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Effects of the outlet pressure on two-phase slug flow distribution uniformity in a multi-branch microchannel

Key words: Two-phase flow, Multi-parallel microchannel, Flow distribution, Slug flow, Split modes

Simulation Model

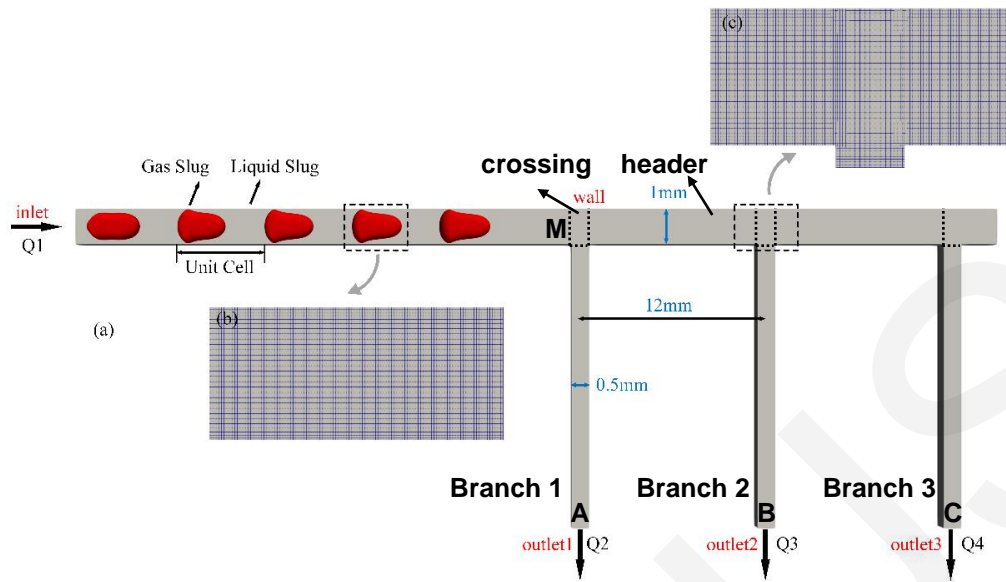


Fig1 Computational domain used in simulations.

(a) Geometry and boundary. (b) Mesh of main channel. (c) Mesh of T-junction

Flow distribution parameter: **Normalized standard deviation (NSTD)**

$$NSTD_j = \sqrt{\frac{\sum_{i=1}^{N_{ch}} (m_{j,i} - 1)^2}{(N_{ch} - 1)N_{ch}}}$$

($j: l - \text{liquid}, g - \text{gas}; t - \text{total}; N_{ch}: \text{number of channel}; m: \text{mass flow rate}$)

