High Performance Computing Facilities

CSE has three high performance computing clusters

- (2) 32 processor (3GHz x86 32-bit) 16 node Linux clusters
  - 4.0 GB RAM per node
- (1) 48 processor (4GHz x86_64 64-bit) 24 node Linux cluster
  - 6.0 GB RAM per node

High performance engineering workstations for each engineer

- Dual-core 4GHz x86_64 Linux workstations
  - 4~16 GB RAM
  - PCI-express graphics bus

State of the art computational and modeling software

- Modeling Software
  - ANSA, ICEM-CFD, Prostar, Gambit, Tgrid
- Computational software
  - Fluent, Star-CD, Acusolve
- *Post-processing*
  - Prostar, Ensight, μETA

What this all means:

Models can be built using the latest technologies to almost arbitrary levels of detail

Models up to 30-50 million cells can be used for analyses when necessary

A typical problem of 5-10 million cells can be run in 3-5 days

Solver can be chosen to suit the needs of a given client or problem

Results can be delivered in a dynamic movie oriented format for use on any platform

CFD Capability and Experience

Optimization

- Combustor nozzle optimization utilizing reacting or non-reacting models
- Premixed and non-premixed combustion analyses for combustor fuel-injector modeling
- Combustor mid-frame / test-stand comparison analyses
- Liner / nozzle and mid-frame sub-models can be coupled to provide boundaries to FEA codes
- Automotive external aerodynamic analysis and optimization

Durability and safety

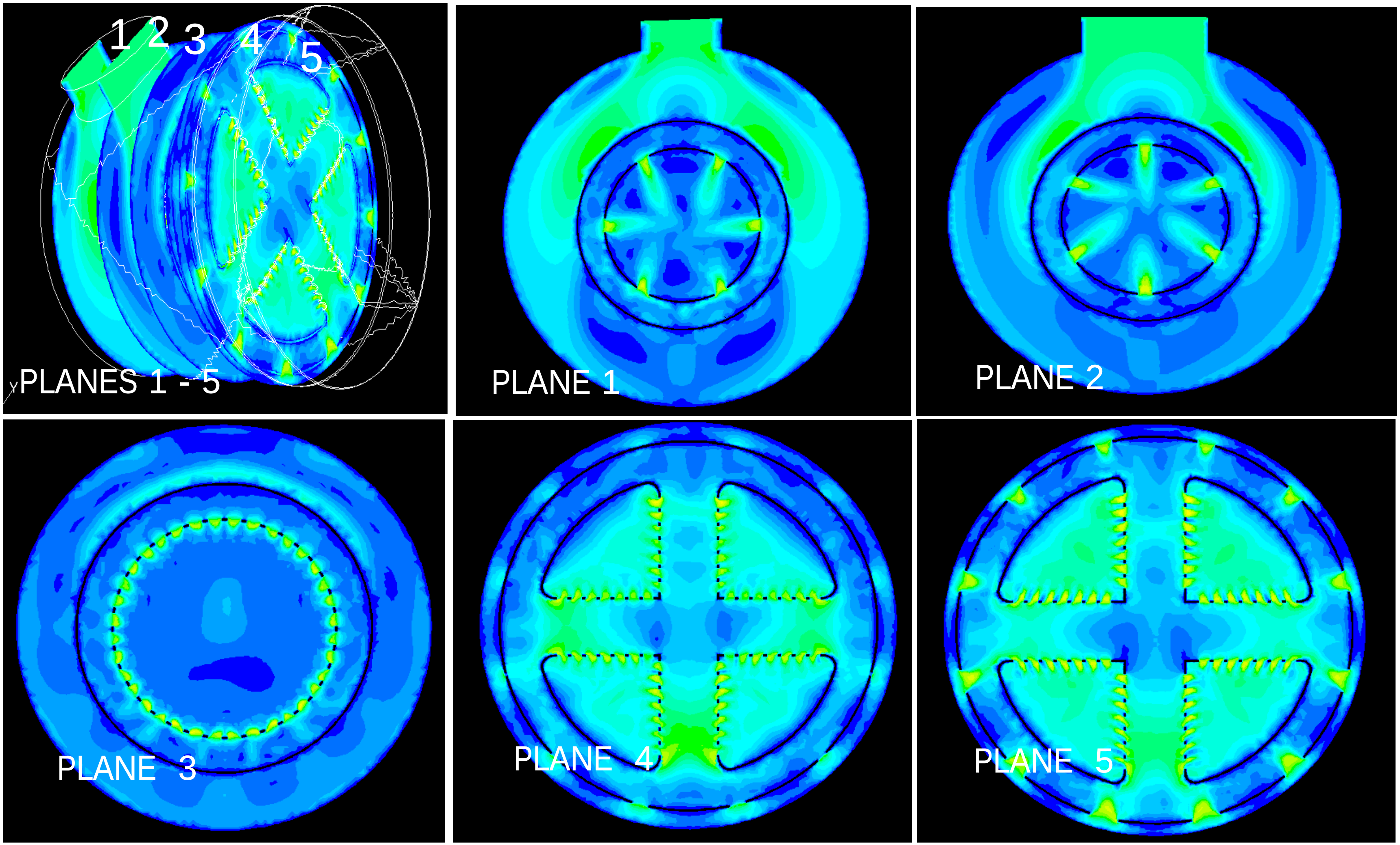
- Gas turbine enclosure / oil platform compartment modeling for hazard and risk analysis
- Fireplace leak risk assessment using compartment modeling techniques
- Conjugate analysis of gas turbine combustors including cross-fire tubes, ignition devices, etc.
- Conjugate analysis of break rotors for durability prediction and further FEA analysis
- Conjugate radiation models for heating and cooling applications
- Automotive / aircraft HVAC and deicing simulations for passenger comfort analyses
- Automotive under-hood / aircraft under-cowl analyses

Specialized Analyses

- Transient wind turbine analysis including topographic models
- Transient car / car interactions (i.e., drafting, passing, etc.) ** in progress
- Discrete multi-phase models (sprays) and Eulerian 2-phase flows
- Validation and comparison of multiple turbulence models (i.e., k-ε, LES & DES)
- Advanced chemistry / turbulence interactions
- Moving mesh and other advanced transient solutions using Acusolve
- PEM fuel cell modeling and design
- Coating and deposition surface reaction models (CVD reactors)
- Steam reforming reactor simulations
- Coal combustion modeling

