Sustainable Process Synthesis-Intensification

The chemical and biochemical industry needs major reductions in energy consumption, waste generation, number of equipment used in the construction of plants and capital/operational cost. These required reductions can be addressed through process intensification that is the efficient use of raw materials (feedstock) and the use of sustainable technologies or processes which directly impacts and improves sustainability/LCA factors. Process intensification is a concept by which processes, whether conceptual or existing, can be designed or redesigned to achieve more efficient and sustainable designs. Therefore sustainable process design can be achieved by performing process synthesis and process intensification together. The main contribution of this work is the development of a systematic computer-aided multi-scale, multi-level framework for performing process synthesis-intensification that aims to make a process more sustainable than a base case design, which represents either a new or existing process. The framework consists of eight steps (step 1 to step 8) that operates at the unit operation scale and task scale, and four integrated task-phenomena-based steps (IT-PBS.1 to IT-PBS.4) that operates at the task scale and phenomena scale. The concept of generating more sustainable designs through the combination of phenomena provides the opportunity to innovate through the generation of novel unit operations and thereby expand the search space of available unit operations. At the unit operations scale a conceptual base case design is synthesized through the sequencing of unit operations. The base case is then designed and analysed for identifying process limitations or bottlenecks (hot-spots) using a comprehensive analysis consisting of economic, life cycle and sustainability analyses that are translated into design targets. These hot-spots are associated with tasks that may be targeted for overall process improvement. Next an integrated task-phenomena-based synthesis method is applied, where the involved phenomena in various tasks are identified, manipulated and recombined using combination rules in order to generate new and/or existing unit operations that are configured into flowsheet alternatives inclusive of hybrid/intensified unit operations. The flowsheet alternatives that satisfy the performance criteria and design targets, give innovative and more sustainable, non-trade off flowsheet designs that otherwise could not be found from the higher scales. The framework is applied to three case studies related to the chemical and bioprocess industry in order to test the applicability of the framework for covering a wide range of applications, showing that process intensification provides major benefits related to the generation of more sustainable process designs.

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