Reactive Extrusion Additive Manufacturing (REAM) of Carbon Fiber Reinforced Epoxy Composites

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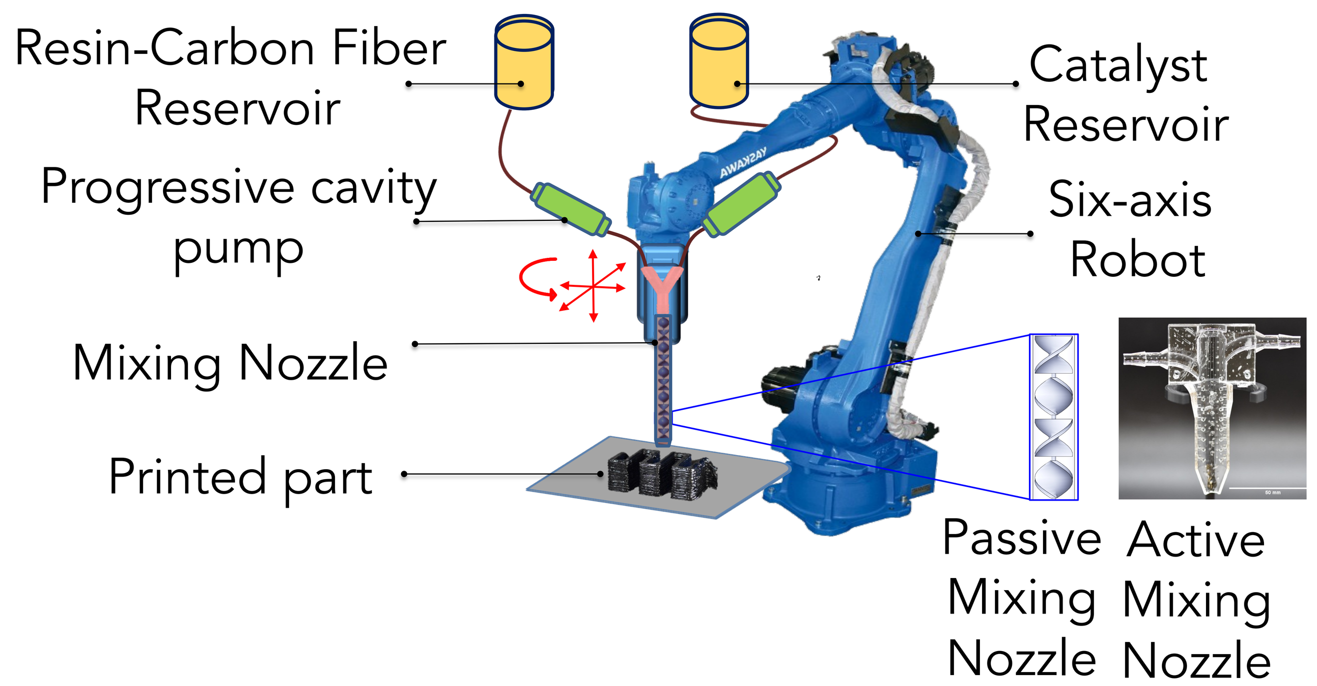
Background

