Control Structure Design and Real-Time Optimization for Continuous Bio-Based Aniline Production

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The transition from conventional fossil-based batch processing to continuous bioprocessing offers significant opportunities for improving productivity, resource efficiency, and sustainability in the production of bio-based chemicals [1, 2]. Within the Horizon Europe project Bio4PURConti, continuous fermentation is being developed for the production of bio-based aniline from renewable feedstocks [1]. However, the process introduces new control challenges arising from nonlinear process dynamics, model uncertainty, limited online measurements, plant-wide interactions, and multiple operational objectives.

This work presents the planned research towards the development of a control structure and Real-Time Optimization (RTO) framework for continuous bio-based aniline production. The proposed methodology begins with control-oriented process understanding and the development of simplified dynamic models suitable for control studies. These models will support the design of a plant-wide control structure, including switching control structures for changing operating conditions [3], advanced control strategies based on state estimation and Model Predictive Control (MPC), and real-time optimization capable of handling plant-model mismatch through modifier adaptation [4]. Surrogate models [5] will be investigated to enable computationally efficient optimization of the process.

The proposed framework aims to provide robust and economically optimal operation while maintaining product quality and process stability under varying operating conditions. The developed methods will ultimately be evaluated at the 150 L pilot scale and demonstrated at the 1.5 m^3 Bio Base Europe Pilot Plant (BBEPP) facility [1]. This work establishes the methodological foundation for advanced control and optimization of a novel continuous bioprocess and supports the industrial realization of sustainable bio-based aniline production.

Keywords

Continuous bioprocessing; Bio-based aniline; Model Predictive Control; Real-Time Optimization; State estimation; Modifier adaptation; Surrogate models

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References

1. https://mailchi.mp/79de47f94c7e/bio4purconti-new-eu-funded-project-for-bio-based-aniline Accessed on: 18.06.
2. B. Winter, R.Meys, A. Bardow, ´Towards aromatics from biomass: Prospective Life Cycle Assessment of bio-based aniline´, Journal of Cleaner Production, Vol. 290, 2021.
3. L. Cammann and J. Jäschke, ´A simple constraint-switching control structure for flexible operation of an alkaline water electrolyzer´ Adv. Control of Chemical Processes, 2024.
4. J. Matias and J. Jäschke, ´Online model maintenance via output modifier adaptation', Industrial & Engineering Chemistry Research, Vol. 58, 2019.
5. B. Williams, J. Otashu, S. Leyland, M. Eden, S. Cremaschi, ´PRESTO: Predictive REcommendation of Surrogate models To approximate and Optimize', Chemical Engineering Science, Vol. 249, 2022.