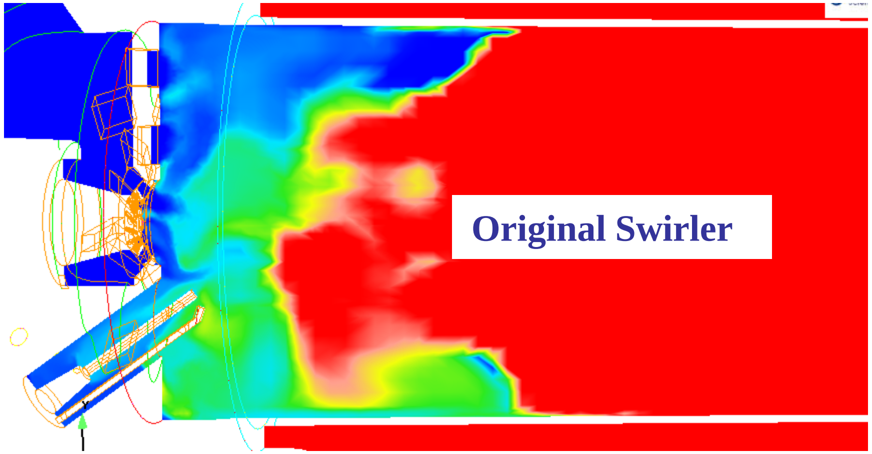
*Note: Red text denotes no accompanying slide

Combustor nozzle design optimization



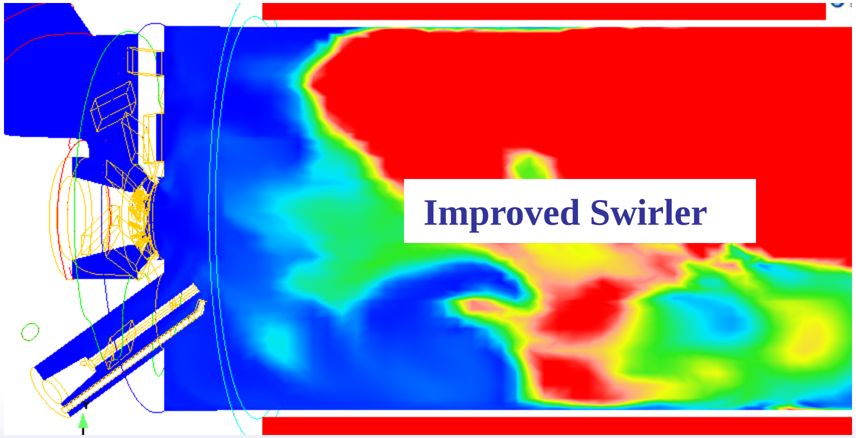
Effects of an outer flow-sleeve on the nozzle burning patterns

Combustor swirler design optimization

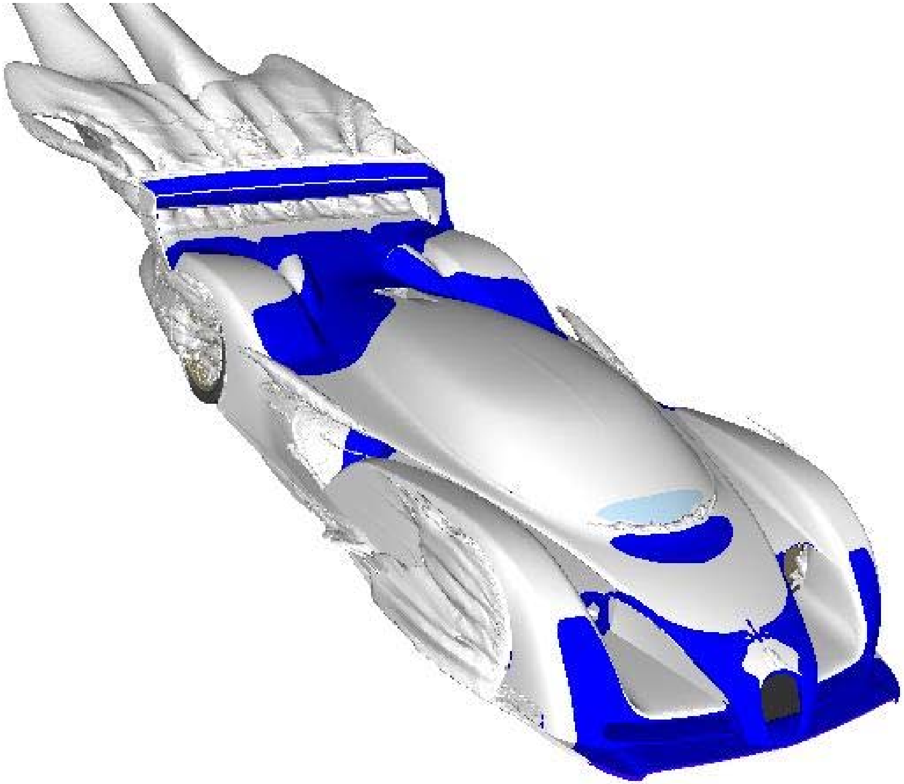


Modification of swirler design led to reduced accumulation of species (soot) near the spark plug

Species concentration at mid-plane of combustor



Automotive External Aerodynamic Optimizations



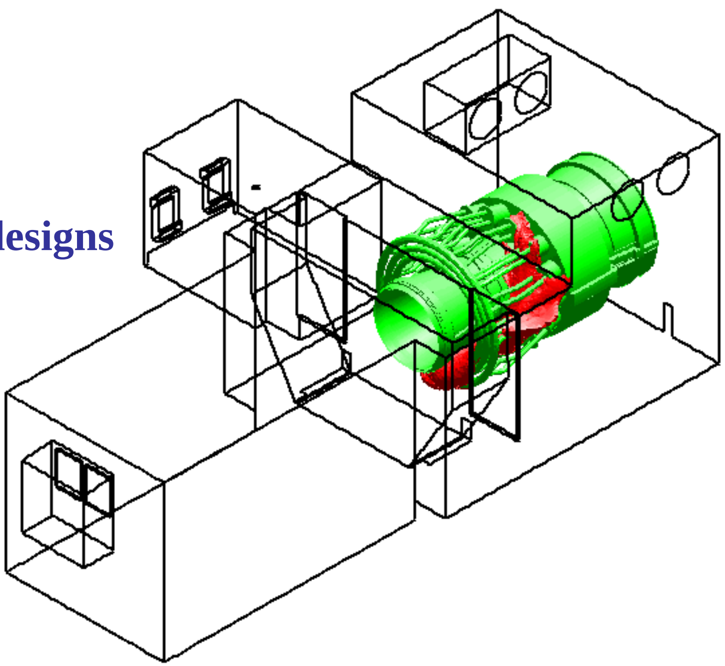
Total pressure coefficient iso-surfaces indicating areas of potential design refinement.