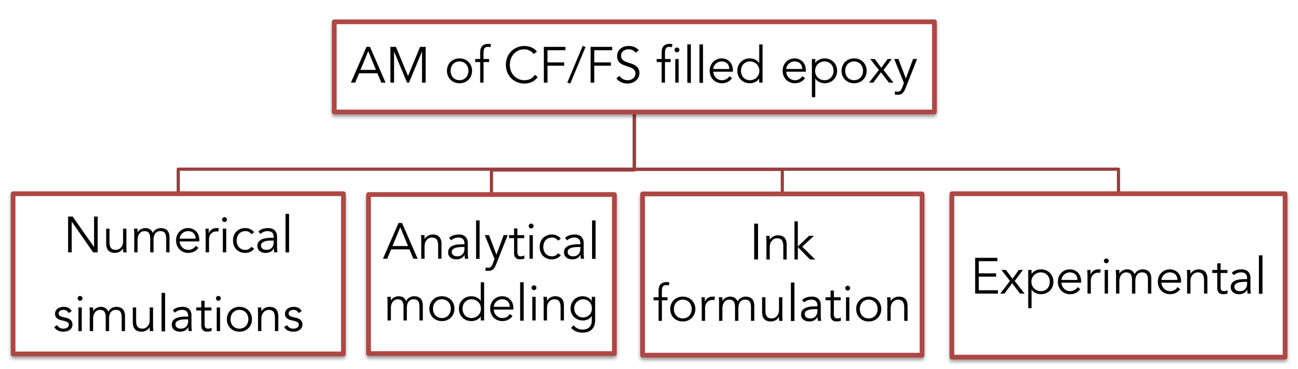
- Additive Manufacturing (AM) with thermosetting composites can enable fabricating complex-shaped structures with strong inter-layer properties
- Reactive extrusion AM (REAM) is energy-efficient and rapid



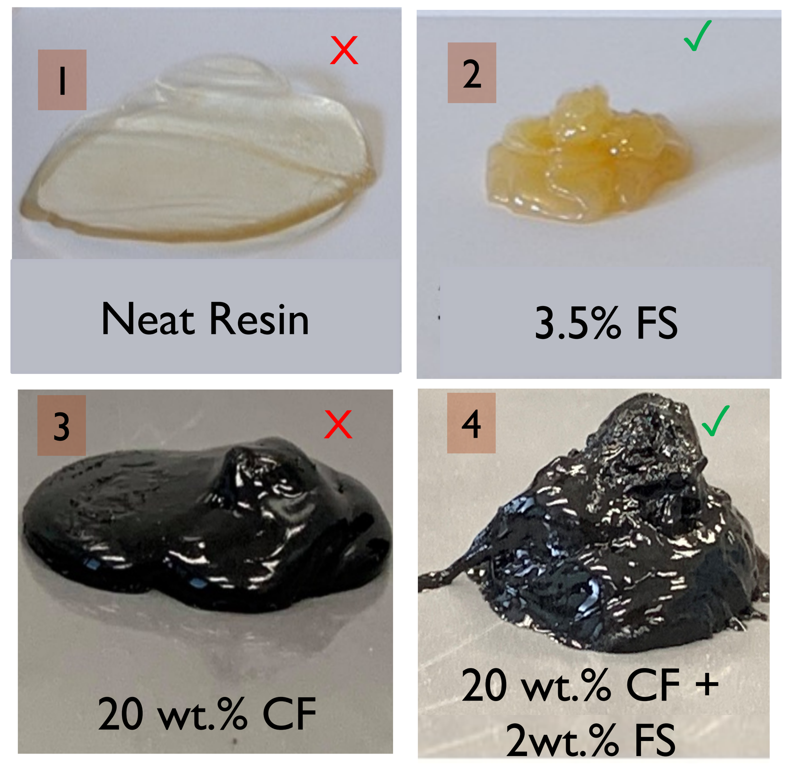
Research Goals

- Investigating the printability of a reactive thermosetting polymer with short fiber fillers.
- Developing an understanding of precursor properties (viscosity , shear yield, and filler content) on printability and properties of resulting REAM parts.
- Finding the optimal fiber content via modeling

