Water and Mercury Pipe Flow Simulation in FLUENT

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Outline

• Straight Pipe flow
• Curved pipe flow
Outline

• Straight Pipe flow
• Curved pipe flow
Straight Pipe flow
— Physical problem

Isothermal mercury/water flow through a 60D straight pipe into the air environment

<table>
<thead>
<tr>
<th>Medium</th>
<th>Reynolds Number</th>
<th>Inner Diameter</th>
<th>Inlet Velocity</th>
<th>Inlet Pressure</th>
<th>Outlet Pressure*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>1500</td>
<td>41.844 μm</td>
<td>4.04 m/s</td>
<td>18.5 bar</td>
<td>15.67 bar</td>
</tr>
<tr>
<td>Water</td>
<td>1500</td>
<td>331.404 μm</td>
<td>4.04 m/s</td>
<td>18.5 bar</td>
<td>18.291 bar</td>
</tr>
</tbody>
</table>

\[ u_{ave} = 0.5 \, u_{max} = (P_1 - P_2)D^2/(32\mu L) \]
Straight Pipe flow in FLUENT
— Mesh

\[ n_x \times n_r \times n_\theta = 190 \times 20 \times 14 \]
\[ \Delta x_{\text{min}} = 0.02D \]
\[ \Delta r_{\text{min}} = 0.0013D \]
\[ n \text{ is the cell No.} \]
Straight Pipe flow in FLUENT
— Simulation parameters

Velocity inlet
$u = 4.04 \text{ m/s}$
$v = w = 0$
Straight Pipe flow in FLUENT
— Central line plot (1)

Units:
r (m); u (m/s); ρ (kg/m³); P (Pa)
Straight Pipe flow in FLUENT — Central line plot(2)

Mercury

Water
Straight Pipe flow in FLUENT — Central line plot(3)
Straight Pipe flow in FLUENT
— Central line plot(4)
Straight Pipe flow in FLUENT
— Radial distribution of axial velocity (1)

Slices are chosen for each 10 pipe diameter
Straight Pipe flow in FLUENT
— Radial distribution of axial velocity (2)

I=0

I=10D
Straight Pipe flow in FLUENT — Radial distribution of axial velocity (3)

I=20D

I=30D
Straight Pipe flow in FLUENT
— Radial distribution of axial velocity (4)

I=40D

I=50D
Straight Pipe flow in FLUENT
— Radial distribution of axial velocity (5)

Mercury

Water

I=60D

Axial Velocity Profile
Straight Pipe flow in FLUENT
— Radial distribution of axial velocity (6)

Non-dimensional axial velocity profile comparison at I=60D
Outline

- Straight Pipe flow
- Curved pipe flow
Curved Pipe flow
— Physical problem

Isothermal mercury/water flow through a bend pipe into the air environment

<table>
<thead>
<tr>
<th>Medium</th>
<th>Reynolds Number</th>
<th>Inner Diameter</th>
<th>Inlet Velocity</th>
<th>Inlet Pressure</th>
<th>Ma</th>
<th>Y values ($y^+=1$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>$8.05 \times 10^5$</td>
<td>0.884”</td>
<td>4.04 m/s</td>
<td>18.5 bar</td>
<td>$2.878 \times 10^{-3}$</td>
<td>0.72 μm</td>
</tr>
<tr>
<td>Water</td>
<td>$8.05 \times 10^5$</td>
<td>7”</td>
<td>4.04 m/s</td>
<td>18.5 bar</td>
<td>$2.751 \times 10^{-3}$</td>
<td>5.74 μm</td>
</tr>
</tbody>
</table>
Curved pipe flow in FLUENT — Mesh (1)
Curved pipe flow in FLUENT — Mesh (2)

<table>
<thead>
<tr>
<th>Materials</th>
<th>Diameter (m)</th>
<th>Height (µm) (cell near-wall, y⁺=40)</th>
<th>Block 1 Size (m)</th>
<th>Block 3 Size</th>
<th>Mesh (Nₓ×Nᵧ×Nₜ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>0.0224536</td>
<td>Upstream 57.916</td>
<td>ODₓ=0.0224536; IDₓ=0.01494</td>
<td>Lₓ=0.00908</td>
<td>218×15×20(B1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Downstream 24.093</td>
<td>ODₐₓ=0.00934; IDₐₓ=0.006215</td>
<td>Lₐₓ=0.00378</td>
<td>218×5×20(B2)</td>
</tr>
<tr>
<td>Water</td>
<td>0.1778</td>
<td>Upstream 458.972</td>
<td>ODₓ=0.1778; IDₓ=0.1183</td>
<td>Lₓ=0.0719</td>
<td>218×10×5(B3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Downstream 190.933</td>
<td>ODₐₓ=0.073965; IDₐₓ=0.04922</td>
<td>Lₐₓ=0.0299</td>
<td></td>
</tr>
</tbody>
</table>
Curved pipe flow in FLUENT
— Slices positions
Curved pipe flow in FLUENT
— Radial distribution of axial velocity (1)
Curved pipe flow in FLUENT — Radial distribution of axial velocity (2)
Curved pipe flow in FLUENT
— Radial distribution of axial velocity (3)
Curved pipe flow in FLUENT — Radial distribution of axial velocity (4)
Curved pipe flow in FLUENT
— Radial distribution of axial velocity (5)
Curved pipe flow in FLUENT
— Radial distribution of axial velocity (6)
Curved pipe flow in FLUENT
— Radial distribution of axial velocity (7)
Curved pipe flow in FLUENT — Parameters at the outlet
Curved pipe flow in FLUENT
— Axial distribution of axial velocity
Appendix A

Analytical solution

\[ u(r) = \frac{(P_1 - P_2)(R^2 - r^2)}{(4\mu L)} \]

**Water**

\[ u_{\text{water}}(r) = \frac{(1.85 - 1.8291)(R_{\text{water}}^2 - r^2)}{(480 \times 0.893 \times 10^{-3} \times R_{\text{water}})} \]
\[ = 7.225617 - 2.942564 r^2 \]

Where \( 0 \leq r \leq 165.702 \)

**Mercury**

\[ u_{\text{mercury}}(r) = \frac{(1.85 - 1.567)(R_{\text{mercury}}^2 - r^2)}{(480 \times 1.526 \times 10^{-3} \times R_{\text{mercury}})} \]
\[ = 8.083395 - 0.0184666 r^2 \]

Where \( 0 \leq r \leq 20.922 \)