Mechanical and Industrial Applications

Inside the CFdesign Advanced Module

Upfront CFD is all about using simulation to drive design decisions. The CFdesign Base Module contains an extensive collection of functionality, and is capable of solving a wide breadth of applications. Some situations, however, are a little more complex, and require physical models that are beyond the scope of the Base System. The best solution for these situations is the CFdesign Advanced Module.

License Requirements: The CFdesign Base System is a requisite for the Advanced Module.

Advanced Simulation Scope

The CFdesign Advanced Module provides additional flow and thermal simulation functionality to further expand the solution scope.

Advanced Fluid Flow

- Supersonic compressible
- Transient (time varying)
- Two-phase flows
  (humidity and steam mixtures)
- Height of fluid formulation
- Two-fluid scalar mixture model
- Compressible liquid (water hammer)
- Cavitation

Advanced Heat Transfer

- Internal radiation heat transfer
- Radiation through transparent media
- Solar Loading
- Temperature dependent emissivity
- Joule heating with temperature dependent resistivity

Advanced Conditions

- Relative humidity
- Steam quality
- Fill level
- Time varying boundary conditions
- Current
- Voltage

It's important, however, to understand how these models solve real-world problems. Let's explore the following questions for the Advanced functional items that are most commonly used for Mechanical and Industrial applications:

1. *What is it?*
2. *Why would you need it?*
3. *What can you do with it?*

"Mechanical and Industrial" contain an extensive collection of engineering applications. It involves the design, placement, and performance of critical components and systems within machinery, hydraulics, pneumatics, valves, nozzles, ovens, burners, and other engineering equipment. Because of the diversity of applications, all of the Advanced Module physical models deliver substantial value to the Mechanical and Industrial engineering design arena.

Transient

What is Transient?

A process that is "transient" varies with time. Unlike a steady state process, the flow distribution and temperature change from one moment to the next. CFdesign uses an implicit time stepping method to compute the time-dependent solution.

Why would you need Transient?

Understanding the effects of time-dependent variations such as oscillatory flow is essential to making informed design decisions. If the amount of flow varies with time, the transient module provides valuable insight into how the flow develops and how the system adapts to changing inputs. If the amount of heat added or removed from the device is controlled with a transient boundary condition, predicting this is even harder with hand calculations or experimental methods.

What can you do with Transient?

The Transient physical model provides value through in many ways:

- Vary the amount of flow or heat entering or leaving the device with transient boundary conditions. Many systems are subject to cyclical inputs, and the Transient module simulates this input variation.
- Simulate flow startup to understand if pressure waves will propagate through the device, causing instabilities and other potentially damaging effects.
- Review the time history by animating results. Share your results using several formats: Dynamic Images for viewing in the CFdesign 3D Viewer, AVI, and MPEG.

Compressible

What is Compressible?
Compressibility in gas flows occurs when the flow velocity is quite high, typically at Mach numbers greater than 0.8. The pressure distribution strongly affects the density of the gas, and shocks can occur.

Why would you need Compressible?
Local compressibility effects are common in many flow-control devices such as nozzles, valves, and diffusers. A good understanding of the demanding flow environments in these devices is essential for making design decisions that lead to optimal performance and durability.

Assessing the flow performance in high-speed devices with experimental methods can be very expensive and time consuming. Hand calculations can be equally problematic.

What can you do with Compressible?
There are many Mechanical and Industrial applications that involve high-speed, compressible gas flow.

- Use the Compressible Flow module to compare design variations and evaluate performance of high speed internal flow devices accurately, safely, and efficiently.
- Predict the pressure drop and velocity distribution of supersonic gas flows in flow control devices such as nozzles, valves, and diffusers.
- Visualize shock formation and reflection in the interior chambers of high-performance flow devices.

Radiation

What is Radiation?
Radiation is a surface-to-surface heat transfer mode that relies on a direct line of sight between surfaces. Unlike conduction or convection, radiation does not need a medium such as a solid or carrier gas. Heat radiates through empty space with electromagnetic waves.

