Overview

Direct Ink Writing allows printing of high-performance composites with aligned fibers.
- How does processing affect fiber alignment?

Velocity gradients determine fiber alignment kinetics

Quantitative, full-field analysis of nozzle flow

Use phase contrast imaging to study fiber flow during direct ink write 3D printing

Key findings

PIV reveals that flow structure depends on flow rate (strain rate). Transition at ~1 mm/s

Conclusions

- Flow transitions from “plug flow” to “pseudo-Newtonian” regime at increasing velocity
- Pseudo-Newtonian flow improves fiber alignment kinetics
Composite 3D printing via Direct Ink Writing (DIW)

Goal: Understand nozzle flow conditions and fiber alignment kinetics
- How does processing affect fiber alignment?
- Can we control or improve the fiber alignment?

XCT analysis showed ~60% fiber alignment

Compton, Adv Materials 2014

Pierson, Exp Mechanics 2019

Unrealized gain
Current DIW

XCT analysis showed ~60% fiber alignment
In situ study of ink extrusion

Methods:
• Phase contrast imaging to study ink flow
• Particle Image Velocimetry to quantify local velocity
Particle Image Velocimetry results

Results:
- Full-field velocity measurements
- Different nozzle positions (nozzle diameter)
- Different print pressures (fluid velocity)

\[ p = 39 \text{ kPa} \]
Particle Image Velocimetry results

Results:
• Full-field velocity measurements
  • Different nozzle positions (nozzle diameter)
  • Different print pressures (fluid velocity)
Conclusions

Phase contrast imaging can access ink flow and fiber alignment kinetics *within the nozzle*.

Flow transitions from “plug flow” to “pseudo-Newtonian” regime at increasing velocity.

Pseudo-Newtonian flow improves fiber alignment kinetics.

![Diagram showing flow transitions and fiber alignment](image-url)