MECHANICAL ENGINEERING MSc SEMINAR (30 min.)

Thursday, November 12 2026 at 13:30-14:00, Dan Kahn Building, Auditorium 1

Capillary-Driven Pore Closure in Yield-Stress Materials

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In direct ink writing (DIW), yield-stress materials are formulated to retain their shape post-extrusion; however, this same resistance to flow can prevent intra- and inter-filament pores from closing. Such residual porosity compromises the mechanical integrity of printed pastes, ceramics, and soft composites. Although surface tension can drive pore shrinkage, comparing capillary pressure to yield stress alone is insufficient to predict complete closure, as shrinkage also deforms the surrounding unyielded material and alters the extent of the yielded region.

To capture these coupled phenomena, we employ a piecewise Bingham–Hooke model that combines Hookean elasticity in the unyielded region with Bingham viscoplastic flow in the yielded region to determine closure conditions, timescales, and the final arrested pore radius. Our analytical results identify distinct thresholds for the onset of yielding and for the complete closure of a vented cylindrical pore, demonstrating that, between these thresholds, shrinkage arrests at a finite radius. The analysis predicts a sharp increase in closure time near the closure boundary and elucidates how elasticity influences yielded-zone growth. Furthermore, a linear perturbation analysis characterizes small departures from circularity and provides an exact analytical solution for perturbation flow in the yielded paste. As closure decelerates, the flow reorganizes into cellular structures aligned with plastic slip lines. These findings indicate that a sufficiently large yield stress promotes pore rounding, in contrast to the stretching predicted for pore collapse in Newtonian liquids. Finally, for printed filament stacks, the model estimates a critical filament radius for pore closure determined by the stacking geometry.