Why would you need Radiation?

Radiation is fundamental to the performance of most applications that involve very high temperature sources. Incorporating radiation often leads to greater solution accuracy for high temperature applications.

In many thermal applications, neglecting radiation can lead to inaccurate temperature prediction, which can lead to flawed design decisions.

What can you do with Radiation?

The CFdesign Radiation Model is a physically rigorous model that provides a high level of solution accuracy. Using an optical view factor calculation, the Radiation model produces an accurate energy balance and enforces reciprocity between solid objects.

- Achieve accurate temperature predictions in demanding, high-temperature applications such as blast furnaces, industrial ovens, and engine compartments.
- Use the radiation model to include the effects of temperature-dependent emissivity to simulate the effects of spectral radiation.
- Compute radiative heat transfer through transparent media such as windows and clear plastic. Simulate real-world objects by specifying the emissivity and transmissivity properties of solid objects.

Solar Heating

What is Solar Heating?

A sub-set of radiation heat transfer, solar heating is radiative heat from the sun. Unlike conduction or convection, solar radiation does not rely on a medium such as a solid or carrier gas. Heat radiates through empty space with electromagnetic waves.

Why would you need Solar Heating?

The Solar Heating model is essential for optimizing the thermal performance of devices that operate out-of-doors, especially in environments exposed to harsh sunlight with little shade.

Critical components such as telecommunications equipment (both civilian and military), buildings, and even cars are subjected to harsh conditions imposed by the sun. They must be designed to withstand the high temperatures and day-to-day thermal cycling that play a serious factor on product life-span and durability.

What can you do with Solar Heating?

CFdesign provides a comprehensive set of tools for specifying the exact location, time, date, and physical orientation to ensure accuracy for a wide range of applications.

- Asses the thermal effects of solar heat loading to make design decisions that will affect product durability and life-span.
- Simulate the effects of shadowing. The relative location of objects significantly influences how solar energy affects other objects or devices.
- Study the long-term effects of diurnal heating. Vary the sky temperature and emissivity to simulate thermal cycling from day to night and back to day.
- Accurately account for the amount of cloud cover and ambient light by specifying the albedo (the amount of radiant energy that is reflected off the sky and back to earth).

Cavitation

What is Cavitation?

Cavitation is a physical phenomenon that occurs in many high-velocity liquid flows when the liquid pressure falls below the vapor pressure. Vapor bubbles form and rapidly collapse, forming a shock wave.

Cavitation is commonly found in high-speed liquid flows within valves and pumps, and can greatly reduce the efficiency and life span of these devices. Prolonged cavitation can lead to pitting and erosion of the device, resulting in costly downtime and repairs.

Why would you need Cavitation?

The insight into the location and severity that the Cavitation physical model provides is invaluable toward creating a design that mitigates cavitation as much as possible. The result is longer component life span and improved efficiency.

What can you do with Cavitation?

The Cavitation physical model solves for the location and size of cavitation regions, providing highly useful design information. Because cavitation occurs in most liquid flows, this information is very valuable in the design of a wide array of flow devices.

- Predict the onset and location of bubble formation due to cavitation using the vapor bubble volume fraction.
- Visualize regions of cavitation by plotting the Cavitation Vapor Volume Fraction. Use Iso surfaces to indicate the location of cavitating flow.

Joule heating

What is Joule Heating?

Also known as “resistance heating” and “Ohmic heating,” Joule heating is the generation of heat that occurs when an electric current is passed through a metal object such as a wire, electrical connector, or stove-top burner element.

Why would you need Joule Heating?

Depending on the application, Joule heating can either be the intended result or something to be avoided. If the design intent is to achieve resistance heating, the Joule Heating physical model provides insight into the temperature distribution throughout the device produced by the heating element. If the design objective is to mitigate the effects of Joule heating (such as in electrical connectors or electrical transformers), use the Joule Heating physical model to modify design for the removal of unwanted component heat.

