14.10 Scaling

During suspension crystallization from aqueous solutions, in indirectly cooled systems, conditions that favour the formation of an ice scale layer on cooled heat exchanger surfaces are created. The formation of the ice layer is undesirable because conductivity of ice is several times smaller than that of materials typically used for the construction of crystallization vessels. The ice layer, therefore, increases thermal resistance and decreases heat removal rate from the suspension, adversely affecting the production rates of ice and salt in an EFC process.

The formation of the ice scale layer can be particularly severe due to the surface that is provided for heterogeneous nucleation, the temperature driving force that is applied across the surface and brines that typically consist of more than 80% water which is, in this case, the scalant. Furthermore, any mechanical equipment within the crystallizer serves as additional surfaces for adhesion and ice growth. Unfortunately, the mechanisms of ice scale formation in a crystallization environment are still poorly understood. Although heterogeneous nucleation is the most likely mechanism in scraped wall crystallizers, the adhesion of the ice crystals onto the cooled wall may initiate scale layer formation, especially in non-scraped crystallizers.[50]

14.10.1 Thermal Boundary Layer

Crystallizer walls experience the lowest temperature within the crystallizers since their externals are in thermal contact with the coolant flowing through the jacket. A thermal boundary layer develops between the wall and the bulk liquid, as depicted in Figure 14.10a. The solution adjacent to the wall surfaces is, therefore, at a higher supersaturation than the bulk. This high local supersaturation prompts heterogeneous nucleation and growth of an ice scale layer on the crystallizer surface as noted by Pronk.[53]

Two main crystallizer configurations have been researched with the aim of combatting scale formation. In a fluidised bed configuration, metal particles are used to mechanically remove ice from the crystallizer walls during fluidisation.[53] Alternatively, a scraped wall crystallizer has been used, where each scraper pass removes the thermal boundary layer as well as any crystals that have formed on the surface. The boundary layer develops again rapidly after each pass, as shown in Figure 14.11, and the average temperature over a complete scrape cycle remains colder at the surface than in the bulk liquid.

14.11 Adhesion

The crystallizer wall is a subcooled surface where adhesion of ice crystals, that formed in the bulk solution, can occur. Furthermore, in scraped surface crystallizers, the mechanical scrapers are subcooled themselves, due to the