

- The fluid outside the tube, water, is selected to have a high thermal diffusivity so that heat generated during sonication is conducted away from the region of high-intensity sonication, to limit the increase in local temperature. Any fluid with high thermal diffusivity could be used in place of water.⁴⁴

5.6 Conclusions and Future Perspectives

This book chapter reviews the current status of segmented/slugs-flow continuous crystallization, with detailed elaboration and demonstration for an advanced slug-flow cooling crystallization process and its associated process intensification strategies. While slug-flow crystallization is a continuous process, each slug is like an individual batch crystallizer, with past knowledge and experience readily applicable. The slug formation, nucleation, and growth processes are decoupled for individual control of each phenomenon. For the slug formation process, the effect of slug stability and geometry on crystallization outcome was analyzed, together with corresponding design and operational parameters and flow fields. The growth process in slug flow has been controlled from both experiments and modeling perspectives, with temperature zone designs set by heat baths or heat exchangers. The nucleation process in laminar flow (before slug formation) focuses on two recent designs: cooling micromixers and focused indirect ultrasonication. These advanced growth control and continuous nucleation designs work for other continuous flow systems as well.

The slug flow and continuous crystallization process is expected to continue to receive high interest.¹ One improvement would be to employ fully automated startup and shutdown, in addition to quasi-steady operations. Also of interest is providing simultaneous control of multiple crystal properties (*e.g.*, size distribution, shape, and polymorphic identity), especially in the presence of process disturbances and variations in crystallization kinetics (*e.g.*, due to changes in the contaminant profile in the feed streams). The design would benefit from advanced process monitoring and controls⁴⁵ (with suitable in-line process analytical technology^{46,47}) and predictive models⁴⁷⁻⁴⁹ based on deeper mechanistic understanding of the crystallization phenomena.⁵⁰

Roman Symbols

	Property	Value
D	diameter of tube (m)	0.0031
D_{diff}	diffusivity of LAM ($\text{m}^2 \text{s}^{-1}$)	10^{-9}
g	gravitational acceleration (m s^{-2})	9.80665
L_{tube}	tube length (m)	15.2