Pressure drop measurements of woodpile structures with variable macroporosity and outer surface area

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Highlights

- Successful synthesis of woodpile structures with different surface area and porosity.
- The nozzle size influences the porosity and the surface area, the infill only the surface area.
- Lower macroporosity as well as higher surface area lead to a higher pressure drop.

1. Introduction

The pressure drop plays a crucial role in industrial catalysis especially in reactions with a high fluid flow. To minimize this value, monolithic catalysts have been developed. They consist of parallel straight channels and combine a high surface area with a low pressure drop. Since there is no connection between the channels, there is no mass transfer in the radial direction. One possible development to overcome this are woodpile structures. They are built by stacking layers of parallel material strains in a defined angle and combine a high outer surface area with good radial mass transfer. Given the relatively scarce information about the pressure drop of these structures, the objective of this study is to systematically examine this parameter.

2. Methods

Using robocasting, woodpile monoliths consisting of aluminum oxide were printed while varying in different parameters like macroporosity and outer surface area by changing the nozzle diameter (0.41 mm, 0.51 mm or 0.6 mm) and the infill ratio (50% or 40%) which is defined as the extruded volume in a layer divided by the volume of a completely filled layer. The monoliths listed in the figures and Table 1 are labeled according to these parameters. 50-0.41 was manufactured using a 50% infill ratio and 0.41 mm nozzle diameter. For the pressure drop measurements an acrylic tube with a diameter of 16 mm is used. Nine monoliths were stacked on top of each other and wrapped with Teflon tape to eliminate the potential of bypass flow. The outer surface area and the macroporosity are calculated based on microscopic pictures shown in Figure 1 according to Danaci et al. [1].

3. Results and discussion

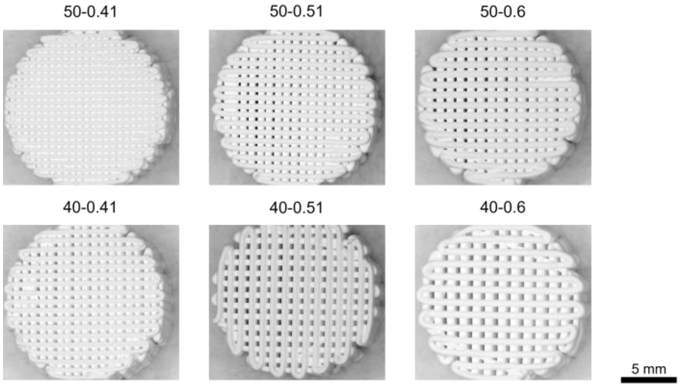

Figure 1. Printed woodpile structures with different infill ratios and nozzle sizes.

In Figure 1, the different printed woodpile structures are depicted. From left to right the nozzle diameter increases. The upper row shows the monoliths with 50% infill and the row below the ones with 40% infill. A decreasing number of strains per layer can be counted as well with increasing nozzle diameter as with decreasing infill ratio. The influence of this observation on the outer surface area and the macroporosity are shown in Table 1.

Table 1. Surface area and macroporosity for the different printed woodpile structures.

Sample	50-0.41	50-0.51	50-0.6	40-0.41	40-0.51	40-0.6
Outer surface area / m^2/m^3	5100	4000	3400	4000	3200	2700
Macroporosity / %	54	51	50	63	60	61

As expected, a higher number of strains using the same nozzle decreases the macroporosity while the outer surface area increases. For different nozzles and the same infill ratio, the macroporosity stays nearly the same with increasing number of strains since the increase is counteracted by the enlargement of the nozzle size. Thus, the macroporosity is mainly influenced by the infill ratio rather than by the nozzle diameter. Since smaller strains have a higher surface area to volume ratio, both an increase in the infill ratio and a smaller nozzle diameter result in a higher surface area. Figure 2 illustrates the corresponding results of the pressure drop measurements for increasing air flow rate.

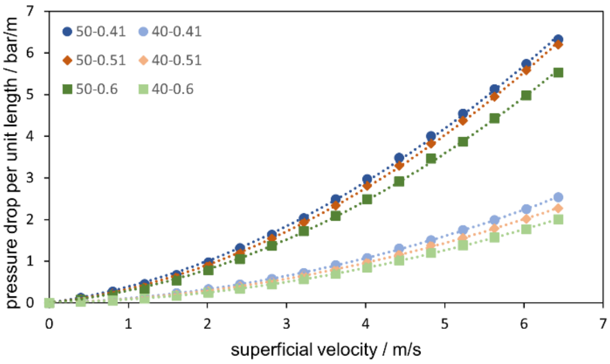

Figure 2. Pressure drop measurements of the different woodpile structures.

As can be seen, the monoliths with a higher macroporosity show a lower pressure drop. Less material that hinders the fluid to pass through the structure is an explanation for this. Comparing the monoliths with the same macroporosity the monoliths with a higher outer surface area exhibit a higher pressure drop. Compared with the macroporosity the outer surface area has a rather small influence on the pressure drop of the structures. Since the air molecules can adhere to the porous surface of the woodpile structures, a bigger surface area results in a higher pressure drop.

4. Conclusions

Woodpile structures with varying macroporosities and outer surface areas were printed, and the corresponding pressure drop was determined. A correlation was identified, indicating that an increase in the outer surface area and a decrease in the macroporosity correspond to rising pressure drops. This aligns with the principles outlined in the Ergun's equation [2]. To get a better prediction of the pressure drop for woodpile structures a correlation should be developed in the future.

References

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[2] S. Ergun, A.A. Orning, Indust. Eng. Chem. 41 (1949) 1179–1184.

Keywords
Additive manufacturing; Direct Ink Writing; Pressure drop; Woodpile structures.