Optimization Design for DTB Industrial Crystallizer of Potassium Chloride

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Summary

CFD model for the simulation of DTB industrial crystallizer was developed. The crystal size distribution and the coefficient of variation of crystal product were studied by CFD simulation of two phase flow model. The impeller shapes and various operating conditions are optimized, to reduce the energy consumption of the crystallization process and to increase the KCl product quality. Based on CFD optimization design, a new impeller was retrofitted into an existing DTB crystallizer with the productivity of 100000 tones KCl/year at Qinghai salt lake plant of china, and its performance was evaluated against data collected using the original impeller.

Keywords: DTB crystallizer, CFD, Multiphase flow, Optimization design

Introduction

Some pioneering studies have been done very well to understand the thermodynamics, kinetics and processes of carnallite dissolution and KCl crystallization, but little work has been done to study the influence of hydrodynamics in an industrial crystallizer of potassium chloride.

The main challenge involved in the design of industrial crystallizers is to predict the influence of vessel geometry, configuration, operating conditions, and the effects of scale on the process behaviour, particle quality, and particle size distribution. Industrial crystallizer design is hindered by the lack of rational scale-up rules and incorporation of hydrodynamic information and kinetics. Computational fluid dynamics (CFD) is a powerful simulation tool that was successfully used to investigate mixing, turbulence, and shear in a crystallizer (1-2). CFD can give a qualitative engineering insight into the effects of the impeller configuration on the crystallization rates and particle size distribution and power consumption (3).

Precipitation of particles with controlled morphology and crystal size distribution (CSD) is of considerable importance in the chemical industry. The energy consumption used in the subsequence drying and filtering processes can be reduced by optimizing the crystallizer design to obtain large crystals which can then be easily separated from the liquid phase. Many studies have been conducted on the optimal operation of crystallization processes in order to maximize the mean size of the product crystals or the production rate of large crystals. The Draft Tube Baffle (DTB) Crystallizer has been used in applications requiring narrow crystal distribution, and larger average crystal size (4-6). The DTB is a combination of a classifier and a crystallizer with mixed suspension, mixed particle removal unit.

In this work, CFD model has been developed for an existing DTB industrial crystallizer with KCl productivity of 100000 tones/year. CFD solver is used to simulate the velocity field in such units, and optimize both the structural design of impellers and the operating parameters to reduce the energy consumption and increase the product quality for KCl production from carnallite.

Optimization Design for an Existing DTB Crystallizer with KCl Productivity of 100000 tones/year

The DTB industrial crystallizer with KCl productivity of 100000 tones/year is optimized by CFD simulation in this paper. Figure 1 show the schematic structure diagram of DTB industrial crystallizer with a axial-flow impeller and three types of the axial-flow impellers used in this simulation.

Figure 1 Schematic diagrams of the structure of DTB industrial crystallizer and the shape of impellers.

The multiple reference frame (MRF) method is used in CFD simulation. The hexagonal and tetrahedral
numerical grids are used to establish meshes in the DTB industrial crystallizer, the total meshes consisted of 866338 cell, as shown in Figure 2. The Reynolds-Averaged Navier–Stokes equation or RANS and the $\kappa-\varepsilon$ model are used in the fluid flow field simulation. The optimization of crystal size distribution in the DTB crystallizer is done by CFD simulation of two-phase flow model, where the dispersed phase model is used to describe the crystal motion and a crystal suspension feed with a given crystal size distribution is assumed.

Figure 2  Hexagonal and tetrahedral meshes of the CFD model in DTB industrial crystallizer

Figure 3 demonstrates the typical fluid flow field in an industrial DTB crystallizer with the propeller calculated by CFD solvers with single phase flow model. A good circulation flow can be formed in the DTB crystallizer. The impeller design and various operating conditions in the industrial DTB crystallizer are optimized by CFD simulation, which include the impeller shape, rotational speed and the installed position, the feedstock flow rate, fluid viscosity, temperature et al.

Figure 3. Fluid flow field in DTB industrial crystallizer with propeller.

The crystal size distribution is another very important design parameter for KCl crystallization. High quality product has a the bigger crystal size and a narrower crystal size distribution. Furthermore, a two phase flow model is used in the CFD simulation, in order to design the optimal operating conditions and increase the product quality. Figure 4 demonstrates a typical crystals trajectories and crystals concentration distribution in DTB industrial crystallizer with propeller. The effects of various operating conditions on the coefficient of variation (CV) of crystals are investigated by two-phase flow CFD simulation, the optimal operating conditions would be found.

Figure 4. Typical crystal trajectories and crystal concentration distributions in DTB industrial crystallizer with propeller.

Based on CFD optimization design, a new designed impeller was retrofitted into an existing DTB crystallizer with KCl productivity of 100000 tones/year at Qinghai Lake Plant of China, and the operating parameters are optimized further by CFD simulation. With the improved impeller and the optimum operating conditions, the product quality is increased, that is the percentage of product with the crystal size more than 2mm is raised from 50% to 90%; the amount of the natural gas consumption is decreased from 22m³ to 15m³ per ton of product. Moreover, the power consumption used by the new impeller also is reduced by 15% in contrast with the original pitched blade impeller.

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