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Impeller geometry effect on crystallization kinetics of borax decahydrate in a batch cooling crystallizer

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ABSTRACT

The effects of impeller type and diameter in a batch cooling crystallizer on the nucleation and crystal growth kinetics as well as on the shape and size distribution of borax decahydrate crystals were investigated. Two different types of impellers of various sizes were applied. Chosen impeller configurations generate completely different fluid flow patterns in the crystallizer what allows to investigate the influence of the axial and radial flow on the kinetic parameters as well. The nucleation in crystallizer was taking place by the heterogeneous nucleation mechanism at all mixing conditions. The number of crystals formed by this mechanism increases as ratio D/d_T decreases and it is higher when an axial flow pattern in crystallizer has been developed. The crystal growth rate increases with increasing the impeller size in observed supersaturation range. The radial impeller defined by ratio $D_2/d_T = 0.58$ could be considered as viable option for growth of borax crystal, since the further enlargement of this ratio does not increase growth rate and can only cause higher power consumption. The maxima in the coarser and finer fractions of CSD indicate a different influence of mixing conditions on the crystal grow and secondary nucleation. An axial flow pattern in crystallizer favors agglomeration of growing crystals increasing that way product mean crystal size, while radial flow results with more regular shape of borax crystals.

Keywords: Mixing; Impellers; Flow pattern; Nucleation; Crystal growth; CSD

1. Introduction

Crystallization as a solid–liquid separation process has become increasingly popular in the chemical industries due to its ability to purify while producing a solid with the desired physical properties. Increasing requirements for higher product purity and consistency have placed new demands on this process (Genck, 2003). In this process molecules are transferred from a solute dissolved in a liquid phase to a solid phase through two main steps—nucleation and crystal growth. Theoretically, nucleation should initiate when solute concentration passes the saturation point and the solution becomes supersaturated (Myerson, 1993). However, it does not occur instantly, and excess of solute remains in solution until a sufficiently high level of supersaturation is generated to induce spontaneous nucleation. The extent of this supersaturation is referred to as metastable zone width. The growth process of generated nuclei, i.e. crystals is described by Nielsen (1987) with several consecutive steps: mass transfer of solute molecules from the solution to the crystal surface, adsorption of the solute on the surface of crystal and the integration of solute into the growth site. The growth rate depends on the level of supersaturation which is the driving force. The crystal growth process takes place within a metastable zone. In this region the solution is supersaturated and no nucleation occurs while the crystals are growing. The growth rate under a metastable supersaturation is affected by the fluid dynamic conditions around the growing crystals. The relative velocity between the crystal and the solution is an important parameter which affects the rate of the mass transfer (Omar and Urlich, 2003). Together, these processes—nucleation and crystal growth, govern the crystal size distribution (CSD) determining the number and size of the crystals present in the crystallizer at the end of the operation.

Borax decahydrate ($Na_2B_4O_7{\cdot}10H_2O$) is one of the most important commercial boron compounds. In fact, there are

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