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INDIGO

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ADDITIVE MANUFACTURING IN FLOW SEPARATOR DEVELOPMENT

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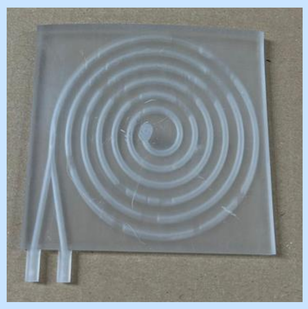
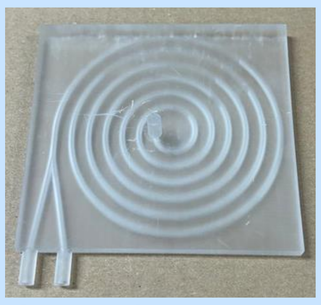
INTRODUCTION

Separation processes are essential in the process industry, particularly for solid–liquid separation. This study investigated **3D-printed microfluidic separators** for **water–solid suspensions** containing quartz sand, talc, and calcium carbonate, focusing on the effects of channel geometry and hydrodynamic forces.



Separator 1
(circular cross-section with a central inlet)



Separator 2
(triangular cross-section with a central inlet)

Separator 3
(circular cross-section with a side inlet)

Separator 4
(triangular cross-section with a side inlet)

EXPERIMENTAL SECTION

The digital models were designed using Autodesk Fusion, a CAD (computer-aided design) software. **Four microfluidic separators with different channel geometries and inlet configurations were fabricated** using an Anycubic Photon Mono 4 Ultra DLP (Digital Light Processing) 3D printer. The separators were designated as follows: Separator 1 – circular cross-section with a central inlet, Separator 2 – triangular cross-section with a central inlet, Separator 3 – circular cross-section with a side inlet and Separator 4 – triangular cross-section with a side inlet.

The separation process was carried out by continuously feeding a particle suspension into the 3D-printed microfluidic separator using a peristaltic pump. Inside the separator, the spiral channel promoted particle separation according to differences in particle behavior within the flow. The separated streams were collected separately at the two outlets. The efficiency of the separation was evaluated by measuring the mass of the collected outlet streams and comparing their particle size distributions using laser diffraction.

RESULTS

The masses and suspension volumes at the inner and outer outlets were normalized. Separation efficiency was evaluated based on the difference in normalized masses (**Δ**), with higher values indicating more pronounced separation.

$$\Delta = |\, m(\, outer\ outlet\ (outlet\ 2)) - m(inner\ outlet\ (outlet\ 1))\, |$$

TALC

Flow rate of the suspension	200 mL/min	250 mL/min	300 mL/min
Δ (Separator 1) g/100 mL water	0.0510	0.0253	0.0120
Δ (Separator 2) g/100 mL water	0.0202	0.0519	0.0259
Δ (Separator 3) g/100 mL water	0.1405	0.0039	0.0078
Δ (Separator 4) g/100 mL water	0.0066	0.0310	0.0401

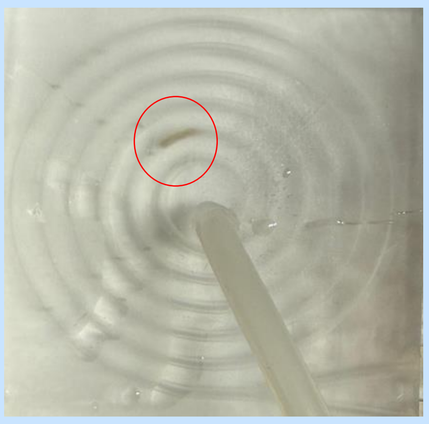
CALCIUM CARBONATE

Flow rate of the suspension	200 mL/min	250 mL/min	300 mL/min
Δ (Separator 1) g/100 mL water	-	-	-
Δ (Separator 2) g/100 mL water	-	-	-
Δ (Separator 3) g/100 mL water	0.0110	0.0071	0.0090
Δ (Separator 4) g/100 mL water	0.0245	0.0487	0.0134

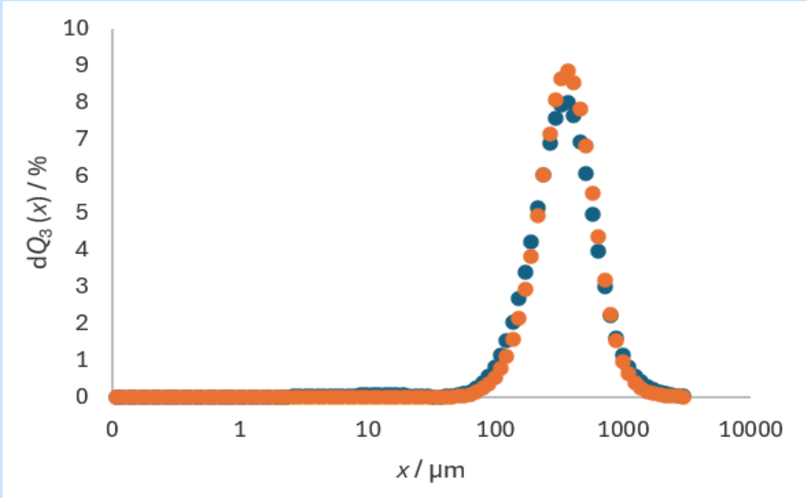
QUARTZ SAND

Flow rate of the suspension	200 mL/min	250 mL/min	300 mL/min
Δ (Separator 1) g/100 mL water	-	-	-
Δ (Separator 2) g/100 mL water	-	-	-
Δ (Separator 3) g/100 mL water	-	-	-
Δ (Separator 4) g/100 mL water	0.4334	0.3495	**0.4639**

Quartz sand–water separation caused **clogging** in Separators 1–3, likely due to an insufficient cross-sectional area relative to the particle size. Separation was achieved only with Separator 4, featuring a triangular cross-section and side inlet. The highest separation efficiency was obtained at **300 mL/min, with Δ = 0.4639 g/100 mL water**. For calcium carbonate, Separators 1 and 2 also experienced clogging and no effective separation was observed; these results are indicated as "–" in the tables.



Differential particle size distribution before and after separation in Separator 4 for quartz sand at a flow rate of 300 mL/min is shown in the graph below. No significant change in particle size distribution is observed after separation. Almost all quartz sand was directed to the outer outlet, while the amount collected at the inner outlet was insufficient for laser diffraction analysis, confirming the high separation efficiency (Δ = 0.4639 g/100 mL).



CONCLUSION

- **Quartz sand:** separation achieved only in **Separator 4** at **300 mL/min** (Δ = 0.4639 g/100 mL)
- **Talc:** best separation in **Separator 3** at **200 mL/min** (Δ = 0.1405 g/100 mL)
- **Calcium carbonate:** best separation in **Separator 4** at **250 mL/min** (Δ = 0.0487 g/100 mL)

- **Key finding: separator 4** showed the highest overall separation efficiency, likely due to its **triangular channel geometry and side-inlet configuration**

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