STABILIZATION OF TUFF MATERIAL BY ELECTROSPINNING ULTRA LOW AREAL WEIGHT BINDER VEILS FROM AQUEOUS SOLUTIONS

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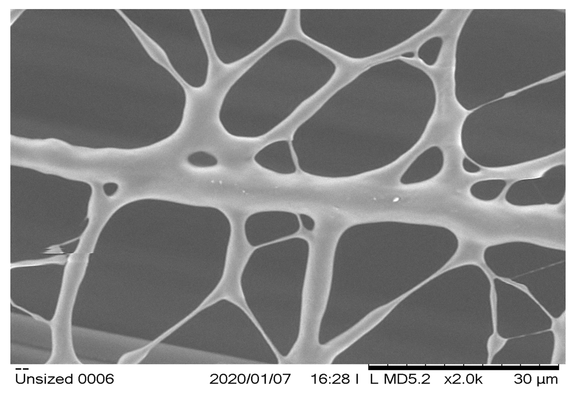
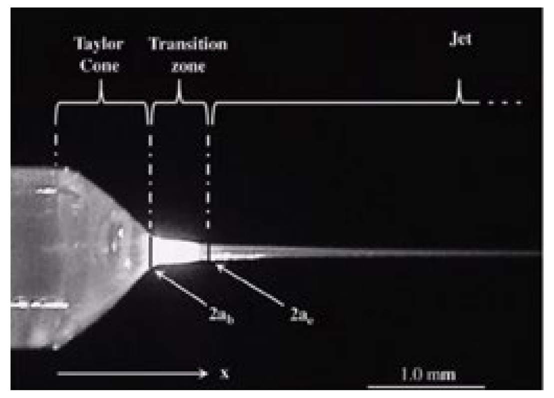
Research Motivation

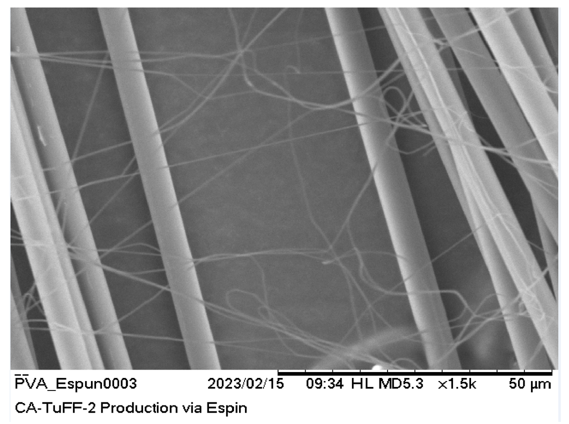
- Handling of short fiber TuFF sheets is difficult
- Small-piece layup with curvature is difficult with dry continuous fiber preforms
- Conventional veil have areal weights of 4-8 gsm which compares to the 8 gsm TuFF Sheet.



- Low/Ultra Low Molecular Weight (MW) aqueous solutions does not affect preform AW and allow less shrinkage
- Electrospinning of Ultra Low areal weight (0.1-1 gsm) veils onto TuFF preforms enhances handling

