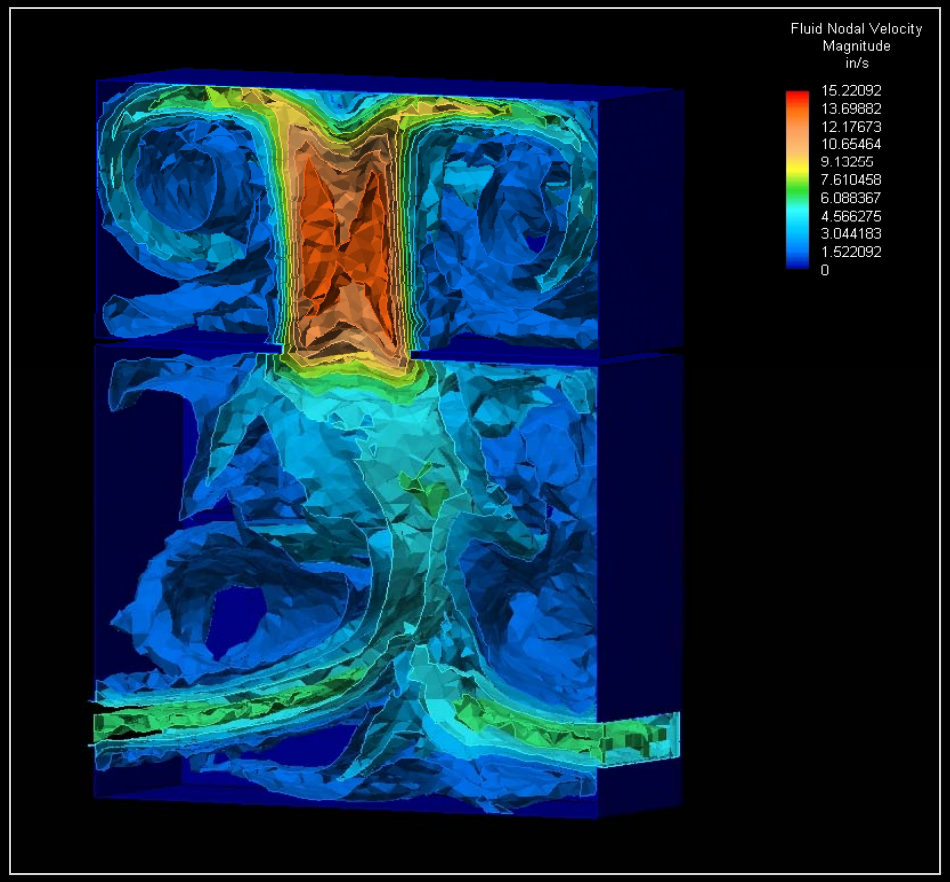
Autodesk Algor Simulation CFD

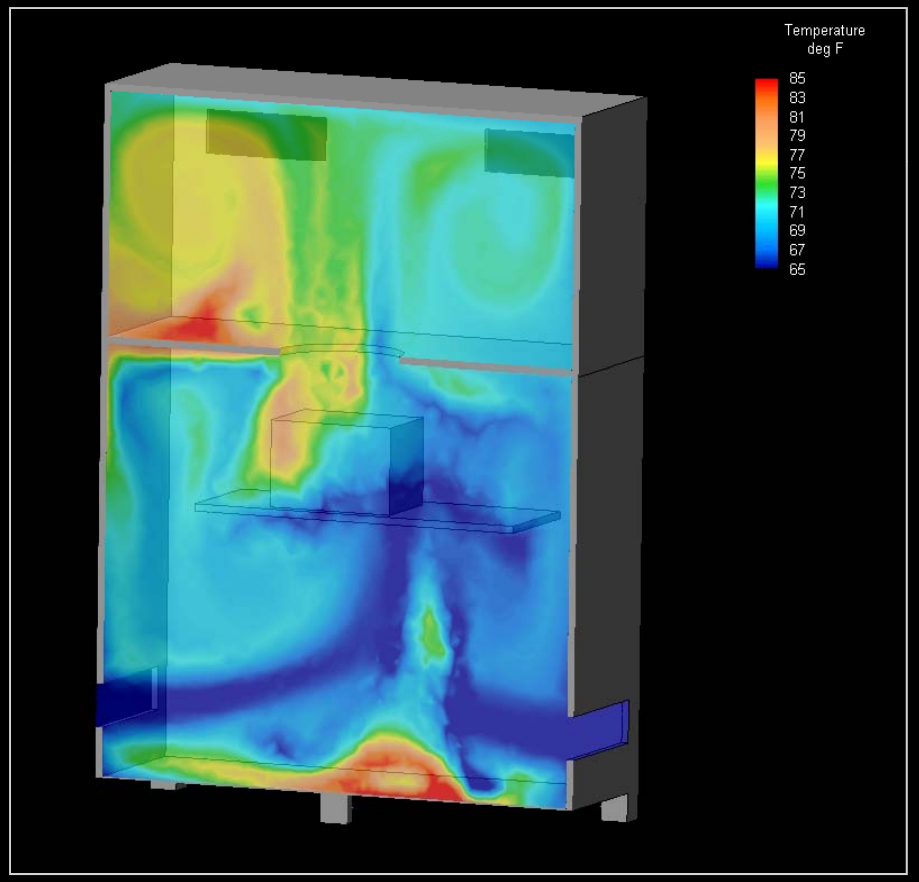
Everything in Simulation plus:

- Steady and unsteady fluid flow
- Open channel flow
- Flow through porous media
- Mass transfer

Analyze the Effects of Fluid Flow

Simulate 2D and 3D flows, with both changing and constant flow behaviors.



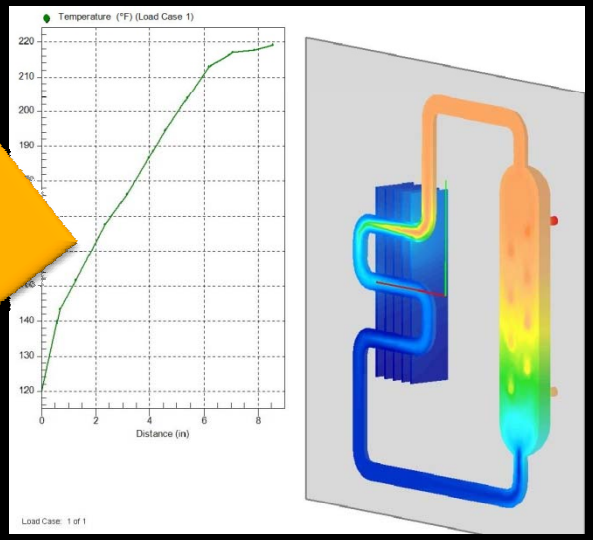