Detailed aerodynamic CFD analyses can aid in the optimization of a proposed design. These iso-surfaces are a depiction of some of the main sources of aerodynamic losses, through 2D and 3D models the design can be globally or locally refined to meet the desired design criterion.

Computational fluid dynamics (CFD) has advanced to the stage where it can be a useful tool in the analysis and design of gas turbine or similar compartments.

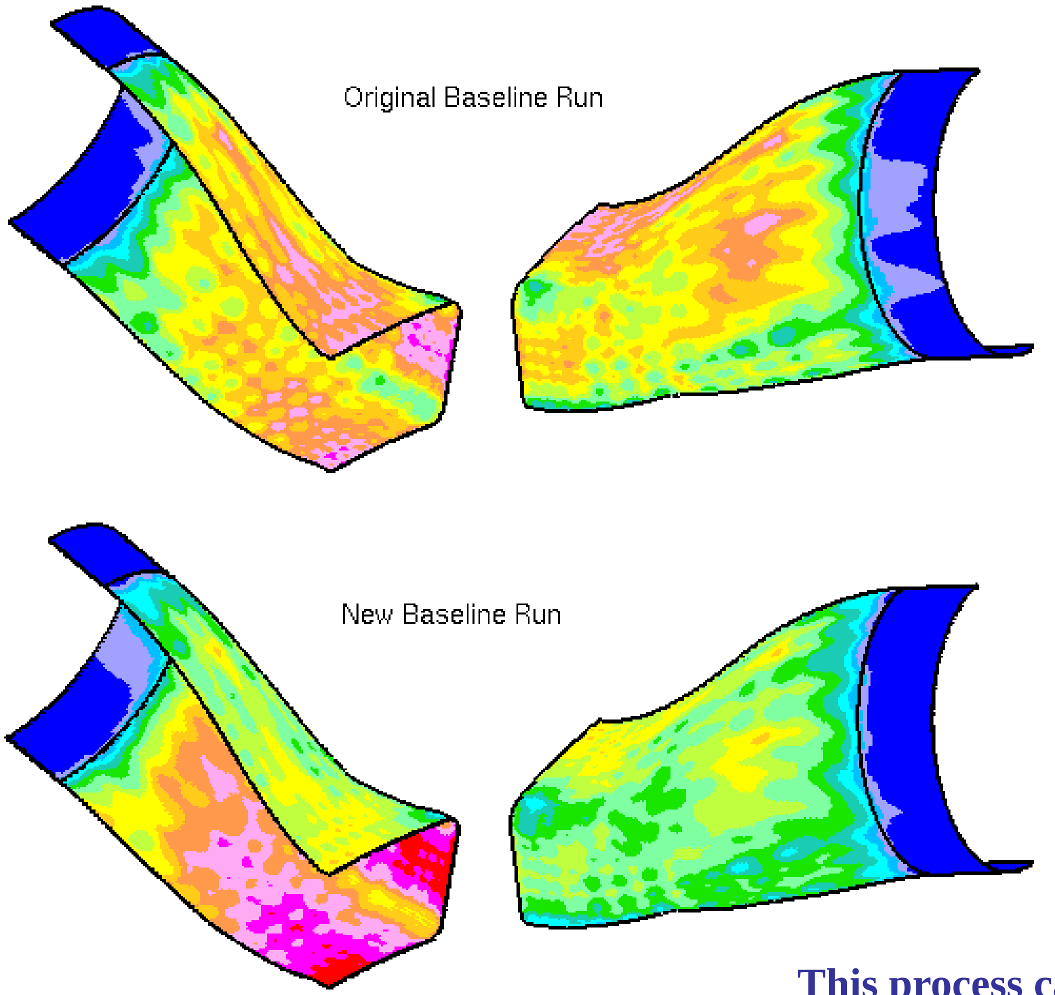
These analyses can be used for:

- **Determining the size of explosive clouds for hazard and risk assessments**
  - » **Fuel leak studies**
    - – **Investigate multiple fuel leak locations**
    - – **Investigate multiple fuel leak sizes**
  - » **Overpressure calculations**
  - » **Area classifications**
    - – **Class 1, division 1 determinations**
    - – **Ignition source locations**
- **Evaluating the effectiveness of forced convection designs**
  - » **Turbine cooling**
  - » **Purge times**
  - » **Purge effectiveness**
  - » **Identifying recirculation zones**
- **Optimize placement of detection systems**
  - » **Evaluate potential detectors**
  - » **Study various fire locations**