Basics of Effective Electrospinning

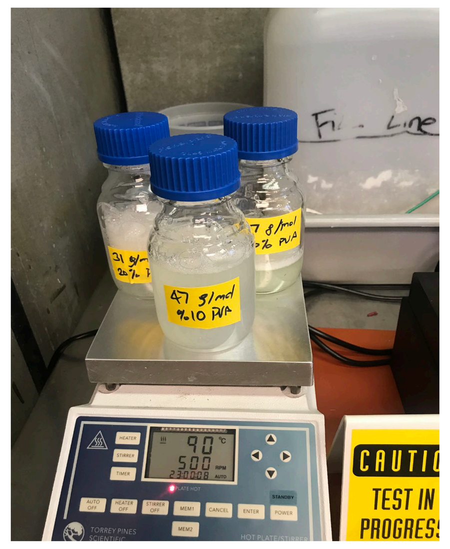


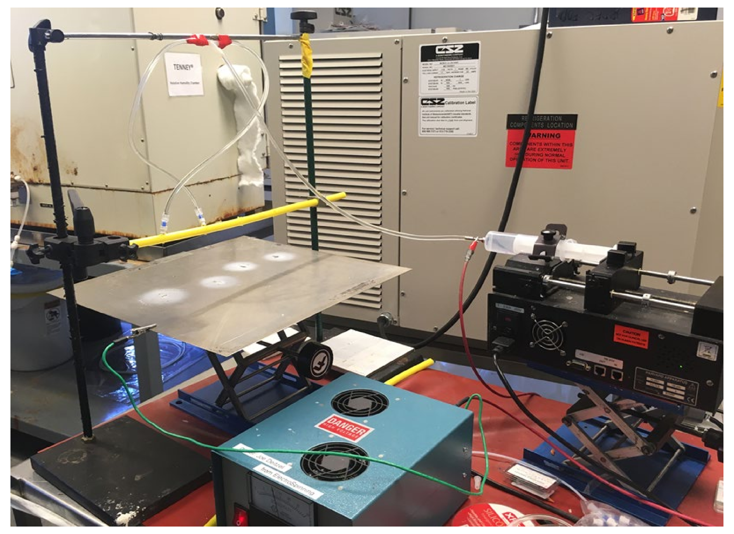


- Electrospinning is a process where filaments are formed via an electrostatically driven jet of polymer solution or melt
- The application of voltage to a pendant drop of polymer solution or melt at the end of a capillary causes the drop to distort into the shape of a cone
- A steady cone jet is initiated when the electric field strength exceeds a critical value at the apex of the fluid cone
- Flow rate, electric currency, and distance to collection plate are main process parameters governing jet stability

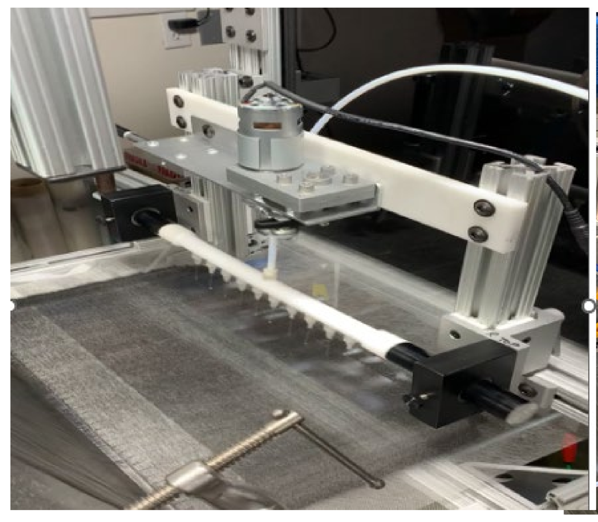
Electrospinning of Aqueous Solutions

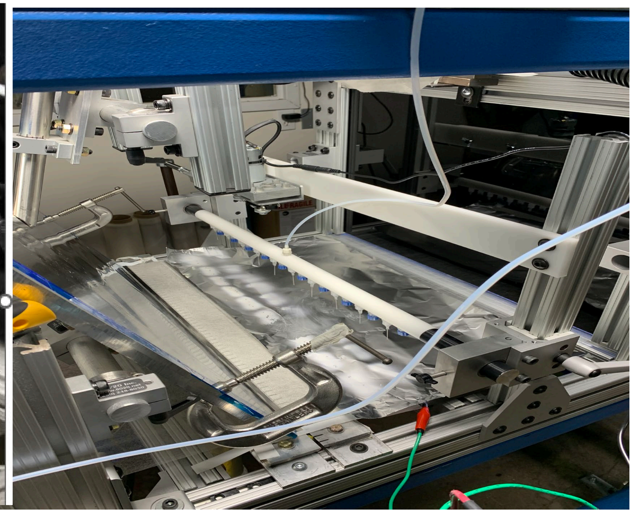
- Low MW (27-31 g/mol) Polyvinyl Alcohol (PVA) is soluble in water when heated. It was chosen as our initial binder because of environmental concerns associated with solvent evaporation
- Once dissolved PVA can be electrospun onto TuFF material in filament form
- After electrospinning, PVA is stable at RT





- Electrospinning parameters are tunable
- Inter-fiber bonding provides product flexibility
- Initial electrospinning device was upgraded to a fully automated setup that can be used while producing TuFF material





- 10-needle automated device was developed first and installed on TuFF-1, and 20-needle device on TuFF-2
- Deposition thickness controlled by adjusting solution flow rate, TuFF belt speed, and electrical currency

