MULTISCALE NUMBERING-UP OF CONTINUOUS-FLOW REACTORS FOR INDUSTRIAL PRODUCTION

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Summary

Continuous flow reactors with millimeter-scale hydraulic channel dimension have recently demonstrated their abilities of delivering better conversion and selectivity, an enlarged operating window, significant reduction of solvent usage.

To achieve targeted industrial production throughput, a number of "identical" reactors need to be installed in parallel via reactor system design (reactor-bank). To ensure the performance of a whole reactor-bank is the same as the performance of single reactor, it has been crucial to design uniform flow distribution from the main flow manifold to a number of individual reactors in parallel.

This paper has presented comprehensive technical assessments, and proposed a multiscale design strategy which relies on both internal flow splitting through fluidic module designs and external flow splitting through reactor-bank manifold designs.

The proposed approach was validated by both flow distribution modeling and experimental tests, and was implemented and demonstrated successfully at industrial scale with good effectiveness and robustness.

This paper has demonstrated that effective numbering-up through Corning multiscale designs enables industrial production (~1000 tons/year) even with millimeter channel size reactors which was impossible before.

Keywords

Process intensification, micro reactors.

Introduction

In order to benefit from the advantages of microreactors for a full scale production, there is a need to install several reactors in parallel ("numbering-up") as a reactor bank. To ensure the performance of the whole reactor-bank is the same as the performance of the single reactor, it has been crucial to design uniform flow distribution from the main flow manifold to a number of individual reactors in parallel [1-4].
The challenge is to minimize this flow deviation, keeping the result of the whole installation as close as possible to what can be achieved in a single reactor.

Different Types of Distribution

A technical assessment of the possible options currently offered or under development (internal and passive, external and passive, external and active), with their advantages and drawbacks, is done and summarized in the Table below.

MANIFOLD TYPES	INTEGRATED	SEPARATE	
		PASSIVE	ACTIVE
COMPLEXITY	APPEARS SIMPLE	APPEARS COMPLEX	
	HIDDEN AND REAL	SIMPLER THAN IT APPEARS	
DIRECT MEASUREMENT	NOT POSSIBLE	EASY	
FLOW ADJUSTMENT	NOT POSSIBLE	POSSIBLE	YES
COST	LOW	LOW	HIGH

Multiscale Design Approach

To ensure uniform flow distribution in both fluidic module (reactor) and reactor bank, Corning has developed a multiscale design approach which relies on an internal flow splitting with recombination of the channels (Figure 1), and a combination of passive at reactor back level and active distribution system at reactor level [5,6].

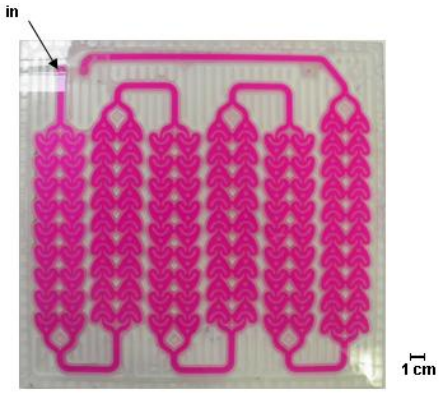

Figure 1. Internal numbering-up via flow splitting [5]

Lab Flow Testing and Modeling

The proposed approach has been extensively tested in an application lab (Figure 2) with many experimental points obtained from different configurations. Good agreement has been achieved between experimental data and numerical modeling,

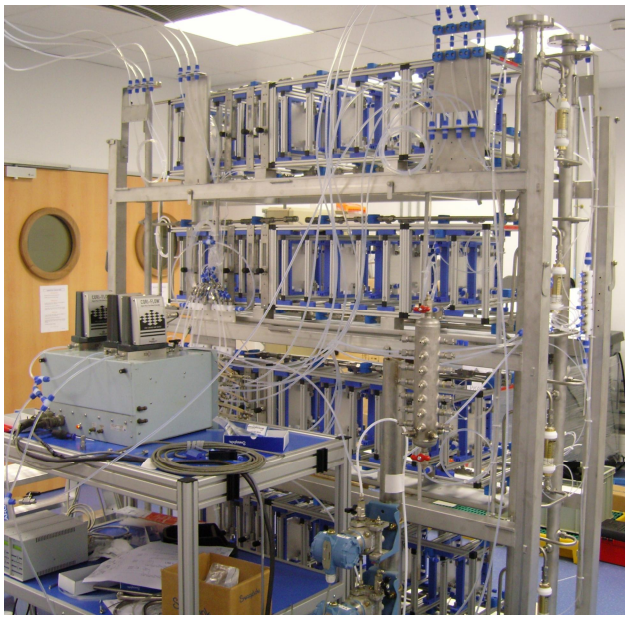
Figure 2. Lab experimental testing set-up

Industrial Implementation

The approach has been implemented in a real industrial production with 8 reactors installed in parallel [6]. The uniformity of flow distribution was satisfactory with low deviations from the averaged flow rate, which led to rather constant conversion and uniform product quality as shown in Figure 3.

In addition to rather uniform flow and conversions cross 8 reactors, the bank system was in a position to cope with an unexpected shut down issue of one of the lines without any significant impact on the remaining 7 reactors.

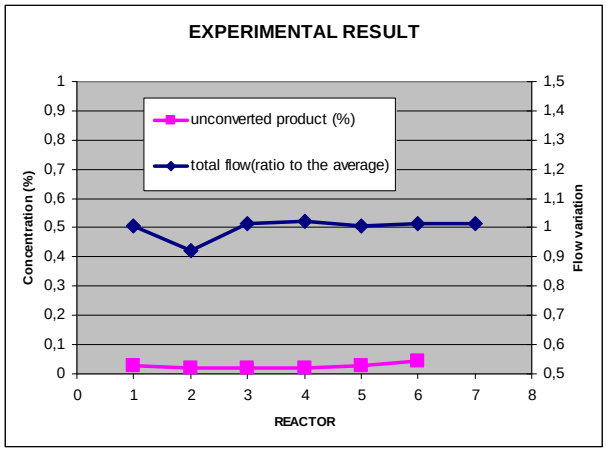

Figure 3. Uniformity of flow (right) and conversion (left) in reactor bank with 8 reactors

Overall, the implemented numbering-up solution has provided the desired reactor bank performance, which is as good as the one obtained from a single reactor.

Concluding Remarks

- Multiscale design of reactor level and system (bank) level proposed by Corning has demonstrated its success of delivering industrial scale product with “numbering-up”
- Full manuscript will detail how to control pressure-drop of individual line of reactor to ensure the pressure distribution within bank system
- Full manuscript will also detail to how to control “back-flow” and manage check valves to address the system (bank).

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