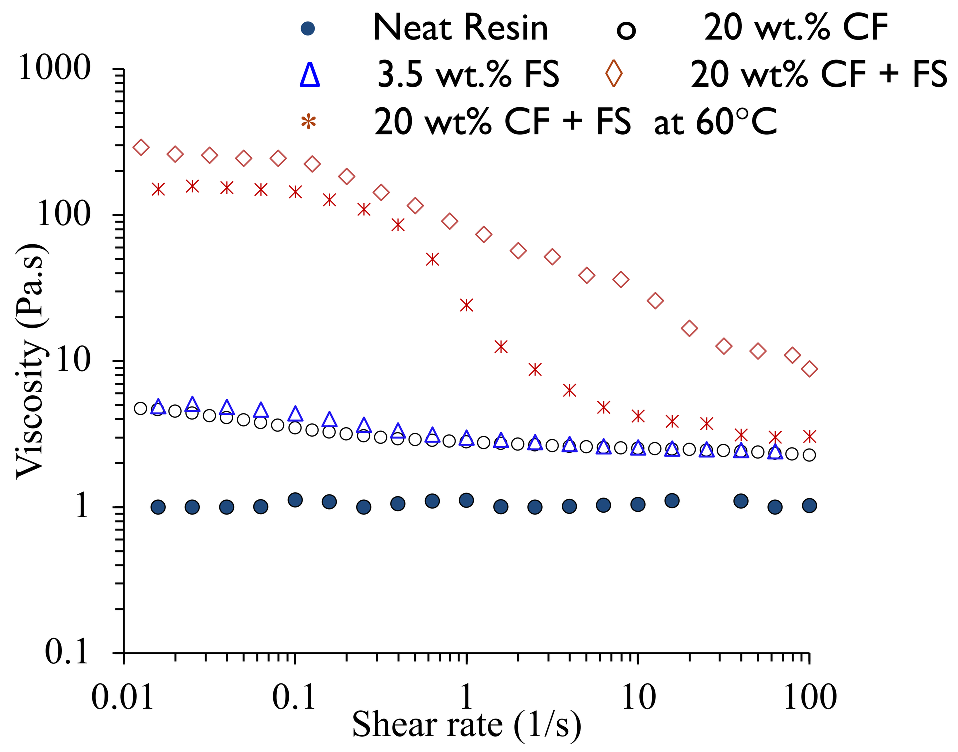
Methods



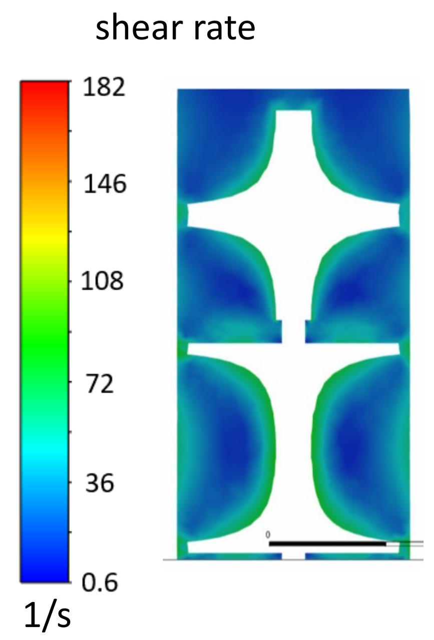
Results



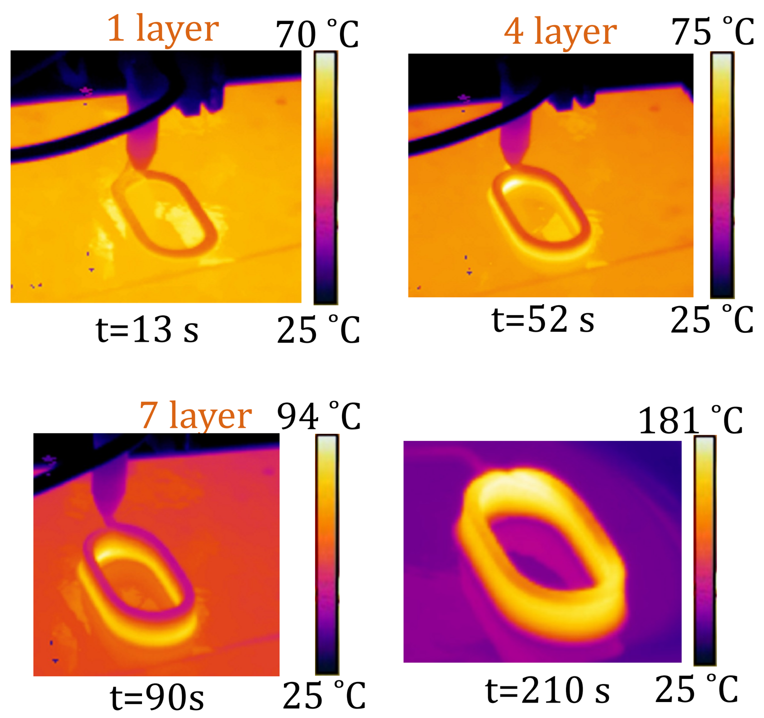
Ability of different formulation to retain shape



