Computational modelling of counter-current multiphase flows

Research student

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Research team

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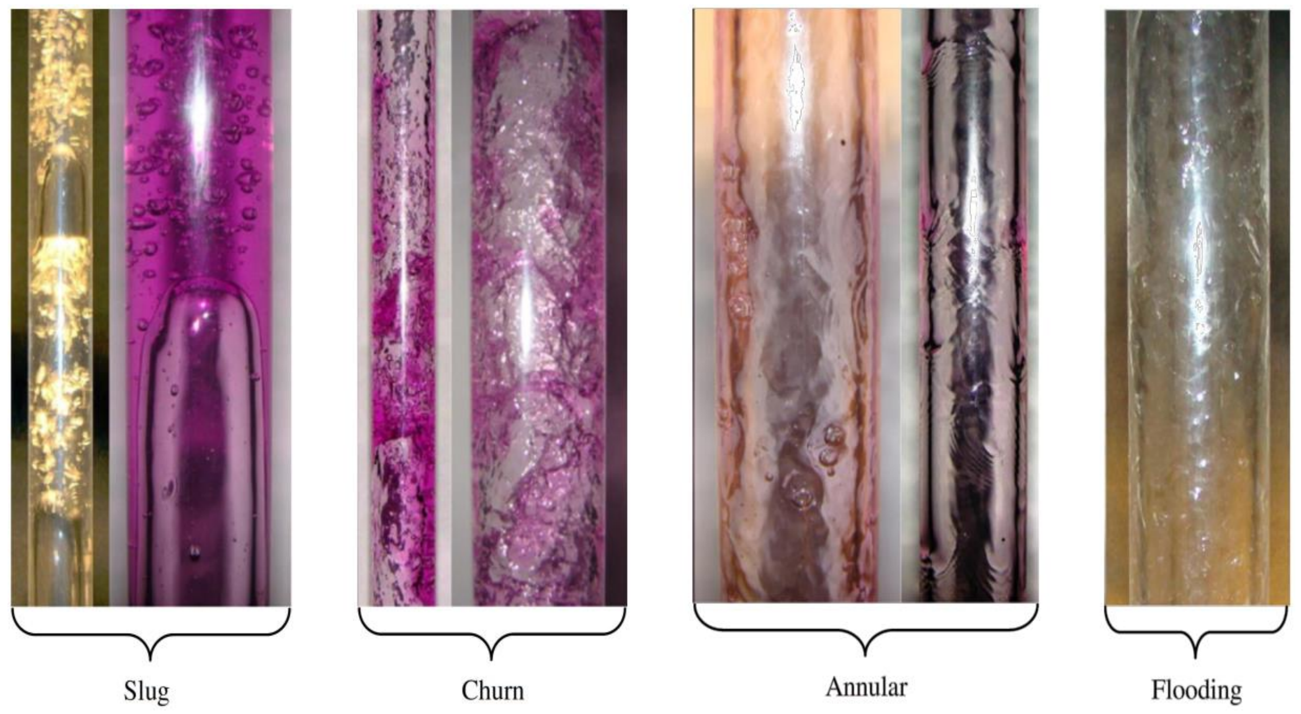
Research with real world impact

Project background

The **bottom hole pressure** (BHP) in natural gas wells is an important parameter in the effective design of well completions and artificial lifting systems. Poor estimation of this can lead to liquid loading in the wellbore and reduced efficiency of the extraction process. The complex interaction of gas and associated water can increase the **uncertainty in pressure gradients** and ultimately affect BHP estimation.



The interaction of the gas and liquid phases are typically captured through **closure models** to reduce complexity and as a result, the computational requirements. Closure models vary in robustness from empirical to mechanistic and describe behaviours such as **bubble propagation rates** as well as mass and **momentum exchange** between phases.

