Nozzle flow measurements during composite 3D printing

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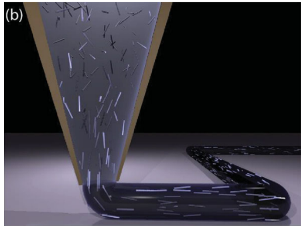
FOCUSING ON THE FUTURE

Overview

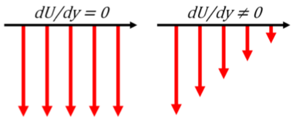
Direct Ink Writing allows printing of high-performance composites with aligned fibers.

- How does processing affect fiber alignment?

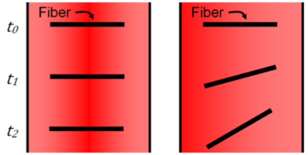


Velocity gradients determine fiber alignment kinetics

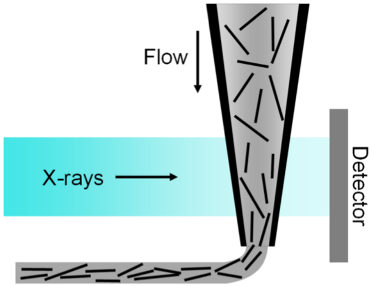
Flow streamlines:



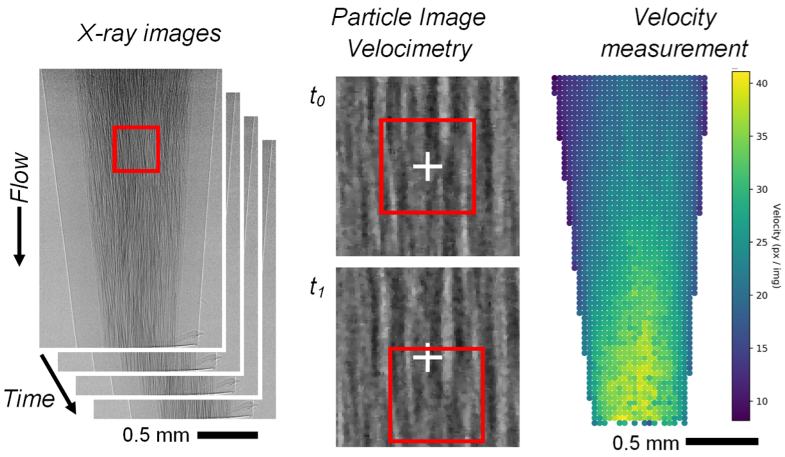
Flow induced alignment:



Quantitative, full-field analysis of nozzle flow

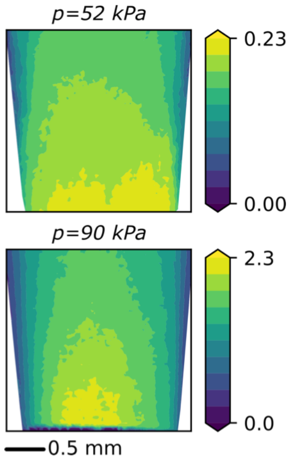


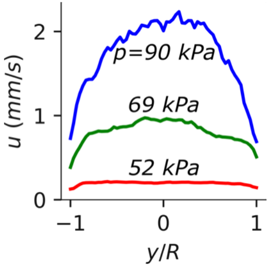
Use phase contrast imaging to study fiber flow during direct ink write 3D printing



Key findings

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





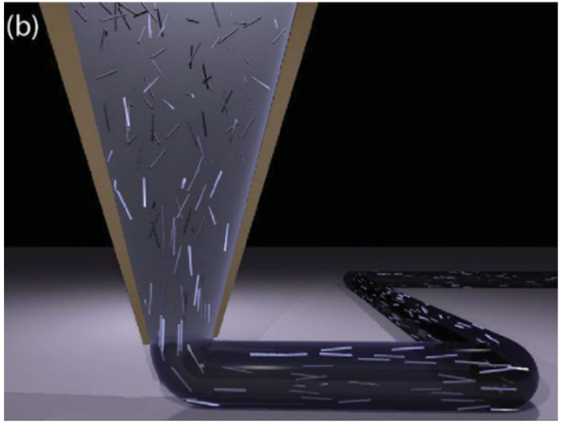
Conclusions

- ✓ *Flow transitions from "plug flow" to "pseudo-Newtonian" regime at increasing velocity*
- ✓ *Pseudo-Newtonian flow improves fiber alignment kinetics*

