Additive Manufacturing of High Temperature Polymer Composites

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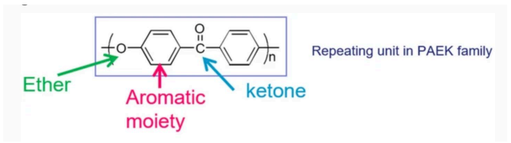
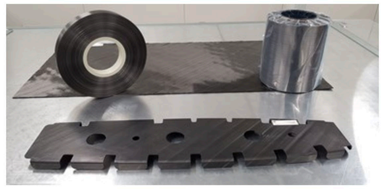
Introduction

Processing PAEK/CF polymers



- PAEK family: high performance thermoplastics act like metals
- Aid in weight reduction in aerospace industry
- CF addition :Improved stiffness, thermal and electrical conductivity
- Require high processing temperature

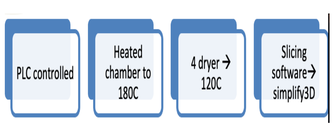
1) Traditional Manufacturing methods

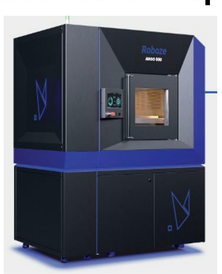


2) Additive manufacturing PAEK/CF

Additive Manufacturing

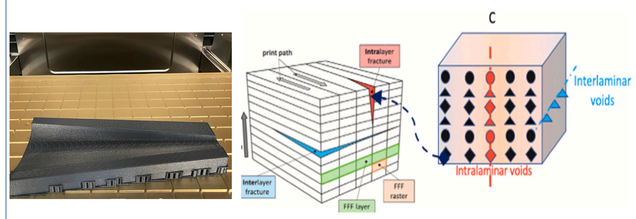
Machine features and Material set-up



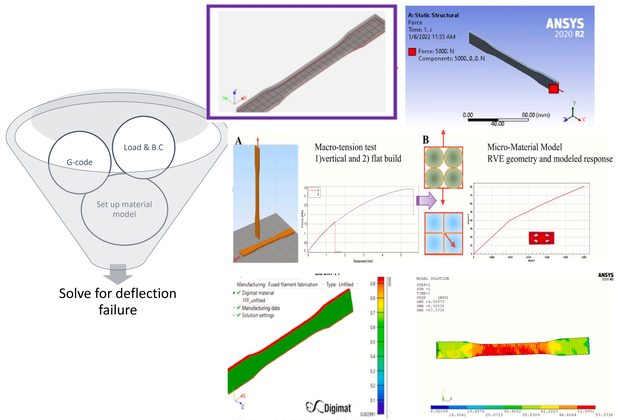


Research Objective

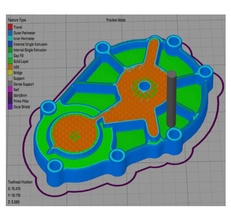
- Identify parameters influence fracture toughness
- Develop physic-based model to predict mechanical properties
- DOE and optimize processing parameters
- Identify multi scale effect of processing parameters on Fracture Toughness



Achievements: Multiscale Model



Achievements : Offline Design of Experiment (DOE)



Parameters	Intensity	Defection at Failure (mm)
Extrusion width %	60	6.25
	105	7.5
	120	8.4
Infill overlap %	10	12.7
	90	7.5
	60	10.1
Layer height (nozzle size) mm	0.1	7.98
	0.25	7.58
	0.3	7.44
Infill shape	Wiggle	6.95
	Rectilinear	6.63
	Full honeycomb	7.83
Solid layers	3	7.2
	0	8.67
	2	7.82
No. of shells	2	11.31
	3	8.43
	0	13.12

change G-code->solve

Achievements : Multiscale Effects

Experimental Set Up

- 5 dog bone V type ASTM samples are made for each process condition.
- The tensile tests were performed using an Instron 4448 machine with a 10 kN loadcell capacity at a rate of 1 mm/min