Characteristics of taylor bubbles

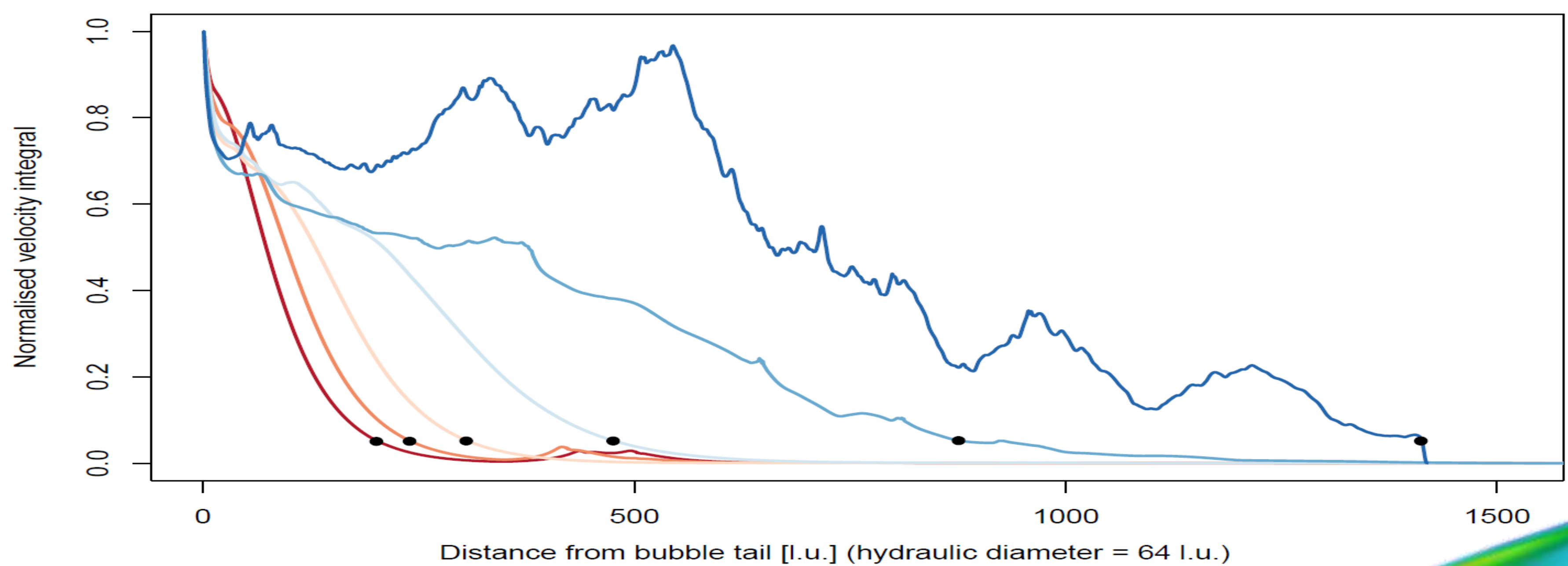
In the **slug flow** regime, elongated Taylor bubbles are observed. The dynamics of these have been heavily studied in **tubular pipes.** Understanding their behaviour in **annular conduits** and the impact on the pressure gradient through such a system is critical for efficient extraction of gas from **unconventional** reservoirs.

Using the developed lattice Boltzmann method [1]:

1. Experimental annular flow tests from [2, 3] were recreated to assess rise behaviour in terms of the dimensionless Froude number (Fr);

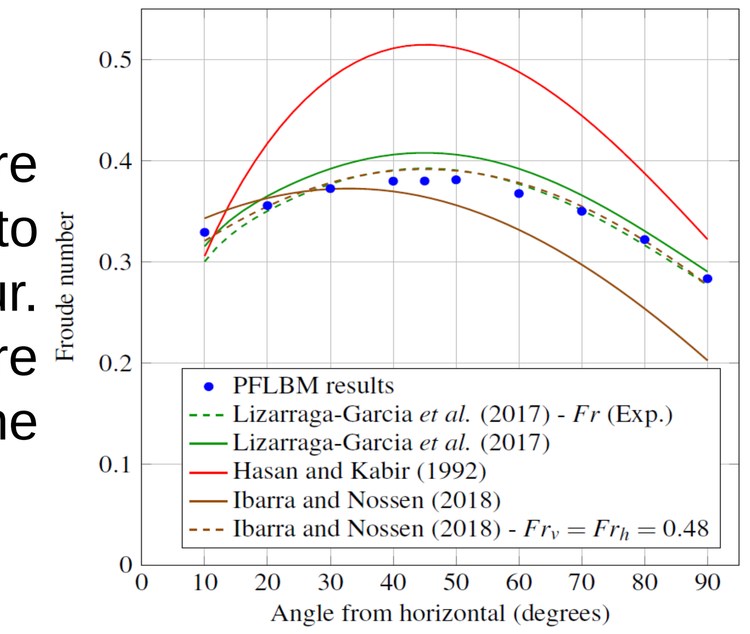
Case:	d_{outer} $[m]$	d_{inner} $[m]$	Fr exp.	Fr sim.	Error (%)
A [2]	0.0254	0.0127	0.277	0.275	0.6
B [3]	0.0147	0.0051	0.270	0.281	4.1
C [3]	0.0147	0.0081	0.245	0.274	11.7
D [3]	0.0191	0.0127	0.235	0.262	11.5