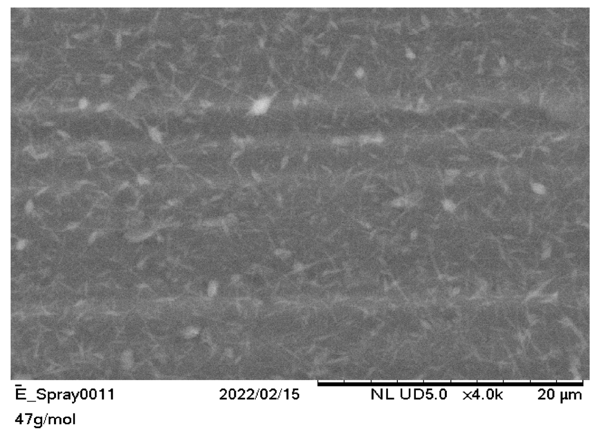
Process parameters

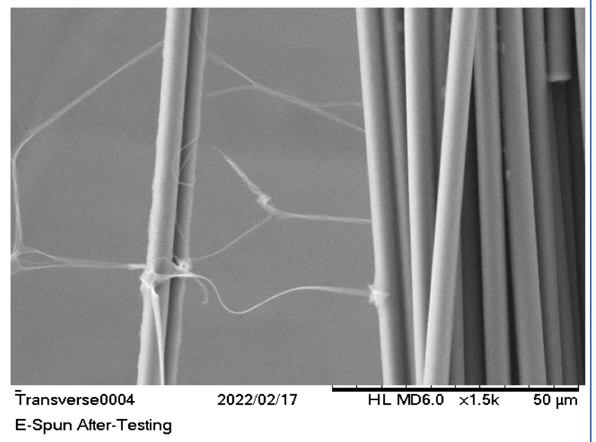
Belt Speed (m/min)	Coating Area (m^2 /min)	Coating Area (m^2 /hr)	Needle volume (mm^3=µL)	Coating via 10 needles µL/min	Coating (mL /hr)	Coating (g/hr)	**Coating (gsm)**
0.165	0.0754	4.524	0.876	8.76	0.53	0.44	**0.1**

Stabilized TuFF with Electrospun PVA Veil

- Manually de-veiling of a single layer PVA electrospun TuFF material made possible

- Single layer PVA electrospun TuFF preform exhibits average 25% extension in longitudinal and 11% in transverse directions



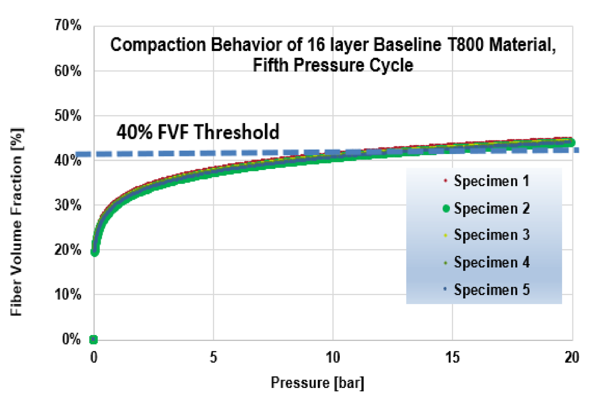


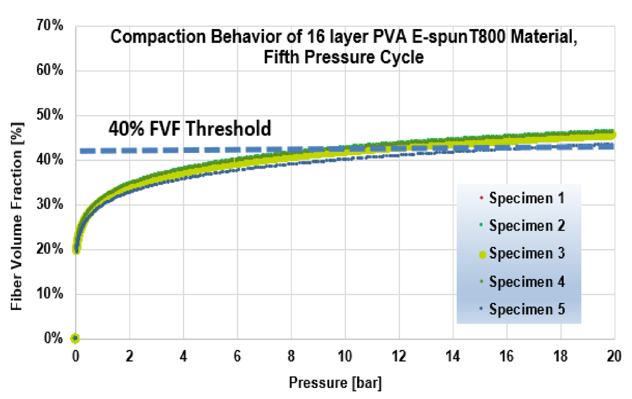
- TuFF Samples stabilized with 0.1 gsm electrosprayed droplets show only 11.5% extension when transversely loaded
- Electrospun PVA filaments are seen well-dispersed under microscopy (right)
- Volume fraction of PVA (0.85%) is low in the composite matrix

FVF Calculation for a TuFF Composite Panel (Fiber, PVA and Resin)

Layer	Panel Area m^2	gsm of material	# of Layers	Total gsm	Weight (g)	Density (g/cm^3)	Volume (cm^3)	Volume (%)
T800 TuFF Fiber	0.052	8	24	192	10.03	1.78	5.64	45.54
E-Spun PVA	0.052	0.1	24	2.4	0.13	1.19	0.11	0.85
Axiom Resin	0.052	73	2	146	7.63	1.15	6.63	53.60
			Total	340.4	17.79	4.12	12.38	100.00