Macroscale: Performance

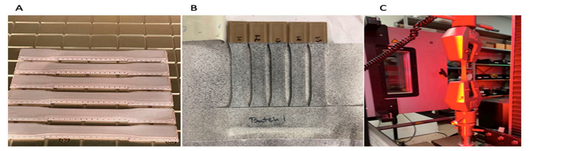
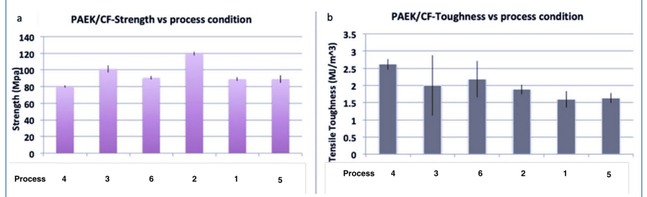


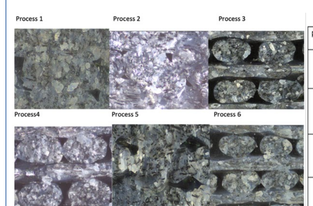
Figure 4. (A) printed dog bone coupons; (B) coupons were painted with a dot pattern so DIC could measure strain variations; (C) DIC-equipped Instron to measure strain using a video extensometer.

Micro scale : Void Shape and Sizes

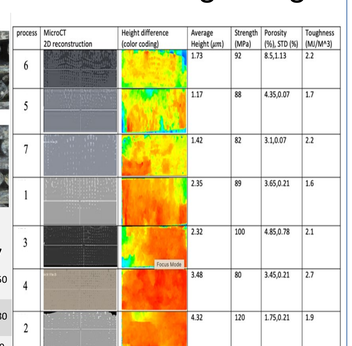


Roughness: 2) Microscopy

- 3D confocal to measure average height

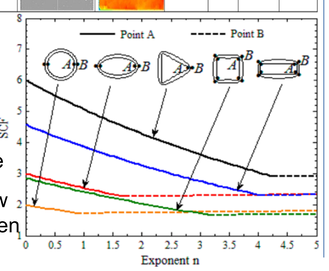


Process parameter (PEEK/CF)	1	2	3	4	5	6	7
Deposition temperature	470	450	470	450	470	470	450
Bed temperature	160	160	160	160	180	180	180
Raster angle	45	45	90	90	45	90	90
Average pore content	8.3%	5.6%	11.1%	10.2%	12.0 %	16.4 %	12.8%

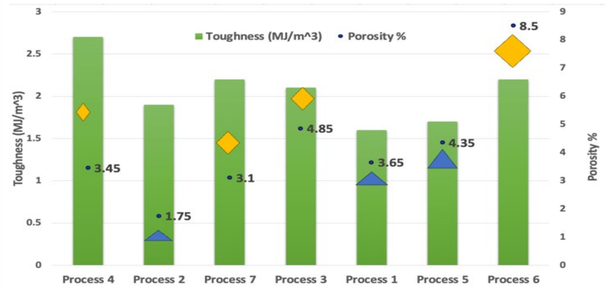


Stress concertation factor(SCF) determines the crack opening mechanisms and type of fracture

Diamond shape voids → with low SCF result in ductile fracture when accompanied with low porosity.



Results: Pore Content vs Toughness



Process	Crack growth (XY direction)	Crack growth (yz direction)	Type of delamination & fracture	Strength (MPa)	Porosity	toughness
Process 2: 450°C-160°C-45-degree raster			Inter- &intra-laminar	High-120	Low	Medium (Bulk failure)
Process 4: 450°C-160°C-90-degree raster			Inter- &Trans-laminar	Low-80	Medium	High (Ductile)
Process 7: 450°C-180°C-90 degree raster			Inter- &intra-laminar	Medium -96	High	Low (Brittle)

Conclusion

Multiscale modeling -> design for any target industry

- Toughness →porosity, void shape and size
- Strength →porosity and bond strength
- Process(450C,160C,90<) --> ductile fracture with highest toughness

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