4.5 Model-based Control Strategies

With the rapid advance of predictive modelling of continuous crystallization during the last decades, model-based control strategies have become very attractive. Linear process models have the advantage of simplicity and well-defined characteristics. A crystallization process model can be linearized either for synthesis of feedback controllers or to be used in MPC. For example, Motz *et al.*[68] proposed a design of a controller based on a simplified process model, which is linearized around a desired steady state such that a transfer function can be derived. The controller uses the third moment of the CSD as controlled variable and the fines dissolution flow rate as manipulated variable. The design of the feedback controller is based on H_∞-theory for infinite-dimensional systems, as a simplified process model is used and plant-model mismatch needs to be mitigated. Dynamic simulations show that the controller can stabilize the oscillations in about 5 cycling periods. Continuous seeding can also be a suitable manipulated variable to stabilize the system.[91]

Predictive crystallization process models have a strongly nonlinear character. Therefore, despite the complications, controllers based on nonlinear process models inherently have better opportunity to provide superior closed-loop performance. Christofides and co-workers have developed a general framework for the design of bounded nonlinear predictive controllers for continuous crystallization processes. A key idea of their approach is to describe the dynamics of a continuous crystallization process by a low-order approximation of the full process model. The full crystallization model involves a population balance for the dispersed phase combined with material and energy balances for the continuous phase. The population balance is difficult to use directly for synthesis of practical model-based feedback controllers.[92] Furthermore, typical numerical solutions of the population balance based on a finite-dimensional approximation are of high-order, which are not suitable for the design of simple model-based feedback controllers. Therefore, they proposed to apply a model reduction based on the method of weighted residuals combined with the concept of approximate inertial manifold to construct a low-order approximation of the process model, which can be used for design of a nonlinear model-based feedback controller that can be implemented in a practical way.[93] The framework provides a basis for the design of robust nonlinear feedback controllers, which address the strong nonlinearity of continuous crystallization processes,[93,94] model uncertainty,[95] constraints on actuators,[96] sensor malfunctions,[97] asynchronous measurement sampling due to technical failures or different sampling rates of various instruments,[98] and fault detection, isolation, and compensation.[99,100] The key features of those controllers are summarized in this section. The reader is referred to the corresponding series of papers for more details.[93–100]