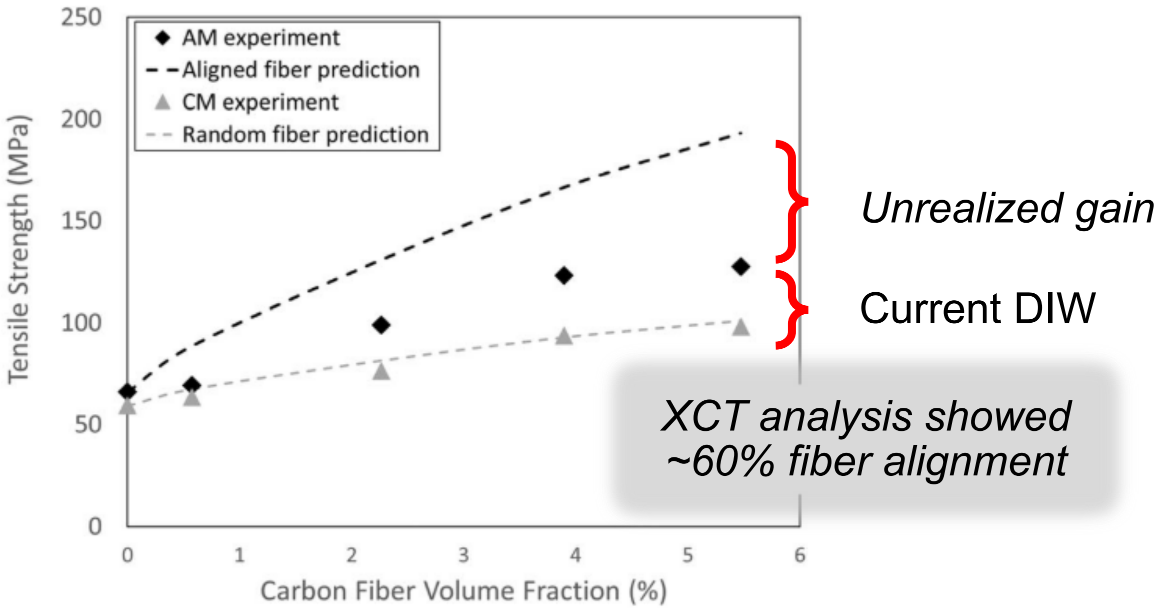
Composite 3D printing via Direct Ink Writing (DIW)

Goal: Understand nozzle flow conditions and fiber alignment kinetics

- How does processing affect fiber alignment?
- Can we control or improve the fiber alignment?