0 ← **more even distribution** $NSTD$ **less even distribution** → 1

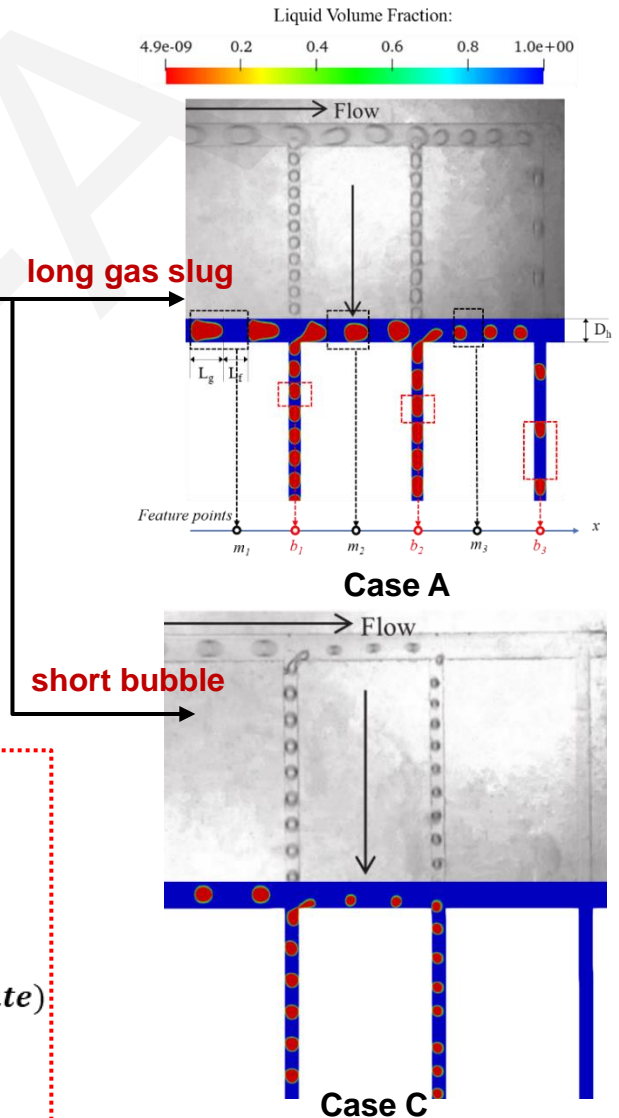
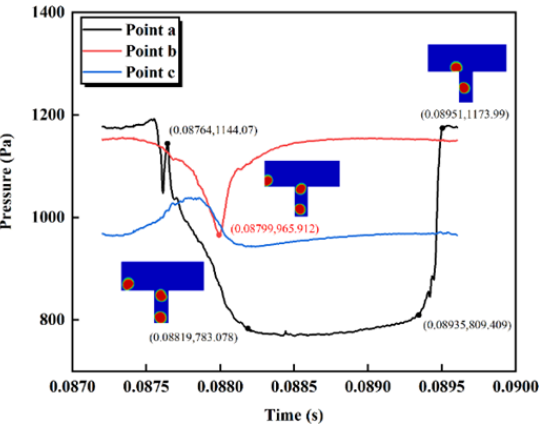
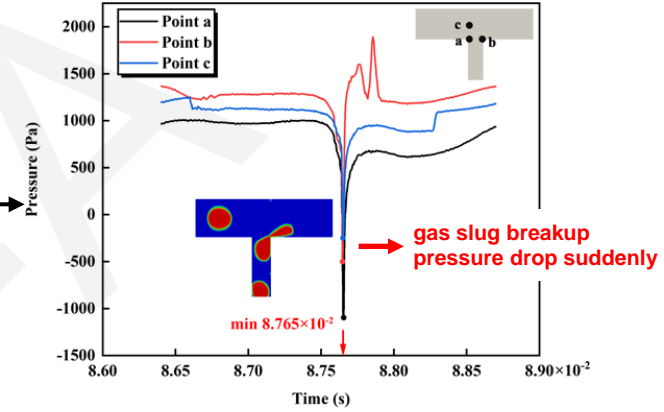


Fig2. simulation result (Liu, et al., 2017a)

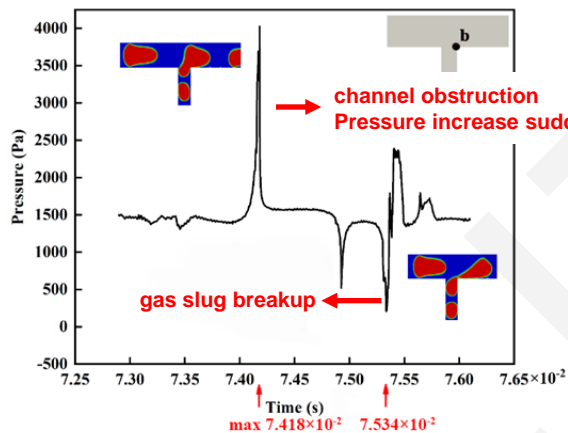
Different Split Modes were Observed



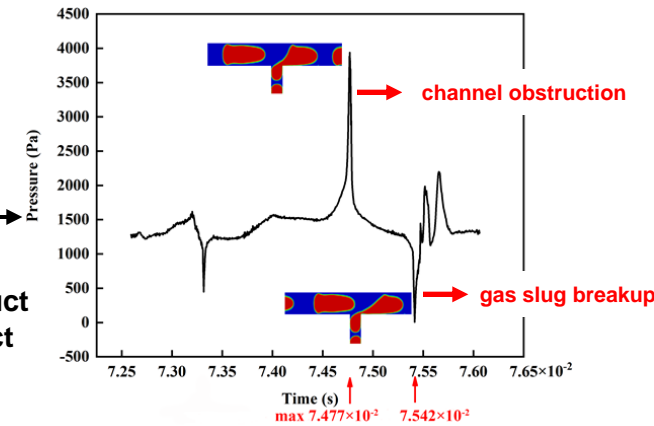
non-breakup/branch flow (NB/B mode)



breakup with permanent tunnel (B3 mode)



breakup with part obstruction (B2 mode)



breakup with permanent obstruction (B1 mode)