***These same processes can also be applied to automotive or airplane cabin comfort analyses**

Gas Turbine Mid-frame optimization

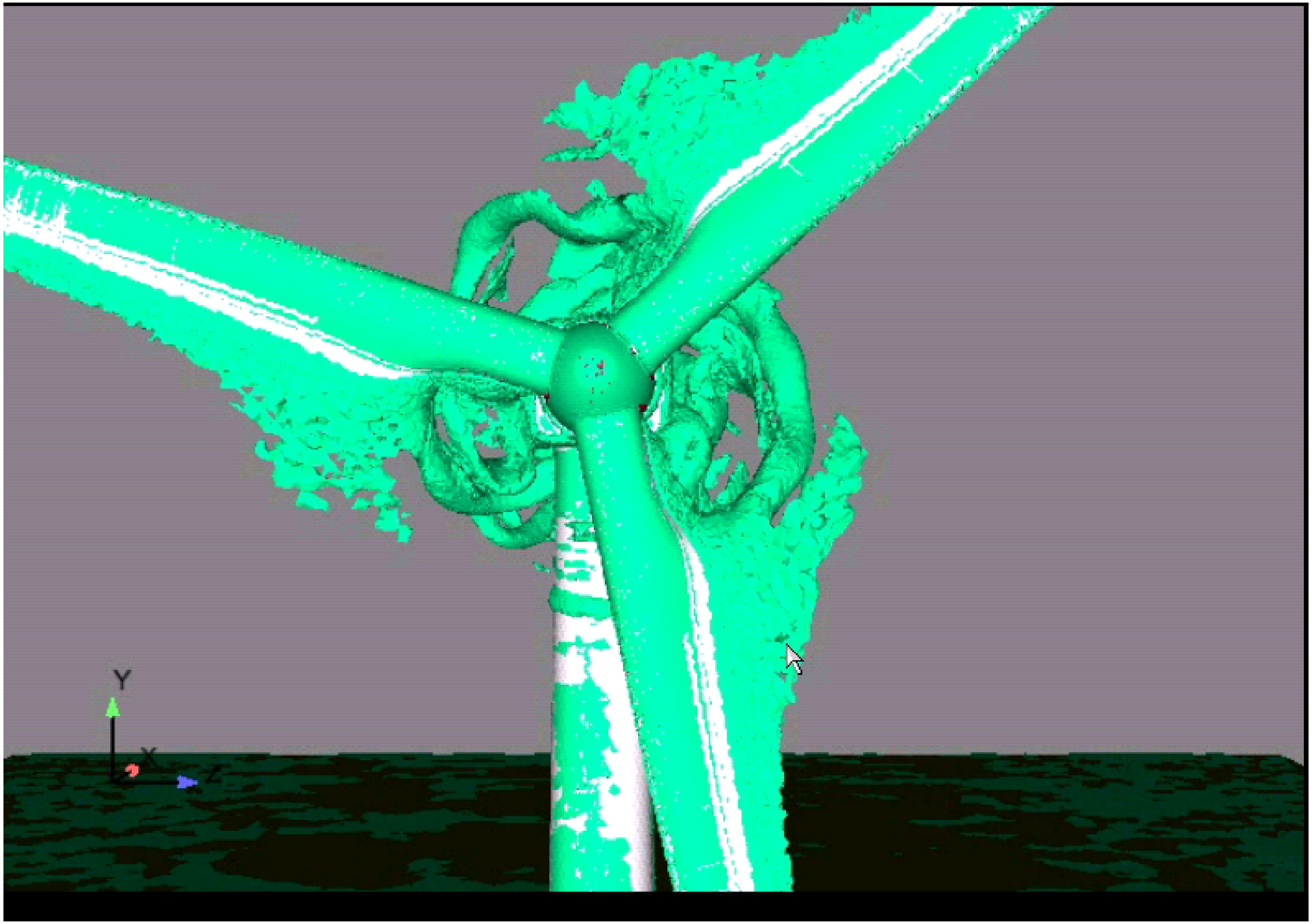


TBC Solid Temperatures
Machine Midframe Model Baseline Comparison

Mid-frame performance can be examined from a thermal heat loading aspect. The corresponding heat transfer coefficients can be applied to a finite element model to determine thermal stresses and strains as well as deformations that are likely to occur. These FEA results can then be used to help determine component durability.

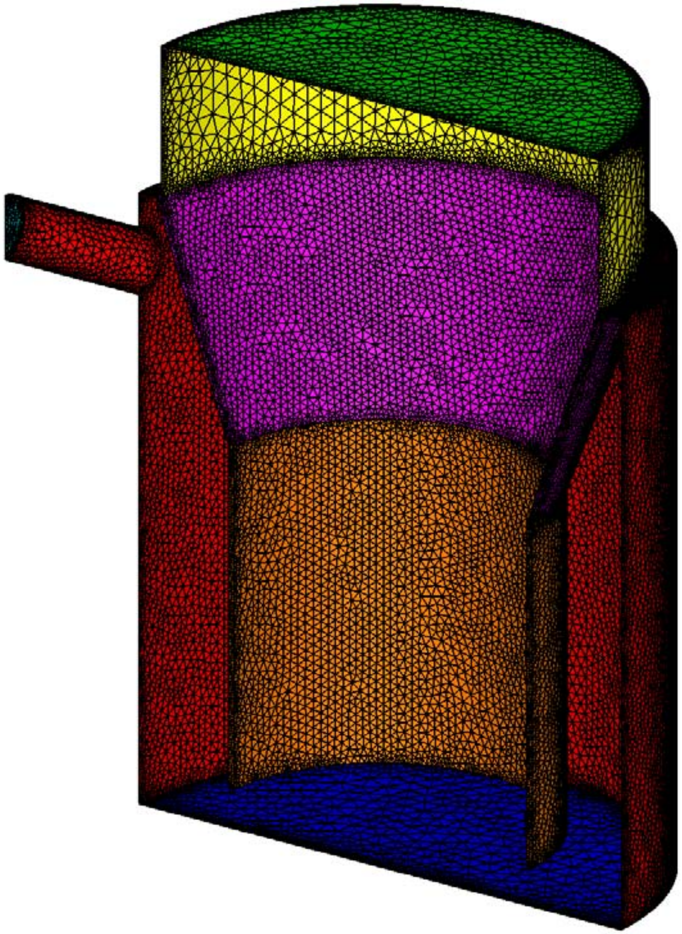
This process can be applied to any type of problem where coupled analysis is desired (i.e., brake rotors, engine cooling jackets, etc.)