Shear rate-dependent viscosity of EPON 8111 resin filled with fumed silica and carbon fiber

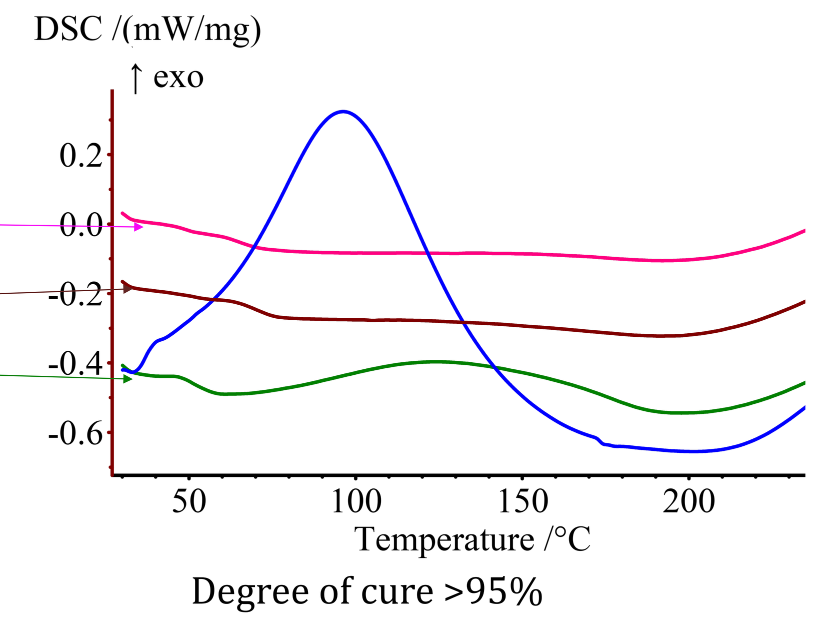


Fluent simulation showing shear rate distribution in a passive nozzle