2. Fluid was varied between oil and water to determine the size of the liquid slug trailing the annular Taylor bubble [4].
   a. Finding for an water-air system the slug length was larger than tubular flow



Pipe inclination & fluid flow

Pipe inclination was assessed against **experimental work** and **correlations**.



Existing correlations were found to be **insufficient** to capture the rise behaviour. So **two closures** were modified (as seen by the dotted lines)

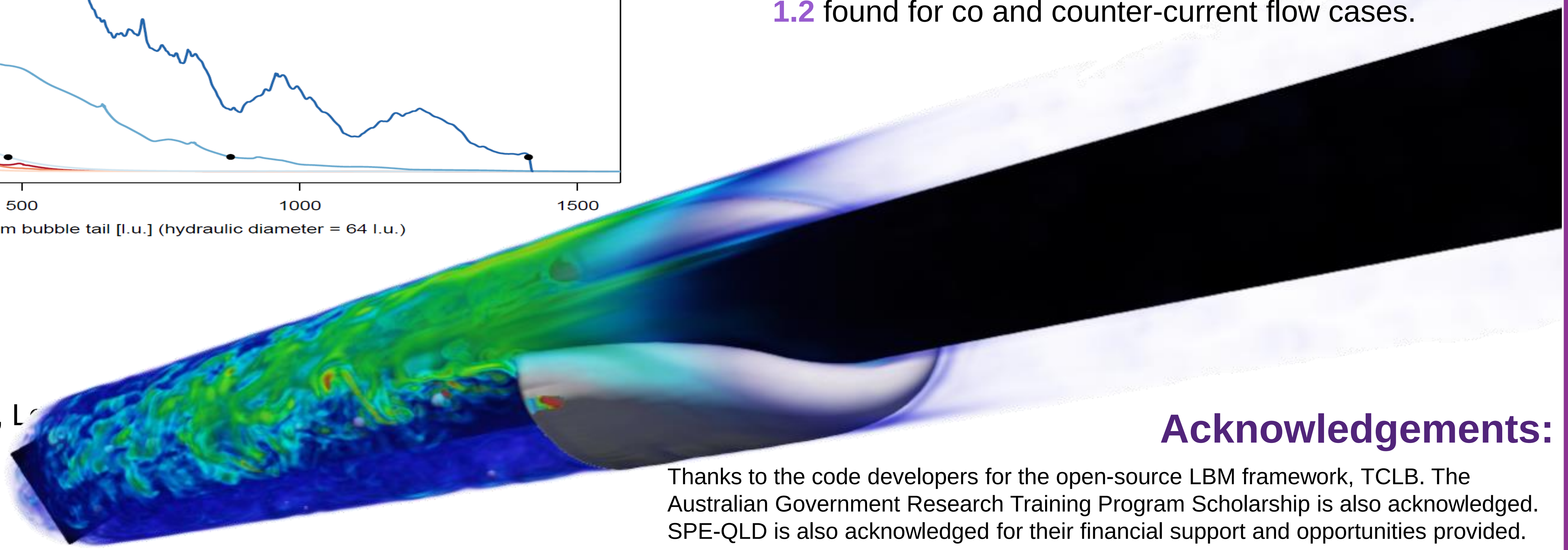
Fluid velocity (u_l) was **imposed** within the simulation domain to judge the effect of co and **counter-current** flow on the Taylor bubble velocity (u_{TB}) in comparison to its drift velocity (u_d).

$$u_{TB} = C_0 u_l + u_d$$

The tubular pipe coefficient ranges from 2.0 → 1.3 with increasing fluid flow:

$$C_0 = 2.0 - 0.7(Re - 2000)/2000$$

However, in the annular pipe, simulations indicated lesser impact from fluid flow with a value of approx. **1.2** found for co and counter-current flow cases.



References

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Acknowledgements:

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