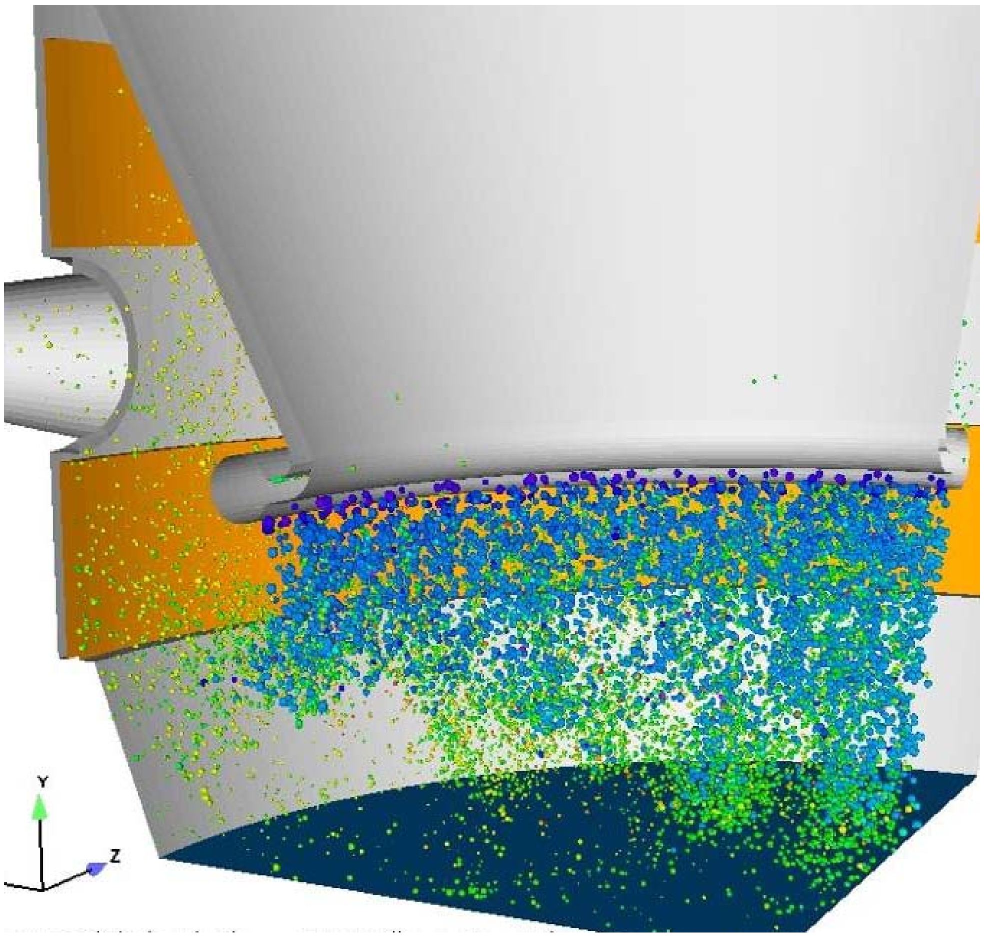
Wind turbine transient analysis



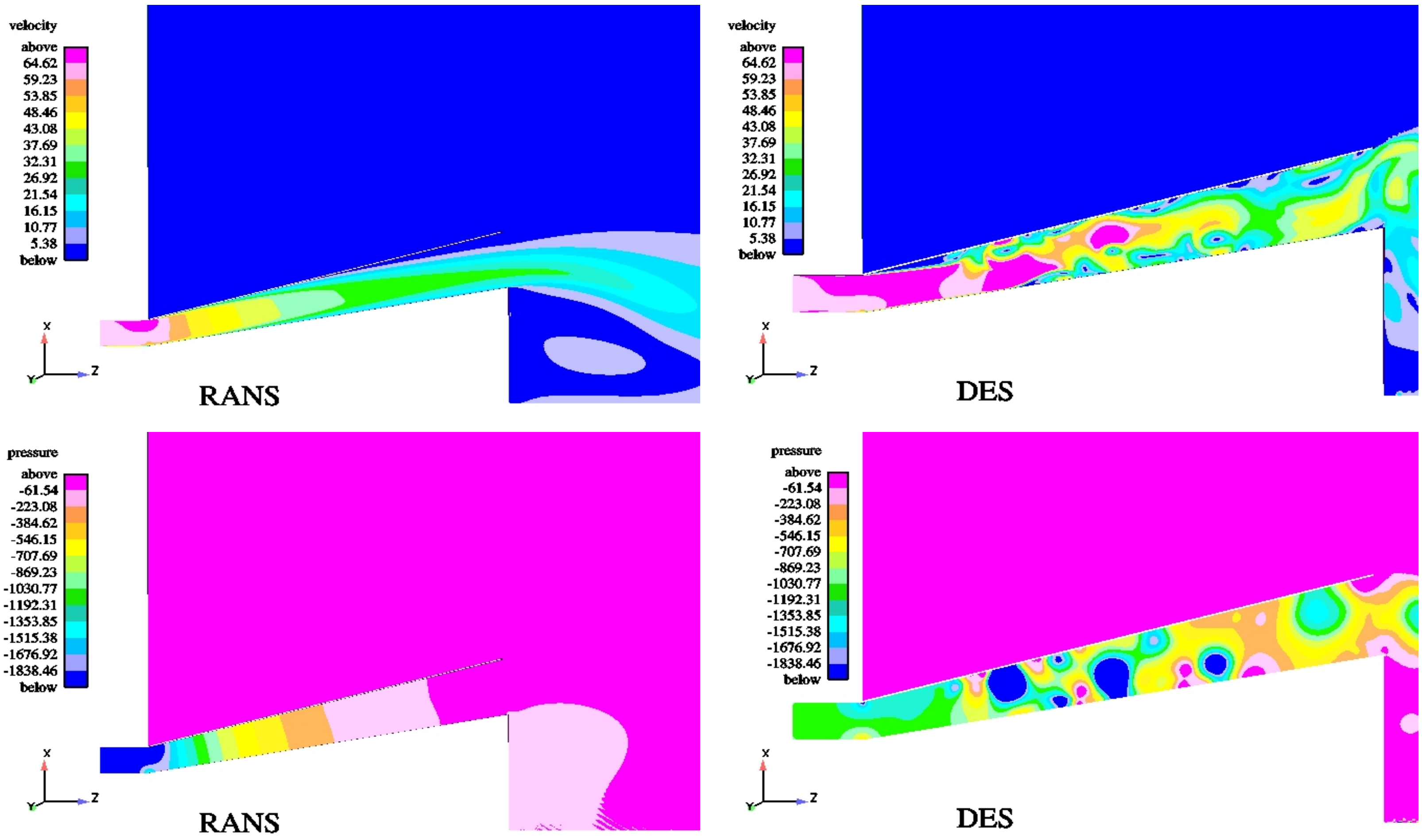
Model quality can be measured based upon how closely the torque is predicted

