Computer Simulation, Mathematical Model, and Experimental Analysis of Severe Slugging in a Riser

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Motivation: What is severe slug flow?

From Schlumberger glossary: A **multiphase-flow regime** in pipes in which most of the lighter fluid is contained in large bubbles dispersed within, and pushing along, the heavier fluid. The word **slug** normally refers to the heavier, slower moving fluid, but sometimes to the bubbles of lighter fluid. There are also small bubbles within the liquid, but many of these have coalesced to form the large bubbles until they span much of the pipe. In gas-liquid mixtures, slug flow is similar to plug flow, but the bubbles are generally larger and move faster. As flow rates increase, slug flow becomes churn flow.
Mathematical model

- From Di Meglio et. al. for using with a control on the slug flow process
- Consists of three differential equations:

\[
\begin{align*}
\dot{x}_1 &= (1 - \epsilon)w_{g,\text{in}} - C_g \max\left(ax_1 - b \frac{x_2x_3}{m_3^A - x_3} - (x_3 + m_{3,\text{still}}) \frac{g \sin \theta}{A}, 0\right) \\
\dot{x}_2 &= \frac{1}{x_3} \left[\epsilon w_{g,\text{in}} + C_g \max\left(ax_1 - b \frac{x_2x_3}{m_3^A - x_3} - (x_3 + m_{3,\text{still}}) \frac{g \sin \theta}{A}, 0\right) - x_2w_{L,\text{in}}\right] \\
\dot{x}_3 &= w_{L,\text{in}} - uC_e \rho_l \left(b \frac{x_2x_3}{m_3^A - x_3} - p_s\right)^{1/n}
\end{align*}
\]

- Mass of gas in bubble
- Mass of gas in riser / mass of liquid in riser
- Mass of liquid in riser

References:
F. Di Meglio, G. -O. Kaasa, N. Petit, and V. Alstad, "Model-based control of slugging flow: an experimental case study,".
CFD Simulation: ANSYS FLUENT

- Similar geometry to experimental setup: pipe diameter and distances
- Input flow rate for gas and water
- Mesh consisted of 17056 nodes
- Solves for mass, momentum balance, phase field and performs linear interpolation to gather data

\[ \frac{\alpha_{i}^{n+1} - \alpha_{i}^{n}}{\Delta t} + \nabla \cdot (\rho \mathbf{u} \alpha_{i}) = \mathbf{F} \]

**VOF:**

\[ \frac{\partial}{\partial t} (\rho \alpha_{i}) + \nabla \cdot (\rho \mathbf{u} \alpha_{i}) = -\nabla p + \nabla \cdot \left[ \mu \left( \nabla \mathbf{u} + \nabla \mathbf{u}^{T} \right) \right] + \mathbf{F} \]

***All equations and pictures were all taken from the ANSYS FLUENT Academic version and its corresponding manual***
Experimental Setup

• Pressure sensor at choke valve
• Riser
• Flow meter
• Air flow meter
• Pressure sensor (base)
• Air compressor
• Water pump
Questions?

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