Impact of Non-Ideality on Stability and Performance of Reactors for Benzaldehyde Production

Giuseppe Andriani[a,*], Paolo Mocellin[a,b], Gianmaria Pio[c], Ernesto Salzano[c], Chiara Vianello[a]

[a] Università degli Studi di Padova, Dipartimento di Ingegneria Industriale, Via Marzolo 9, 35131 Padova, Italia.
[b] Università degli Studi di Padova, Dipartimento di Ingegneria Civile, Edile e Ambientale, Via Marzolo 9, 35131 Padova, Italia.
[c] Università di Bologna, Dipartimento di Ingegneria Civile, Chimica, Ambientale e dei Materiali, Via Terracini 28, 40131 Bologna, Italia.

E-mail: giuseppe.andriani@unipd.it

Exothermic reactive processes inherently carry the risk of runaway phenomena, making the development of reliable tools for their design, control, and optimization critical. Stability analysis offers a promising approach, but its effectiveness hinges on accurate reactor modelling. Traditionally, following the seminal work of Varma, Morbidelli, and Wu, tubular reactors have been studied using the ideal plug flow reactor (PFR) model. However, relying on idealized assumptions may result in a partial assessment of critical operating regimes, particularly those associated with thermal runaway. Incorporating non-ideal models, such as the PFR with axial dispersion, is thus essential to improve predictive accuracy and enhance process safety.

This work investigates the impact of non-ideal reactor behaviour on the stability and performance of reactive systems. Sensitivity-based stability analyses are performed, comparing results from ideal and axial-dispersed PFR models. A case study on the design of a tubular reactor for benzaldehyde production illustrates the approach. Results show that idealized models may significantly underestimate runaway risk: the instability region predicted with axial dispersion is notably wider, emphasizing the need for realistic modelling to ensure safe operation. Furthermore, accounting for back-mixing effects reveals lower conversions and outlet temperatures, implying the need for longer reactor lengths or reduced flow rates to achieve target specifications. Recognizing these deviations at the design stage enables safer and more efficient reactor development, minimizing costly corrective measures during operation.

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