Discrete Phase Water Spray Cooling

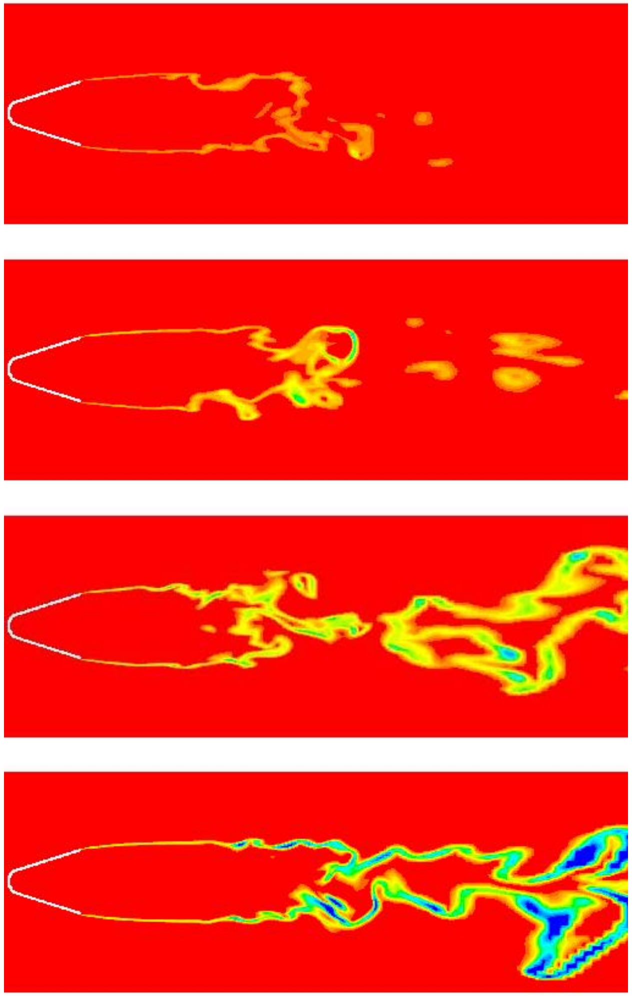




Turbulence Model Characteristics



Performing a transient simulation using Acusolve with a DES turbulence model pressure vibrations inside a combustor compressor discharge diffuser can be resolved



