**Crystal Growth Simulation in a Continuously Operated Helically Coiled Tube.**

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**Highlights**

* The crystal size distribution width stays constant in the helically coiled flow tube.
* The crystal product-to-seed ratio attains a saturation level at increasing tube length.
* For a tube length of up to 150 m, the crystal residence time is in the order of minutes.

**1. Introduction**

Continuous crystallization can be advantageous in continuous process chains when a constant product quality is required. The product quality is influenced by the product crystal size distribution. A narrow size distribution and a low number of additives are often preferred considering downstream steps in the process chain as solid liquid separation. Hence, cooling crystallization is selected. Among the continuous crystallizers, tubes offer narrow residence time ranges and thus narrow product crystal size distributions may be reached through crystal growth. Breakage and abrasion are negligible compared to setups with active mixing. Among the tubes, helically coiled flow tubes (HCTs) have a compact geometry and mixing properties, which are necessary to realize narrow residence time distributions. The potential of this novel crystallization device and a reasonable operation regime regarding residence times and tube lengths are estimated.

**2. Methods**

A simulation study is carried out for varying flow rates and crystallizer lengths. The model is a coupled population balance equation (PBE) system that is based on experimental results. The system consists of a PBE that is dominated by (1D) growth [1] and (1D) convection along the axis of the HCT and of mass balances for the continuous phase. The partial differential equations are solved by discretization on an equidistant grid of finite volumes using a slope limiter. Numerical diffusion can be adjusted by the number of control volumes to reflect hydrodynamic dispersion and growth rate dispersion. The investigated model substance is univariate potash alum. For this substance, experiments showed that aggregation could be neglected [2]. Further, the model includes experimentally measured size-dependent crystal residence times at two selected laminar fluid velocities of 0.27 m/s and 0.35 m/s [3]. The laminar flow range is selected to realize sufficient residence times at reasonable tube lengths. The inlet temperature was 41 °C. It was assumed that the temperature profile decayed exponentially along the tube to 35 °C while it reached 35.5 °C at a tube length of 10 m.

**3. Results and discussion**

As expected, the mean product size and mass increase with the tube length. The width of the crystal size distribution stays constant in the simulations due to the size-dependent crystal velocity despite growth rate dispersion. At a length of 25 m, the mean crystal size increased from 80 µm to 119 µm at the low flow rate. At a length of 100 m, it increased only slightly more to 124 µm while the standard deviation of the product crystal distribution was still equal to the initial standard deviation of 15 µm. Similarly, the crystal product-to-seed mass ratio saturates with the tube length in Figure 1. Since the temperature profile is fixed along the HCT, the supersaturation approaches the equilibrium solubility with an increasing tube length and the driving force for crystal growth diminishes. For a tube length of 25 m, the crystals occupy 9 % of the HCT volume at steady state while they occupy 11 % for a tube length of 100 m. For a tube of 25 m length, the crystal residence time is about 8 min while it is about 30 min for 100 m. For the higher fluid flow rate, the residence time is only about 10 min at 100 m. Only for large tube lengths, the product to seed mass ratio is higher than for the low flow rate.



**Figure 1.** Left: Crystal number distribution per second at steady state in the feed and in the product over crystal size for two laminar flow rates at varying tube length. Right: Ratio of product to seed crystal mass at steady state over tube length for two laminar flow rates under fixed conditions.

**4. Conclusion**

Continuously operated helically coiled flow tubes can produce narrow crystal size distributions. For a fixed temperature profile, the product to seed mass ratio saturates with the tube length. When the product crystal mass shall be maximized, it depends on the tube length whether low or high flow rates are advantageous assuming that sedimentation is avoided. In this case, a tube of 0.06 m diameter and of up to 25 m length for the low flow rate and up to 100 m length for the high flow rate seems to be reasonable.

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**References**

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