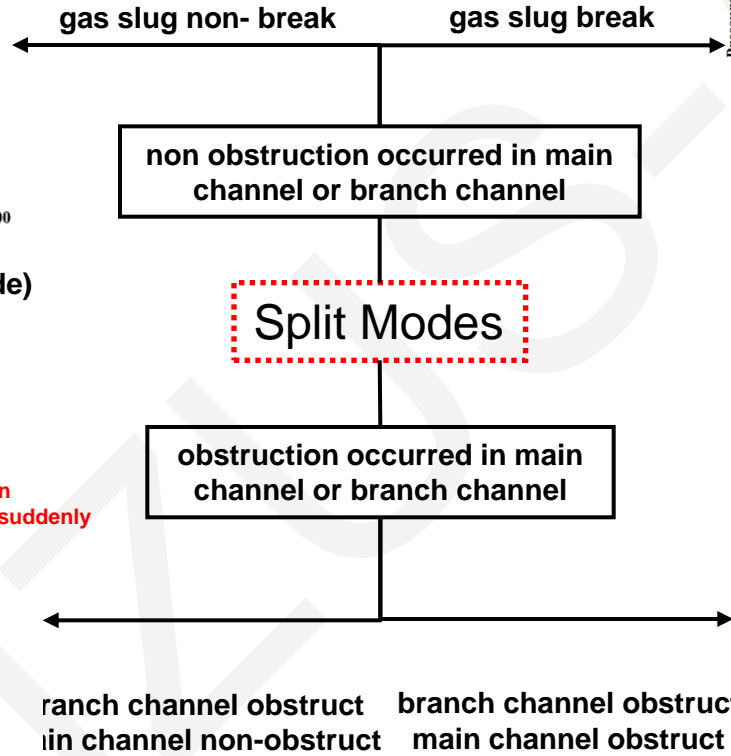
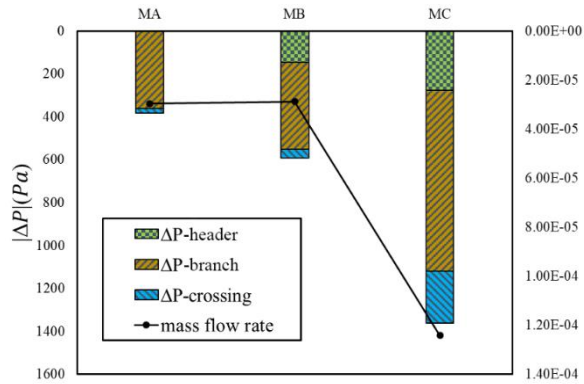


Fig3. Pressure change of feature point during one gas slug pass through T-junction

Optimization Scheme



original case: $NSTD_I=0.52$
less even flow distribution

after optimization: $NSTD_I=0.26$
More even flow distribution

The maldistribution phenomenon can be optimized by changing the differential pressure of branch channel

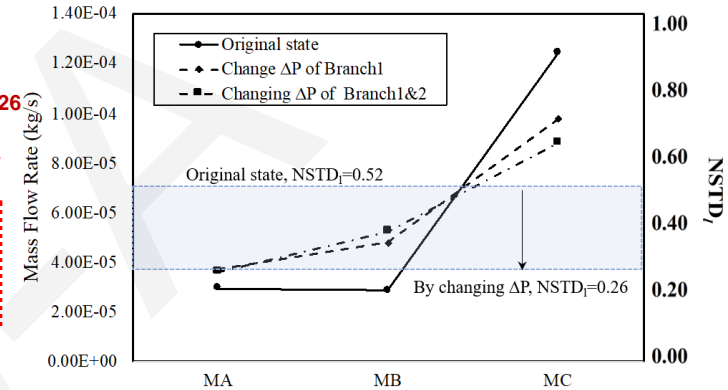


Fig4. Pressure drop and mass flow rate distribution of case A.

