SECONDARY NUCLEATION IN AGITATED CRYSTALLIZERS

UGO FASOLI and ROMUALDO CONTI
Instituto di Chimica Industriale del Politecnico di Torino, Italy

INTRODUCTION

The causes of secondary nucleation may be divided into two main groups. In the first are the physical-chemical causes such as cluster formation (1), the presence of impurities (2) and the catalytic behaviour of seed crystals. In the second group are the mechanical causes such as the detachment of nuclei by collisions of the crystals with themselves, the stirrer, the baffles, the walls of the crystallizer, etc. The possibility of detachment of nuclei without any mechanical action in the presence of a highly supersaturated solution has been demonstrated by photographic methods (3),(4).

COLLISION NUCLEATION

Most authors agree that the specific nucleation rate \( r \), i.e. the number of nuclei generated by a seed crystal per unit time is a function of the power \( P \) dissipated in the crystallizer per unit volume, of the equivalent diameter \( D_s \) of the generating crystals and of the number of collisions. More exactly it has been found (5) that the dependence on \( P \) is linear while \( D_s \) enters into the relationship with an exponent between 3 and 5 (ice crystals).

A theoretical study of the influence of the above-mentioned parameters together with the size \( D_a \) of the generated nuclei and the weight concentration \( c_s \) of the generating crystals has been presented in a previous report (6).

If \( k \) is the energy needed to detach a fragment of unit area
and $\alpha_a$ is a surface shape factor of nucleation, the energy spent per unit time by a seeded crystal to breed new nuclei is:

$$r \ k \ \alpha_a \ D_a^2$$

[1]

This energy is equal to the power spent per unit volume $P$ multiplied by the volume of suspension engaged by the crystal and by an efficiency coefficient, taking account that the energy spent for nucleation is only a part of the total energy spent by the crystal (the other part is dissipated by friction losses, elastic behaviour, and so on). Experimental data have shown that the volume engaged is proportional to the volume of the crystals and therefore it is possible to write:

$$r \ k \ \alpha_a \ D_a^2 = \eta_1 \ N \ \alpha_s \ D_s^3 \ P$$

[2]

where $\eta_1$ is the efficiency coefficient which is a function of the ratio between the energy spent to breed new nuclei and the kinetic energy of the crystal dissipated in the collision, $\alpha_s$ is a volumetric shape factor and $N$ is a dimensionless number whose meaning will be explained later.

A theoretical analysis of the problem (6) has demonstrated that it is also possible to write

$$r \ k \ \alpha_a \ D_a^2 = \eta_1 \ n \ m_s \ u \ \frac{\alpha_s D_s^2 P}{2}$$

[3]

where $u$ is the mobility of the crystal, put equal to the ratio between its velocity $v$ and the force $F$ applied to it, $n$ is the number of collisions of the crystal in the time unit (and therefore equal to $1/z_s$ where $z_s$ is the time interval between two subsequent collisions) and $m_s$ is the mass of the crystal.

By comparing expressions 2 and 3 we can get:

$$N = \frac{1}{2} \ \frac{m_s v}{F z_s}$$

[4]

which shows the meaning of the dimensionless number $N$ since $m_s v$ is the momentum of the crystal and $F z_s$ the impulse of the force applied to it: $N$ is the ratio between the theoretical maximum energy proportional to $m_s v$, and the energy dissipated in the surrounding fluid going to the shear stress, proportional to $F z_s$. 