What can you do with Joule Heating?

Use Joule heating to simulate thermal performance of a wide variety of devices including electrical resistance heaters, stove-top burner elements, and electrical transformers.

- Specify either a current or a potential difference across the device.
- Define temperature-dependent resistivity physical properties for a physically realistic simulation.
- Visualize the temperature distribution throughout the device and the neighboring components within the system. This provides design insight into how effective heat is removed from the device and sunk to other areas or to the ambient.

Scalar Mixing Model

What is the Scalar Mixing Model?

The Scalar Mixing Model provides a mechanism to track the concentration of a quantity introduced into a flow.

Why would you need the Scalar Mixing Model?

There are many applications in which knowledge of concentration is important for making good design decisions. Examples include the salinity of a seawater solution or a marker quantity to track the distribution and location of stagnation regions. Additionally, understanding the relative concentrations (mixture fraction) of two fluids in a multi-species mixing simulation can be very valuable for designing many types of industrial and chemical processes.

What can you do with the Scalar Mixing Model?

The Scalar Mixing Model is highly versatile, and lends itself nicely to a wide range of applications.

- Track the concentration of a quantity introduced into a flow.
- Simulate the mixing of two similar fluids by using a Scalar mixing condition and by defining scalar-dependent fluid properties.
- Specify a diffusion coefficient to control the mass diffusivity of the scalar quantity into the surrounding fluid. A value of 0 prevents any diffusion of the scalar quantity. This quantity is D_{AB} in Fick's Law.

Steam

What is Steam?

Steam is the vaporous state of water, and its application in energy production and other industries is far-reaching.

Why would you need Steam?

The ability to simulate steam is essential for understanding the distribution of steam quality within a saturated vapor.

What can you do with Steam?

The Steam physical model assumes a homogeneous two-phase mixture to solve for the steam quality within the flow distribution. It adds value for applications that focus on the flow and physical state of saturated steam:

- Understand the flow distribution of saturated steam.
- Visualize steam quality as well as the temperature and enthalpy within a saturated steam vapor flow.

Humidity

What is Humidity?

Humidity is the amount of water vapor contained within air.

Why would you need Humidity?

It is crucial to regulate the relative humidity and to safeguard against condensation in situations that contain sensitive components such as clean rooms and data centers. An early understanding of where condensation occurs is a valuable design tool. Educated design decisions can lead to significant cost savings in terms of equipment life-span and process efficiency.

In some industrial processes, the relative humidity is intentionally elevated to enhance heat transfer. Understanding the humidity distribution and its effects on the process is necessary for making educated design decisions.

What can you do with Humidity?

- Study the relative humidity in and around sensitive components. Ensure that air handling equipment and methods effectively manage the relative humidity early in the design cycle, decreasing the risk of costly redesigns and equipment malfunctions and failures.
- Visualize where condensation occurs and the amount of liquid condensed.
- Calculate the condensed liquid as a mixture fraction: the mass of the condensed liquid divided by the total mass of the liquid, vapor and carrier gas

Water Hammer (compressible liquid)

What is Water Hammer?

Water hammer, also known as hydraulic shock, is a pressure pulse that propagates through a liquid at the speed of sound as a result of a sudden momentum change. An example is when a valve in a high-velocity water pipeline is suddenly closed. A pressure pulse propagates rapidly through the water, and can bounces off the pipe ends until losing strength due to viscous dissipation.

Why would you need Water Hammer?

In certain conditions, a water hammer pulse can be quite damaging. It can cause excessive noise, pipe rupture, or even collapse the pipe. Being able to identify if a water hammer will occur, its strength, and its velocity can lead to the addition of buffer zones, accumulators, and other cost-saving measures to the system.

What can you do with Water Hammer?

- Using transient and compressibility, “slam” a valve closed suddenly during a fully-developed flow.
- Animate the movement of the resulting pressure pulse
- Determine the strength, extent, and “lifespan” of the pulse.