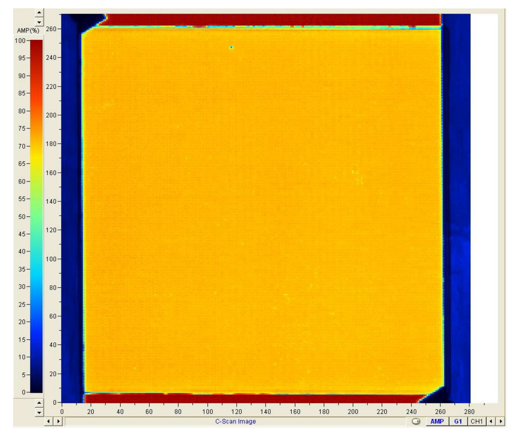
- Baseline and PVA-Electrospun T800 TuFF material compaction levels measured equal

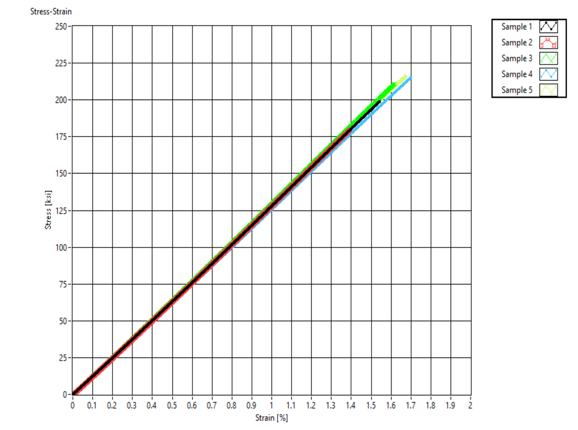




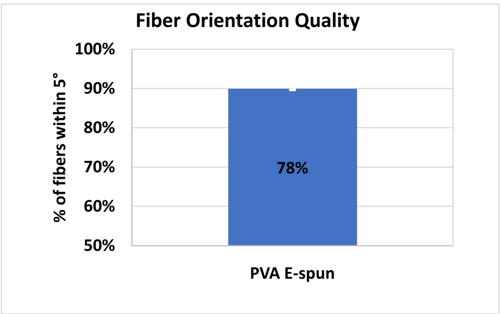
Mechanical Test Results

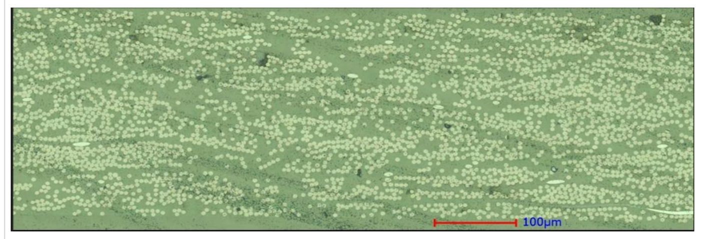
- In-line PVA electrospun test panel produced
- There is no voids observed in the C-scan



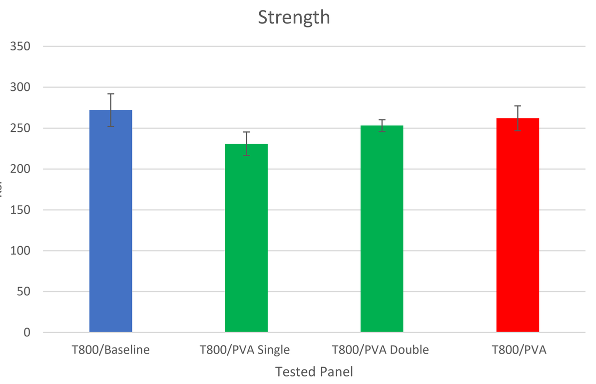


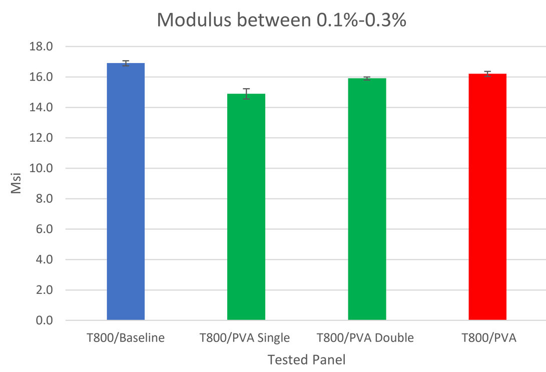
- Fiber alignment is ~78% in 5 degrees of orientation direction





- Baseline, single-layer manual layup, Double-deposition and In-line (automated) PVA electrospun material produced (via 0.1 gsm PVA) coating
- Compared to the Baseline T800 test panel, In-line PVA E-spun test panel average strength and modulus retention levels are 96%





Future work

- Areal weight optimization
- In-line heat-stabilization of TuFF material via lower gsm PVA coating
- Resin compatible veil material options

Acknowledgements

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