ϕ : 0.45

ϕ : 0.5

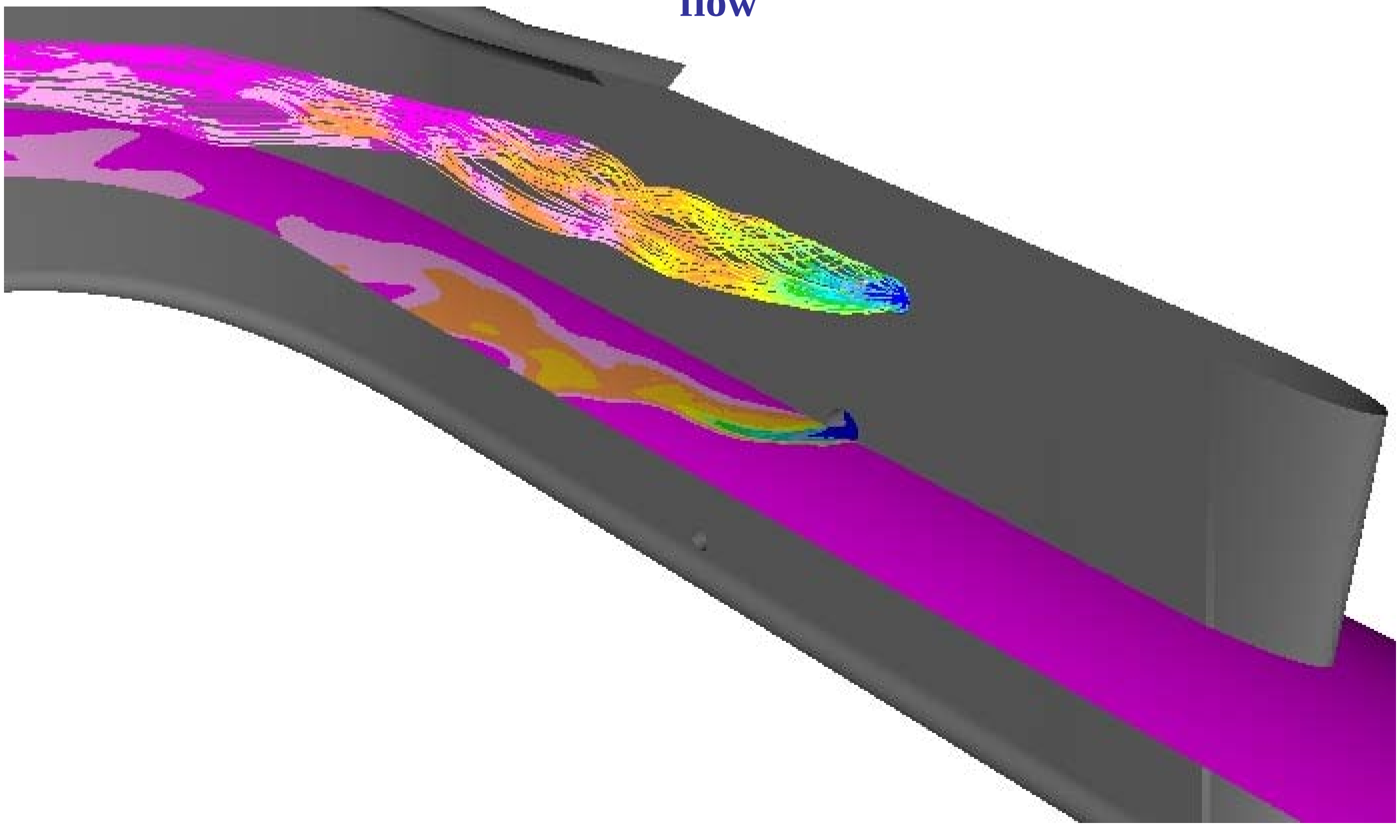
ϕ : 0.55

ϕ : 0.6

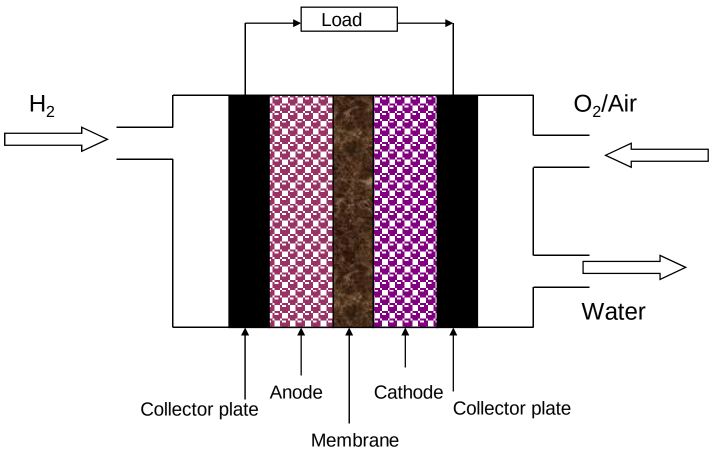
Reaction Rate Contours

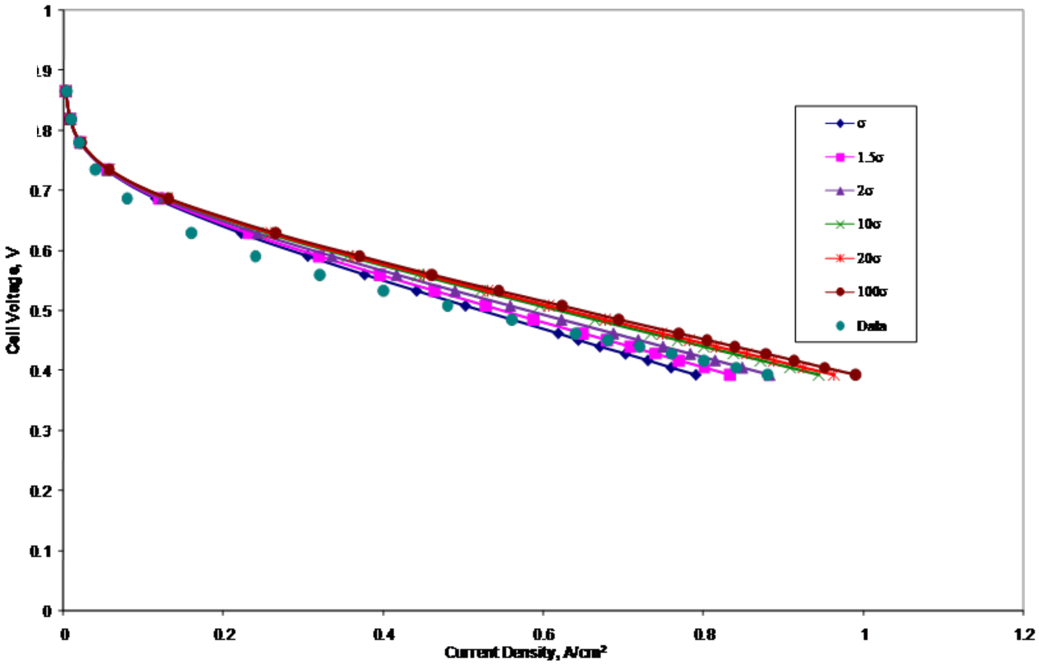
Custom reduced chemical reaction mechanisms are used in conjunction with LES turbulence models in a transient simulation to determine the effects of phi on blowout predictions

Acusolve using a DES model is used to predict the flow separation near the blade tip for the injection flow



Fuel Cell Simulation





Physics Modeled:

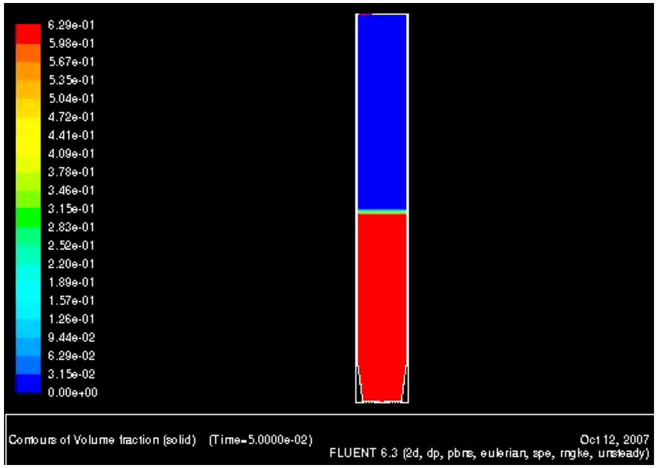
- **Flow**
- **Porous Medium**
- **Heat & Mass Transfer**
- **Electrochemistry**

There is a limit to which membrane conductivity affects cell performance, cell performance is better enhanced by proper design and manufacture of catalyst.

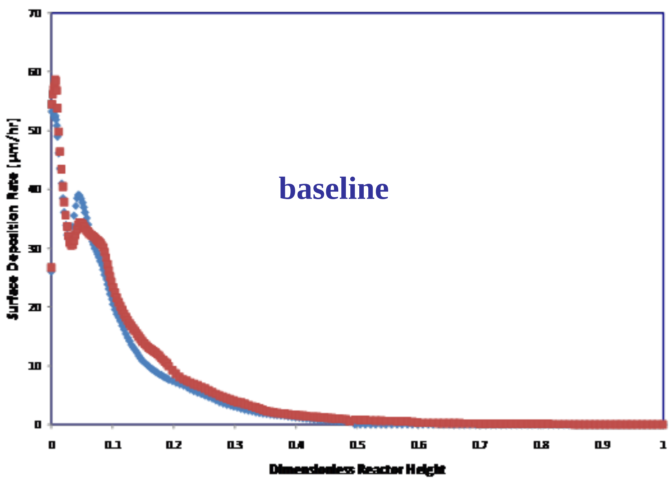
Chemical Vapor Deposition Reactor

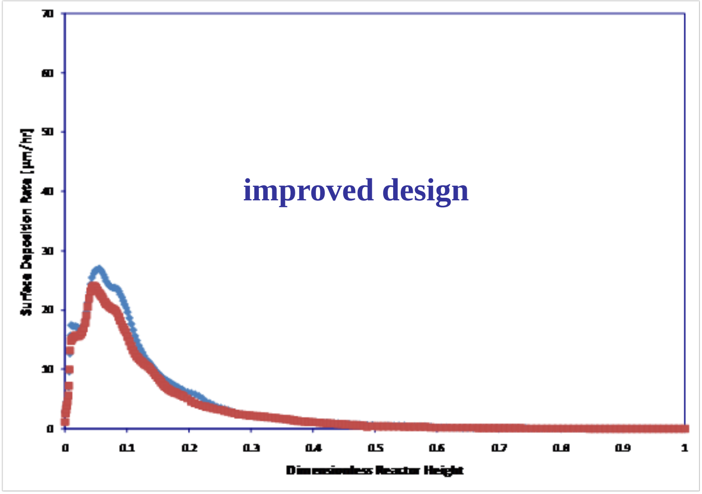
Specialized Analyses

Conjugate solution using multiphase physics with homogeneous & heterogeneous reactions, simulation leads to design improvements that increase the reactor lifespan by reducing deposition on the reactor walls



