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**Garg, Nipun; Gani, Rafiqul; Woodley, John**

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# A Method for Chemical and Biochemical Sustainable Process Synthesis, Design and Intensification

Nipun Garg [a], Rafiqul Gani [a], John M. Woodley [a*]
[a] Department of Chemical and Biochemical Engineering, Technical University of Denmark, Søltofts Plads, Building 229, DK-2800 Kgs. Lyngby, Denmark

The aim of systematic process synthesis-design is to identify the processing route which gives a desired product from a set of raw materials including unit operation design, utility needs, waste generation and sustainability parameters. While, Process Intensification (PI) provides a way to design new and innovative solutions or redesign existing ones leading to more sustainable and efficient solutions. Thus, it is logical to integrate process synthesis-design and intensification to achieve sustainable chemical and biochemical solutions.

In this work, a generic three-stage hierarchical decomposition framework is applied to get intensified solutions. These stages work at unit operation, task and phenomenon levels. In stage 1, process synthesis is performed i.e. a processing route is generated using computer-aided flowsheet design method (CAFD) [1]. Superstructure optimization can also be performed through Super-O [2], a software interface that guides the formulation and optimization of the superstructure to find optimal processing route. These tools provide alternatives that are quickly screened to identify the optimal route(s). In stage 2, the base-case design is developed based on route selected in stage 1 which is further analyzed to identify the process hotspots. This analysis is performed using indicator based tools for economic analysis, sustainability evaluation and life cycle assessment [3]. These hotspots are then translated to design targets that are used in the next (3rd) stage where, a phenomenon based intensification method [4] is applied to find intensified and more sustainable design. This approach breaks tasks into phenomena within the unit operations involved. These phenomena are analyzed and re-combined using combination rules to generate new and/or existing unit operations including hybrid operations. The result is intensified and more sustainable solution satisfying set design targets based on process hotspots. These alternatives provide a solution that reduces the effort to be put into experimental verification.

To conclude, an integrated multi-scale computer-aided framework will be presented together with computer-aided methods and tools needed to achieve more sustainable and intensified design. Application of three stages of the framework will be highlighted through different case-studies generating intensified and sustainable solutions for the next generation chemical and biochemical processes.

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nipgar@kt.dtu.dk