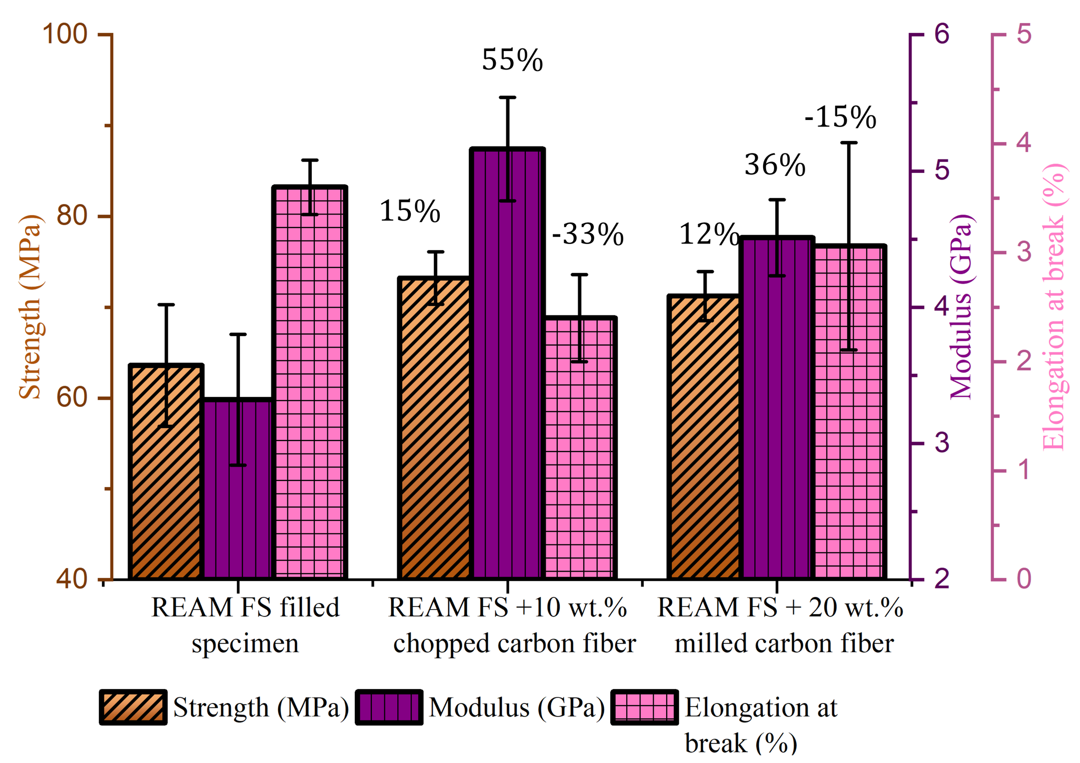


Thermal footprint of a carbon fiber filled part during REAM

Printed part



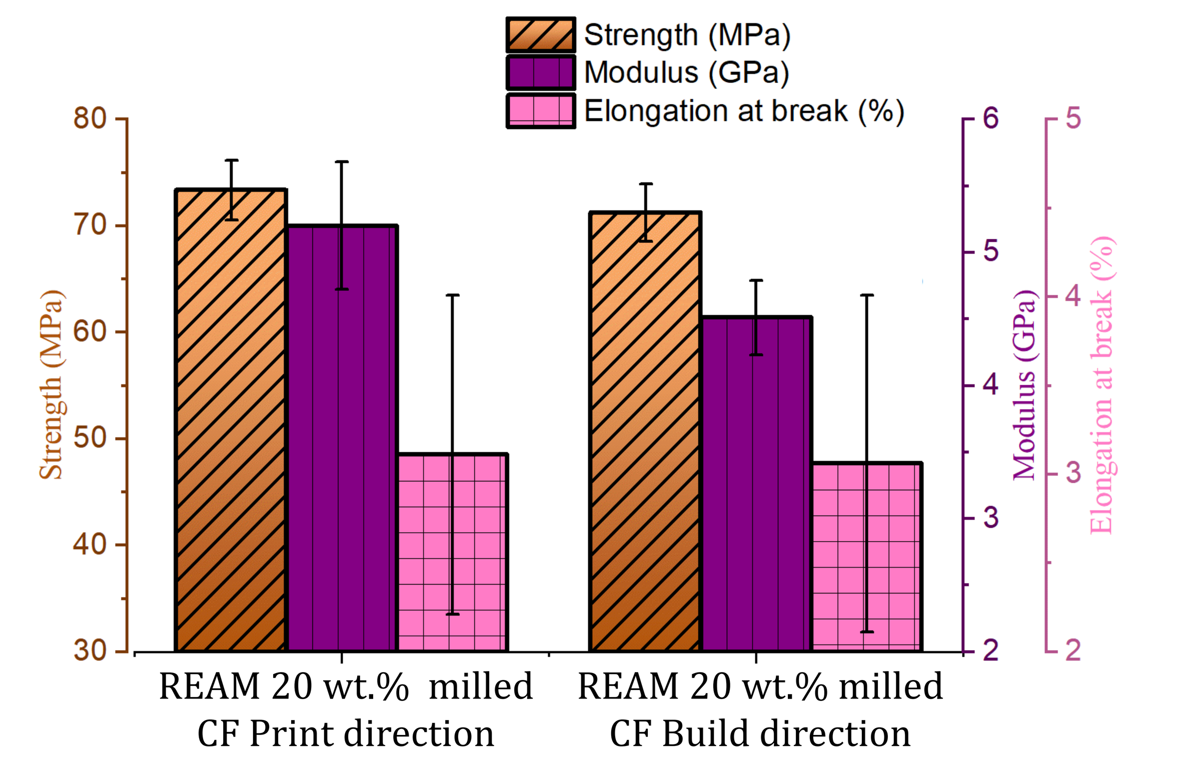
Degree of cure of 10 vol.% milled carbon fiber epoxy coupon at different locations