Solid Volume Concentration

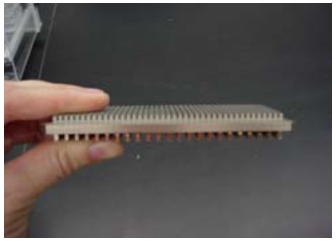


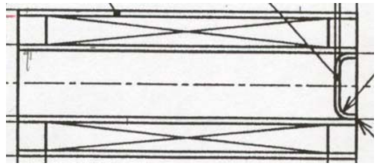


Wall Deposition Profiles

Steam Reforming Reactor

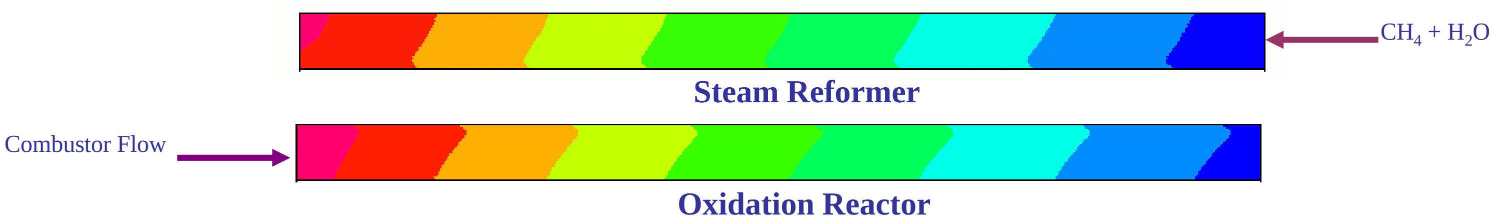
micro HEX





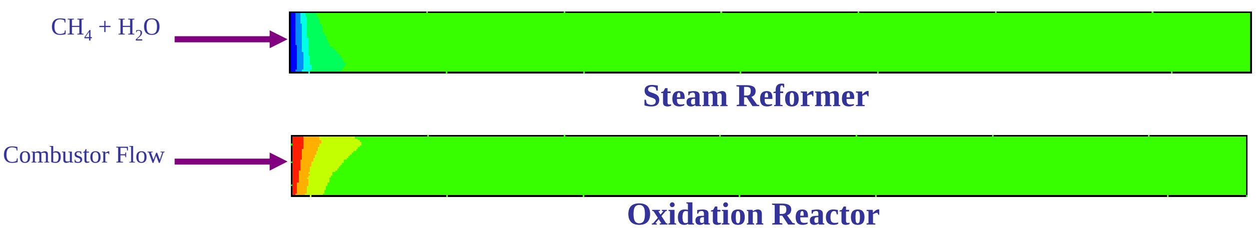
Conjugate simulation using porous media and homogeneous and heterogeneous reactions

Counter Flow Configuration

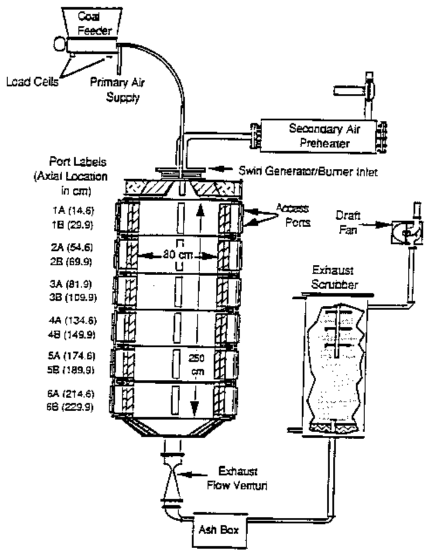


The temperature contours in the reactor indicate that the parallel flow configuration is better for isothermal reforming

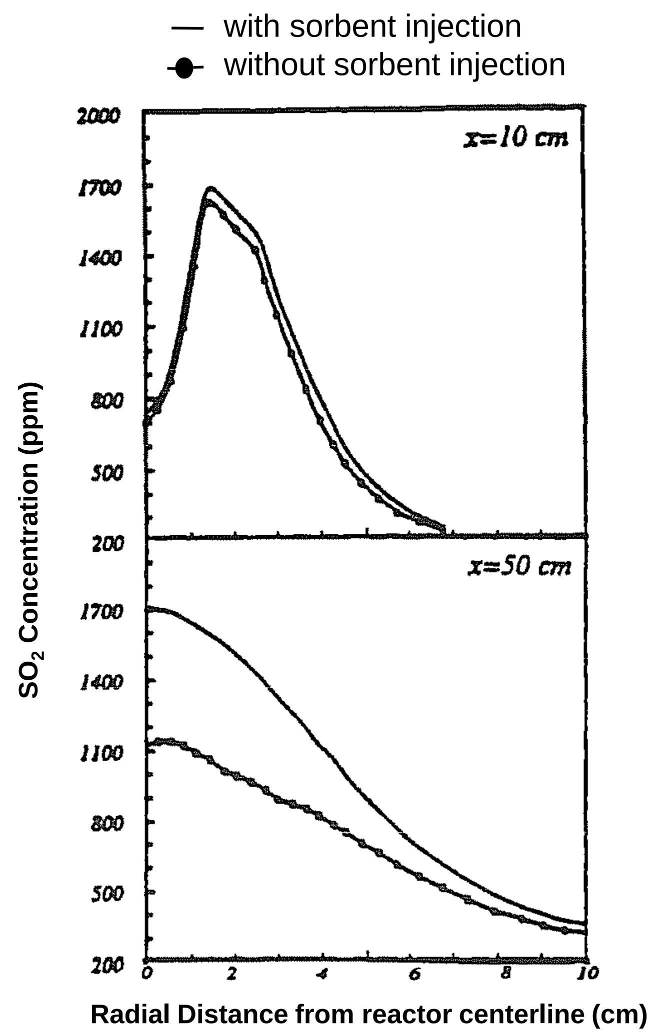
Parallel Flow Configuration



Coal Combustion Simulation



Coal Combustion Reactor



Conjugate simulation using porous media and homogeneous and heterogeneous reactions

Prediction and Capture of Acid Rain Precursors -- SO_x