Compton, *Adv Materials* 2014

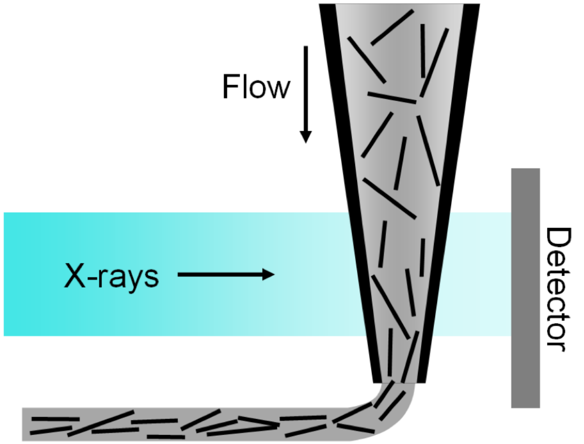


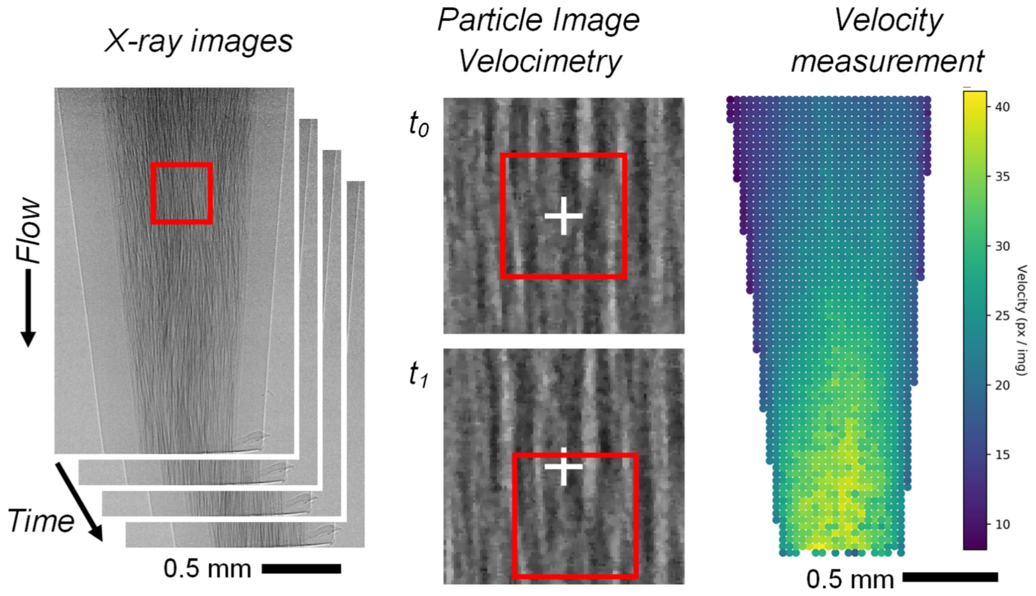
Pierson, *Exp Mechanics* 2019

In situ study of ink extrusion

Methods:

- Phase contrast imaging to study ink flow
- Particle Image Velocimetry to quantify local velocity

