The Influence of Geometric Parameters of 3D Structured Bed on the Hydrodynamic Characteristics of the Trickle-Bed Reactor

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Highlights

- Experimental study of pressure drop under single-phase and two-phase flow condition.
- A parametric set of ten POCS structures was manufactured using 3D printing technology.
- Comparison of the new structures with commonly used randomly packed beds.
- Comparison of experimental data with data obtained by CFD modeling.

1. Introduction

Current 3D printing technologies offer extensive possibilities for optimizing chemical reactors and their components that traditional manufacturing technologies cannot provide. This work is focused on the study of geometric parameters of Periodic Open Cellular Structures (POCS) as a bed for a trickle-bed reactor [1]. In industrial applications, beds consisting of randomly packed particles (spheres, cylinders, Rashig rings, etc.) are commonly used. However, these beds are susceptible to non-uniform flow distribution, causes relatively high pressure drop, and have imperfect heat conduction. POCS structures, due to the ability to precisely define their geometry using software tools, offer potential for better control of flow in trickle-bed reactors. [2-4].

2. Methods

The study examines a parametric set of ten POCS (***Figure 2***), in which parameters such as strut diameter d_s (1-1.64 mm) and cell size c_s (1.95-3.9 mm) are varied. These changes are made with an emphasis on maintaining comparable porosity and specific surface area. Three types of randomly packed beds of spheres and two types of cylinders were also studied. POCS structures were manufactured using the Fused Deposition Modeling (FDM) 3D printing method with PLA material and the Stereolithography (SLA) 3D printing method with resin material. Using laboratory apparatus (**Figure 1**), pressure drop was measured during single-phase flow (gas – air) and two-phase flow (gas/liquid – air/low viscosity PDMS). The experiments were conducted for combinations of gas flow rates ranging from 0 to 2500 $dm^3.h^{-1}$ and liquid mass flow rates ranging from 0 to 14 $kg.h^{-1}$. The column is designed for cocurrent flow, with an internal column diameter of 25 mm and a height of packing of 410 mm.

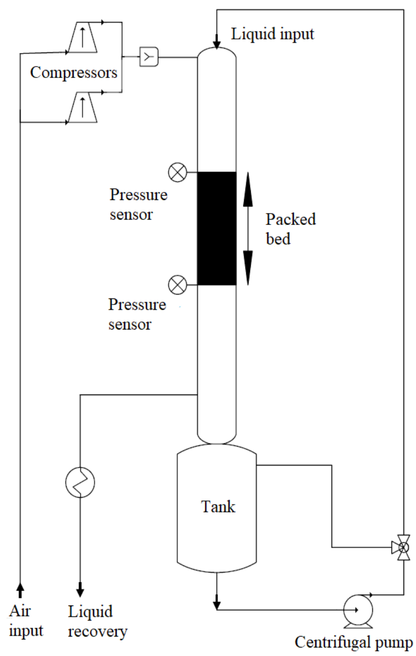

Figure 1: Laboratory apparatus.

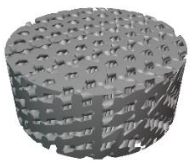

Figure 2: POCS.

3. Results and discussion

The results constitute a comprehensive set of pressure drop data for the parametric set of POCS structures and randomly packed beds. In the case of POCS structures, a significant reduction in pressure drop was observed, as illustrated by the following graph (**Figure 3**). Here, pressure drop under single-phase air flow condition is evaluated for POCS structures made of PLA material and randomly packed particle beds.

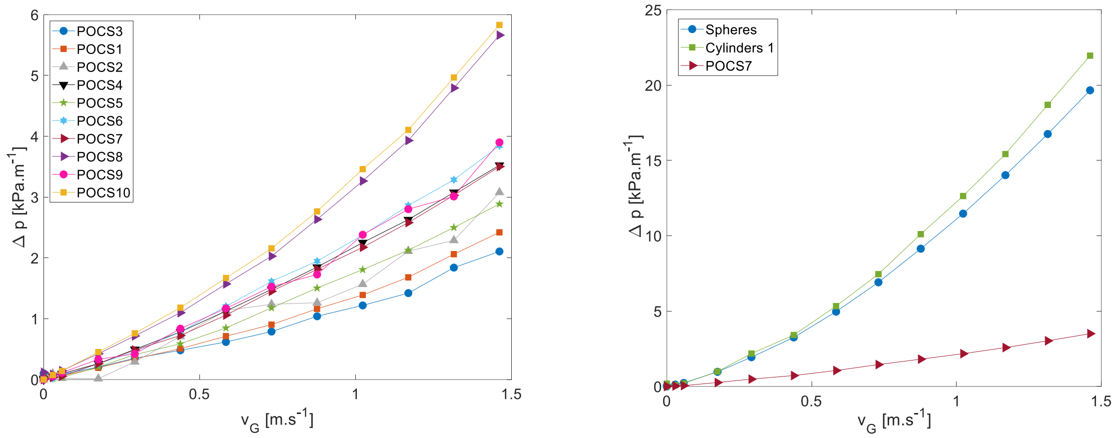

Figure 3: Pressure drop results for single-phase flow.

A part of the experimental data is supplemented with data obtained by Computational Fluid Dynamics (CFD) [5]. However, in the case of POCS structures, a difference of up to several tens of percent is observed between the experimental and predicted data [1,5]. Therefore, the production of POCS structures using a more precise technology (SLA 3D printing) and a detailed analysis through CFD simulations should lead to a more thorough understanding of the impact of geometric parameters of these POCS structures on the hydrodynamic parameters of the trickle-bed reactor.

4. Conclusions

This work constitutes a comprehensive study of the influence of geometric parameters of POCS structures on the hydrodynamic characteristics of the trickle-bed reactor, particularly on pressure drop under both single-phase and two-phase flow conditions. The parametric set of ten POCS structures was prepared using 3D printing technology, characterized by porosity and specific surface comparable to commonly used randomly packed particles. In the case of POCS structures, a significant reduction in pressure drop was observed. Experimental data were also supplemented with data obtained through CFD. In the case of POCS structures, the difference was even in the tens of percent. However, for randomly packed particle beds, the predictions were relatively consistent.

References

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Keywords

Trickle-bed reactor, pressure drop, POCS, 3D printing