

*Engineer's Handbook*¹⁸ and for instance in *Thermal Separation Technology* by Mersmann *et al.*¹⁹ Probably of high value, although in German language, is *Kristallisation in der industriellen Praxis* by Hofmann (ed.).²⁰

Over the years, the proceedings of the triannual *International Symposium on Industrial Crystallization (ISIC)* are a good documentation of the advances made.^{21–36}

6.3 Challenges

Important challenges in industrial bulk processes are energy efficiency, space time yield, yield, purity and product properties and last but not least the compatibility to the process as a whole. To all of them continuous crystallization offers established solutions.

If it comes to energy efficiency, then continuous crystallization is the stronger variant compared to batch and semi-batch, because heat transfer processes can be designed for low temperature differences (minimum exergy loss), and because efficient measures for saving heat are applicable (multi-effect evaporation, vapour recompression, integration into a heat transfer network which may be optimized according to pinch-point analysis³⁷).

Space-time-yield (production rate per installed volume) is essential for minimizing the investment costs. Unproductive pause time and costly storage volume with perhaps even more costly product inventory can be avoided in continuous processes. Furthermore, the solids fraction (suspension density = mass of crystals per volume of suspension) may be set up to its technological limit, and hence, the crystallizer volume may be minimized further.

Yield and purity often go hand in hand. In continuous crystallization processes, a proven measure for increasing the yield is to install recycle streams which in turn increase the impurity level in the system. The maximum impurity level in the system is reached, when the resulting impurity level in the product is no longer acceptable. For continuous crystallization, the distribution coefficient between the impurity level in the crystal related to the impurity level in the mother liquor is favourable due to the well-controlled steady state conditions.

The particle size distribution is a decisive product property. Continuously operated well mixed crystallizers are in principle not good in this respect. Nevertheless, particular measures are well known for tackling this drawback: One such measure is sieving to fulfill the customer's demand for a narrow size distribution. Other measures are fines dissolution, classified product removal or cascading.

These solutions to the various challenges are not only applicable for continuous crystallization of bulk chemicals, but for continuous crystallization of fine chemicals, too.