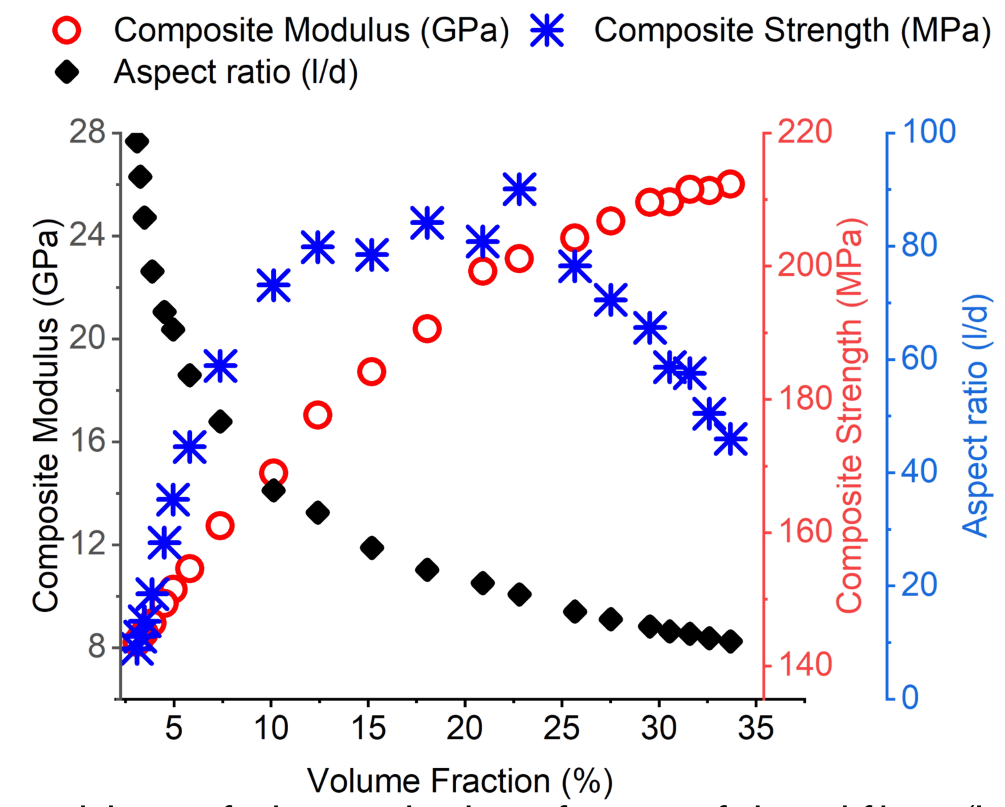
Tensile properties of REAM composites in the print-direction

Partial alignment of milled carbon fibers along the print direction and between the layers

Results



Tensile properties of REAM composite in print- and build- directions



Analytical modeling to find optimal volume fraction of aligned fibers (l_c =350μm)

Conclusions

•REAM is an ultra-fast and low-energy process.

•Fumed silica and carbon fiber (either milled or chopped) can effectively modify the rheological behavior of the resin, rendering it printable.

•A carbon fiber filled composite was successfully printed with a degree of cure at ~95%, using active mixing, and displayed robust inter-layer properties.

•The incorporation of carbon fiber notably enhanced stiffness, although the strength wasn't affected.

•Adjusting the fiber length, volume fraction, and alignment could potentially lead to substantial improvements in both strength and stiffness.