CONTINUOUS CRYSTALLIZERS

8.1. INTRODUCTION

In Chapters 5–7, the batch and semibatch modes of operations have been discussed. In this chapter, crystallizers operated in a continuous mode are considered from both process simulation and identification analyses. These crystallizers are generally suited to the manufacture of large-tonnage bulk commodity crystalline products because they can be operated at the desired operating conditions under steady state, thus yielding constant product quality. Since the early sixties, the steady-state continuous crystallizer studies have been used in the laboratory for industrial crystallization research.

The two simple and ideal continuous crystallizer models are the plug flow and the complete mixing flow models, which represent two extremes. Although no actual crystallizers can be fully represented by these idealized flow patterns, a number of crystallizers behave so closely to ideal that these models may be adopted with negligible error. At one extreme, the liquid flow patterns and slurry characteristics in a crystallizer may be regarded as plug flow, with no longitudinal mixing but with complete radial mixing. This pattern of flow can be characterized by an identical velocity and residence time of all clumps, particles, or elementary elements within the crystallizer. For example, the flow pattern in a Kenics static mixer or a Couette flow device under restricted operating flow conditions may be approximated by plug flow. The other extreme is a completely mixed flow, characterized by a well-defined residence time distribution of exponentially decaying function and possessing identical clump attributes in the exit stream and in the vessel contents within the crystallizer. The behavior of many vigorously stirred tank crystallizers may closely approximate this flow model. Randolph and Larson (1971) introduced the term mixed suspension mixed prod-
uct removal (MSMPR) crystallizer to represent the ideally mixed-flow configuration.

8.2. CONTINUOUS MSMPR CRYSTALLIZER

This type of crystallizer unit will ensure perfect mixing without any spatial variations of attributes within the whole contents, and is therefore analogous to the continuous stirred tank reactor (CSTR) or the completely backmixed reactor used in chemical reaction engineering. Thus, the crystallizer behaves as though it were perfectly mixed, i.e., in any arbitrarily small element of volume or clump, regardless of its location in the mixed section of the crystallizer, a full and uniform crystal size distribution is assumed to exist. Further, such a crystallizer has unclassified product withdrawal, indicating that the same crystal size distribution exists in the product slurry and in the crystallizer contents.

In many crystallizing systems, crystal breakage or agglomeration can be negligible. For a given system, it is quite common to have the same crystal habit or shape for crystals of different sizes. The crystal size may then be represented by one characteristic dimension, usually the second largest axis or, in practice, the size of a standard screen through which it just passes.

8.2.1. Steady-State Population Balance

The steady-state crystal size distribution from a continuous MSMPR crystallizer, as shown in Figure 82, having clear feed and negligible breakage or agglomeration, is given by the solution of the population balance equation.

\[
\begin{align*}
Q (\text{kg/s}) & \quad Q (\text{kg/s}) \\
V (\text{m}^3) & \quad n(L) (\text{no./m kg})
\end{align*}
\]

Figure 82. Schematic representation of an MSMPR crystallizer. S (kg); V (m³); n(L) (no./m kg).