CFD
Use and benefits
What is CFD?

“Computational Fluid Dynamics”

- An Engineering Tool
  - Design
  - Troubleshooting
  - “Virtual laboratory”
- A Numerical Method
  - Solves equations of motion for fluid
  - Steps:
    - set up problem
    - solve
    - view results
CFD: Numerical method

- CFD solves the Navier-Stokes equations, i.e. Conservation Principles of
  - mass,
  - momentum,
  - energy, chemical species, turbulence...

\[
\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x_i} (\rho u_i) = 0
\]

\[
\frac{\partial (\rho u_i)}{\partial t} + \frac{\partial}{\partial x_j} (\rho u_i u_j) = -\frac{\partial p}{\partial x_i} + \frac{\partial \tau_{ij}}{\partial x_j} + \rho g_i + F_i
\]
Getting at the solution

- Problem set up, or “pre-processing”
  - integration with design group / CAD
  - graphical interface
  - parametric studies
- Solver computes the flow field
  - speed, accuracy, reliability
  - features “models”
- Viewing results, “post-processing”
  - numbers, graphs, figures, animations
The CFD process

- Create or import your geometry using CAD-style tools
- Discretize the geometry: mesh generation, fluid and solid domains
- Define flow conditions, fluid properties, physics
- Submit the calculation (solve the conservation equations for mass, momentum, energy)
- Review results (graphs, data)
What can be modeled?

**Devices**
- Compressors
- Expansion Turbines
- Heat Exchangers
- **Valves**
- Separators
- Filters
- Ducting
- Dryers

**Results**
- Performance
- Visualization
- Erosion
- Fouling/plugging
- Pressure losses
- Heat transfer
- Cavitation
- Noise
## Setting expectations

<table>
<thead>
<tr>
<th>To expect</th>
<th>NOT to expect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Values for</td>
<td>Replacement for good engineering judgement</td>
</tr>
<tr>
<td>- Performance</td>
<td>- Complete replacement for testing</td>
</tr>
<tr>
<td>- Forces</td>
<td>- Immediate and effortless results</td>
</tr>
<tr>
<td>- Pressures</td>
<td>- Accurate results require</td>
</tr>
<tr>
<td>- Erosion</td>
<td>- Detailed models</td>
</tr>
<tr>
<td>Parametric studies</td>
<td>- Knowledge of your problem</td>
</tr>
<tr>
<td>Visualization</td>
<td>- Knowledge of limitations</td>
</tr>
<tr>
<td>Qualitative behaviour</td>
<td></td>
</tr>
<tr>
<td>Investment that pays off</td>
<td></td>
</tr>
</tbody>
</table>
Benefits of CFD

Reduce design time
Understand problems and physics involved
Improve performance
Enhance product quality
Ball valve

Path lines colored by velocity magnitude
Ball valve

Static pressure estimate Cv
Control check valve
Control check valve

Path lines colored by velocity magnitude
Control check valve

Pressure acting on disc: calculate forces and torque
Control check valve

Velocity vectors
Safety relief valve

Path lines colored by velocity magnitude
Safety relief valve

Contours of velocity in the disc zone
Safety relief valve

Pressure acting on disc: calculate forces & spring

V&W valves
Control valve

Path lines colored by velocity magnitude
Control valve

Highlight design failures:

The combined action of the wall (too close to the cage) and the eddy gets the flow out of the hole, making it ineffective.
Control valve

Highlight design failures:
Backflow regions in some holes
CFD: in summary...

- Complements physical modelling.
- Provides comprehensive data not easily obtainable from experimental tests.
- Is more cost-effective than physical modelling.
- Reduces the product-to-market time scale.
- Answers the “what if...?” question.
- Highlights the cause, not just the effect.