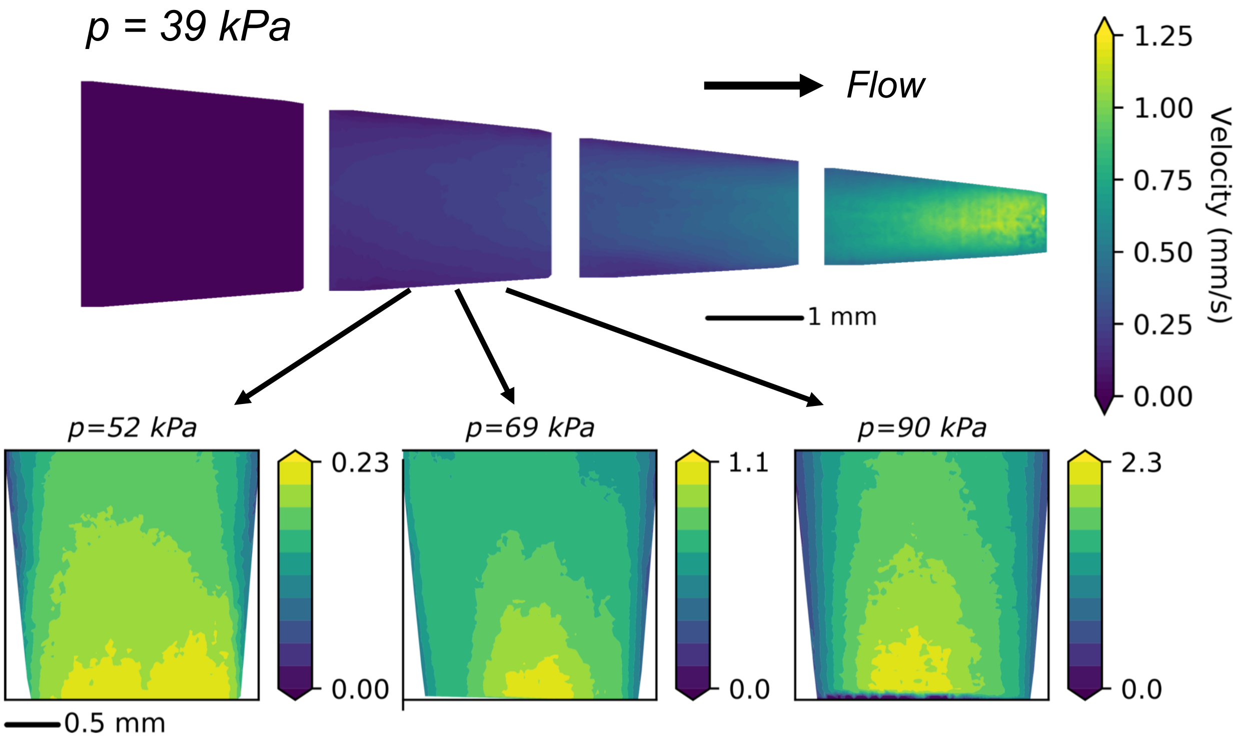




Particle Image Velocimetry results

Results:

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



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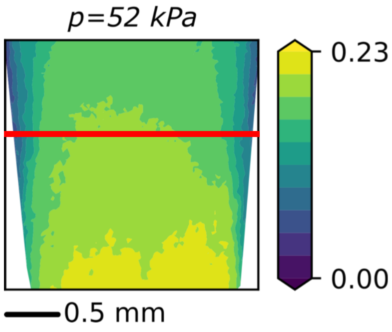

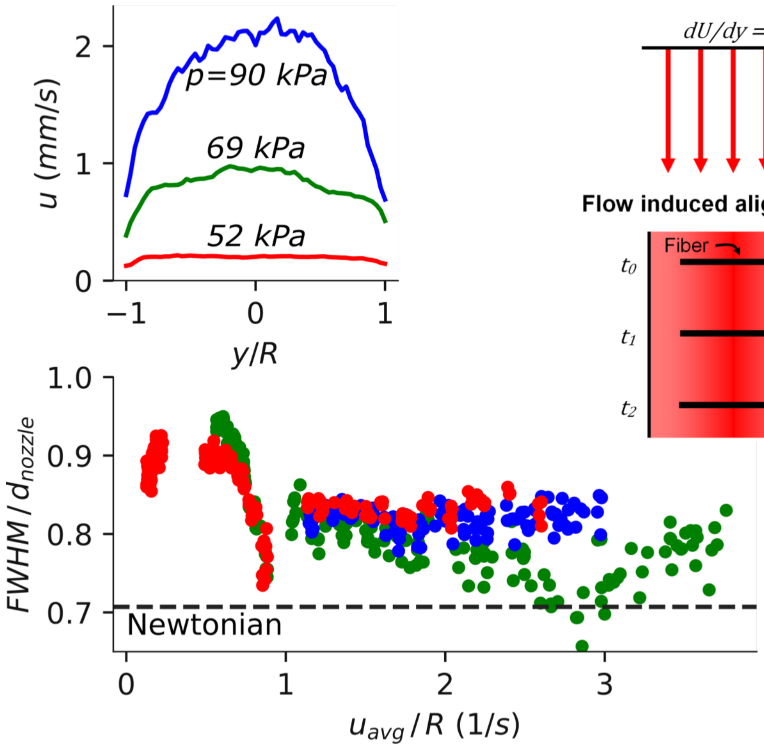

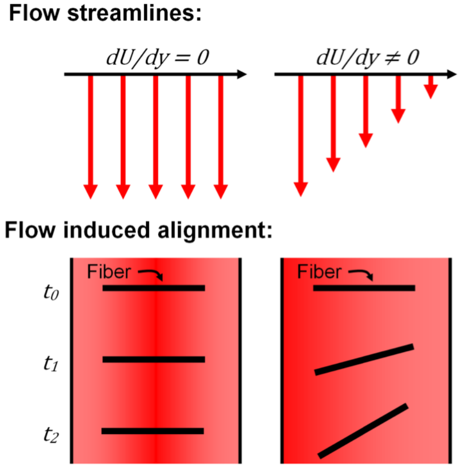

Conclusions

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