Fluid Modeling with OpenModelica:
Recent improvements and Further Needs

OpenModelica Workshop 2011
Agenda

- Recent improvements, that make fluid modeller happy
- Test Case
  - Tube Hydrodynamics
  - Media properties calculation with TTSE
- Benchmark results
  - Compilation performance
  - Simulation performance
  - TTSE performance
- Needed Changes
  - Modelica Media -> TTSE
  - Builtin-Functions and Naming
  - Initialization
- Outlook
- Your Feedback
Major Improvements
With respect to fluid modeling

- Stream Concept
  - Modelica.Fluid port besides Medium, X, c

- Build system
  - Nightly builds
  - Stability

- Analytic jacobian

- OMEdit

- FMI Implementation on the way
Tube hydrodynamics

Mass balance
\[ \frac{\partial}{\partial t} \rho + \frac{\partial}{\partial z} (v \rho) = 0 \]

Momentum balance
\[ \frac{\partial}{\partial t} (\rho v) + \frac{\partial}{\partial z} (v^2 \rho) = -\frac{\partial p}{\partial z} - \rho \left( f_{\text{fric}} + f_{\text{hyd}} \right) \]

Energy balance
\[ \frac{\partial}{\partial t} \left[ \rho \left( e + \frac{v^2}{2} \right) \right] + \frac{\partial}{\partial z} \left[ v \rho \left( e + \frac{v^2}{2} \right) \right] = \lambda \Delta T - \frac{\partial}{\partial z} (v p) - \rho v f_{\text{hyd}} + \frac{U \dot{q}_{\text{inf}}}{A} \]

Sources
- Pressure differences
- Friction
- Gravitation
- Heating
Changes needed to Fluid models for OMC
Use TTSE (or any external Media) instead of Modelica.Media

Stored grid/table of water thermodynamic properties $z(x_i, y_j)$ and their partial derivatives calculated with the standard IAPWS-IF95 (scientific use) and with pressure ($x$) and enthalpy ($y$) as variables.

Properties are calculated on each cell ($i,j$) with the Taylor Series Expansion:

$$z = z_{i,j} + (x - x_j)\left(\frac{\partial z}{\partial x}\right)_{i,j} + (x - y_j)\left(\frac{\partial z}{\partial y}\right)_{i,j} + \frac{1}{2}(x - x_j)^2\left(\frac{\partial^2 z}{\partial x^2}\right)_{i,j} + \frac{1}{2}(y - y_j)^2\left(\frac{\partial^2 z}{\partial y^2}\right)_{i,j} + (x - x_j)(y - y_j)\left(\frac{\partial^2 z}{\partial x \partial y}\right)_{i,j}$$

Call of the function in the TTSE library and derivative computation.
TTSE
Accuracy

Fast computation time: from half (regions 1 and 2) to one-tenth of the standard IF97

Computation time ($10^{-6}$s/call) for Prandtl number for TTSE (TT), IF97 (97) and IAPWS 95 (IA) (Kiyoshi Miyagawa report)
Simple test case

- sine
- freqHz = ?
- ramp1
- duration?
- m?
- ramp2
- duration?
- P
- w at?
- real? 1e6
- prescr?
Simple Test Case
How to reduce the burden of getting started
Simple Test Case - Benchmark
Comparison of Compile Time

![Comparison of Compile Time Chart](chart.png)
Simple Test Case - Benchmark
Comparison of Simulation Time

![Bar chart showing comparison of simulation time for different numbers of nodes and software tools.](image-url)
### Needed changes
Modelica Media -> TTSE

<table>
<thead>
<tr>
<th>DymolaModelica</th>
<th>OmcModelica</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modelica.Media.Interfaces.PartialMedium;</td>
<td>SiemensPower.Media.TTSE.OMC.T_ph(p, h[j]);</td>
</tr>
<tr>
<td>Medium.BaseProperties h2o[N];</td>
<td>rho[j] =</td>
</tr>
<tr>
<td></td>
<td>SiemensPower.Media.TTSE.OMC.Rho_ph(p, h[j]);</td>
</tr>
<tr>
<td>h2o.h = h;</td>
<td>drdp[j] =</td>
</tr>
<tr>
<td>h2o.d = rho;</td>
<td>SiemensPower.Media.TTSE.OMC.Rho_ph_dp(p, h[j]);</td>
</tr>
<tr>
<td>...</td>
<td>drdh[j] =</td>
</tr>
<tr>
<td></td>
<td>SiemensPower.Media.TTSE.OMC.Rho_ph_dh(p, h[j]);</td>
</tr>
</tbody>
</table>
### Initial Equations

<table>
<thead>
<tr>
<th>DymolaModelica</th>
<th>OmcModelica</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>initial equation</strong></td>
<td></td>
</tr>
<tr>
<td>if (steady_enthalpy_inflow and steady_state and dynamicSimulation) then</td>
<td></td>
</tr>
<tr>
<td>der(h[1])=0;</td>
<td></td>
</tr>
<tr>
<td>end if;</td>
<td></td>
</tr>
<tr>
<td>if (steady_state and dynamicSimulation) then</td>
<td></td>
</tr>
<tr>
<td>for j in 2:N loop</td>
<td></td>
</tr>
<tr>
<td>der(h[j]) = 0;</td>
<td></td>
</tr>
<tr>
<td>end for;</td>
<td></td>
</tr>
<tr>
<td>end if;</td>
<td></td>
</tr>
</tbody>
</table>
Outlook
With respect to fluid modeling

- Performance, Performance, Performance.

- Initialization support.

- Status and error messages, debugging support.

- OMEdit: Stability and Performance.
Your Feedback

Thank you for your attention!
Needed Changes
Minor issues

- Builtin-functions
- Naming