Comparison of possible improvements of a periodically operated adiabatic CSTR with inlet concentration modulation for different shapes of the forcing function

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Abstract
Deliberate periodic operations have been recognized as one way of process intensification for several decades. Special attention has been dedicated to possible improvements of chemical reactor performance through periodic modulation of one or more inputs. In our previous investigations we have developed a new, nonlinear frequency response (NFR) method, as a fast and easy analytical method for evaluating the performance of forced periodically operated chemical reactors. The NFR method is based on nonlinear frequency response analysis and the concept of higher order frequency response function (FRFs) [1]. In its essence the method is approximate and it is limited to analysis of stable, weakly nonlinear systems. The method gives an answer whether, and in which cases, it is possible to obtain process improvement through periodic operation. It also gives an approximate quantitative estimate of the improvement. In addition, the method enables choosing the best forcing parameters of the modulated input(s) (frequency, amplitude and, for multiple input modulation, the phase difference between the input waves).
The NFR method was originally developed for sinusoidal forcing function(s) [1]. Recently, it was extended to a general case which is applicable for any shape of the periodic input modulation, by expanding the input function into Fourier series and taking into account only a finite number of harmonics [2]. This opens a new possibility of choosing the best shape of the input wave, as well.
In this paper, the NFR method is used to evaluate the performance of a forced periodically operated adiabatic continuous stirred tank reactor (CSTR) in which an exothermal reaction of hydrolysis of acetic acid anhydride to acetic acid takes place [3]. The analysisis performed for periodic modulations of the acetic anhydride concentration in the feed stream, around a previously established optimal steady state. Different shapes of the input forcing function (sinusoidal, square-wave, triangle, saw-tooth,…) were analyzed, in order to determine the best strategy of performing periodic operation. The acetic acid yield is used as a measure of the reactor performance. The increases of the product yield (relative to the steady-state value) for different shapes of the forcing function are compared. Finally, the best forcing strategy (regarding the shape, frequency and amplitude of the input wave) is chosen to be applied for experimental investigation in a lab-scale adiabatic CSTR.

References:

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