Fig7. mass flow rate distribution

changing the differential pressure of branch1



- The value of $NSTD_I$ has an obvious turning point when the flow state (two-phase flow or single-phase flow) of any branch channel change.
- Changing the pressure of multiple branch channels at the same time can achieve better optimization results.

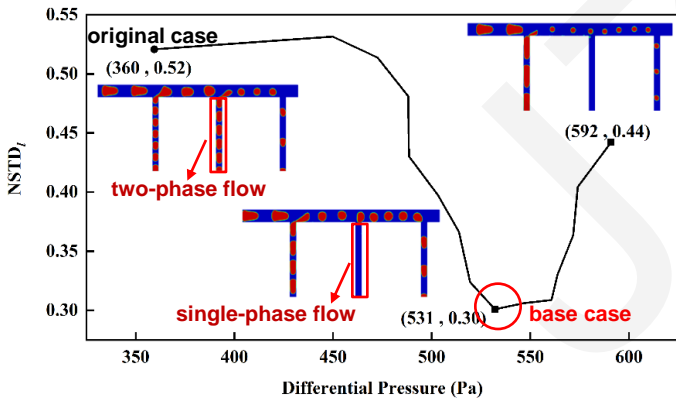


Fig5. $NSTD_I$ vs. differential pressure (branch1)

changing the differential pressure of branch2

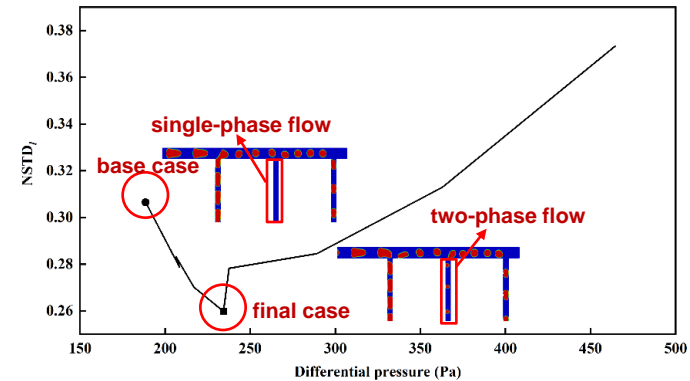


Fig6. $NSTD_I$ vs. differential pressure (branch2)

Conclusions

- As the gas slug moves and splits in the liquid phase, the pressure in the channel shows a trend of periodic changes. For different gas slug splitting modes, the pressure changes are similar. That is, when the gas slug is about to split into daughter bubbles, the pressure in the channel drops sharply and pressure fluctuations appear. For B1 and B2 modes, a sudden increase in pressure can be observed due to the gas slug blocking the main channel, but for B3 and NB/B modes, there is no such phenomenon. Among them, NB/B mode shows a completely different pressure trend from the other three separation modes.
- The differential pressure of each branch channel directly affects the flow distribution in the micro-channel. By controlling the branch pressure, different flow distributions can be obtained. If the differential pressure of branch channel 1 is changed separately, the maldistribution phenomenon of the whole model can be optimized to some extent. The NSTDI value of the model decreases from 0.52 to 0.30. However, changing the differential pressure of branch channel 2 alone will make the maldistribution phenomenon more obvious which means that the flow difference between the three branch channels will be further increased.
- The special elongated bubble structure formed during the gas slug splitting process helps the liquid phase enter the branch channel. When the flow state of a branch channel changes from two-phase flow to single-phase flow, the mass flow rate of the branch channel, with the change of differential pressure, has an obvious turning point.
- When changing the differential pressure of branch channel 1, also changing the differential pressure of branch channel 2 appropriately to maintain branch channel 2 in a two-phase flow state can further minimize the maldistribution phenomenon of the whole model. The optimum NSTDI value was reduced from 0.52 to 0.26. In the actual application process, the same optimization effect can be achieved by changing the diameter of each branch channel.