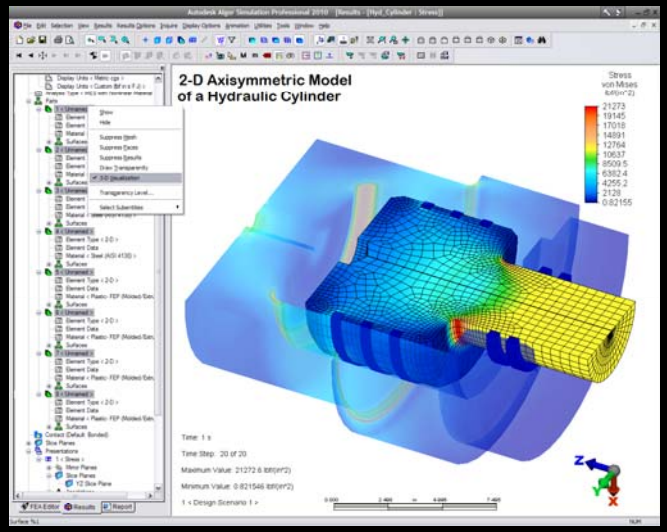
Thermal and Fluid Coupling

Evaluate and Present Simulation Results

Use a wide range of tools and wizards for model visualization, results evaluation, and presentation. Features include multiple-window displays, fast dynamic viewing controls, and customization options.

Indicates fluid temperature within heat exchanger's interior.






Questions?