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Optimization of 3D Printed Continuous Carbon Fiber Reinforced PETG Composites

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INTRODUCTION

3D printing of continuous carbon fiber reinforced thermoplastic composites (CCFRCs)

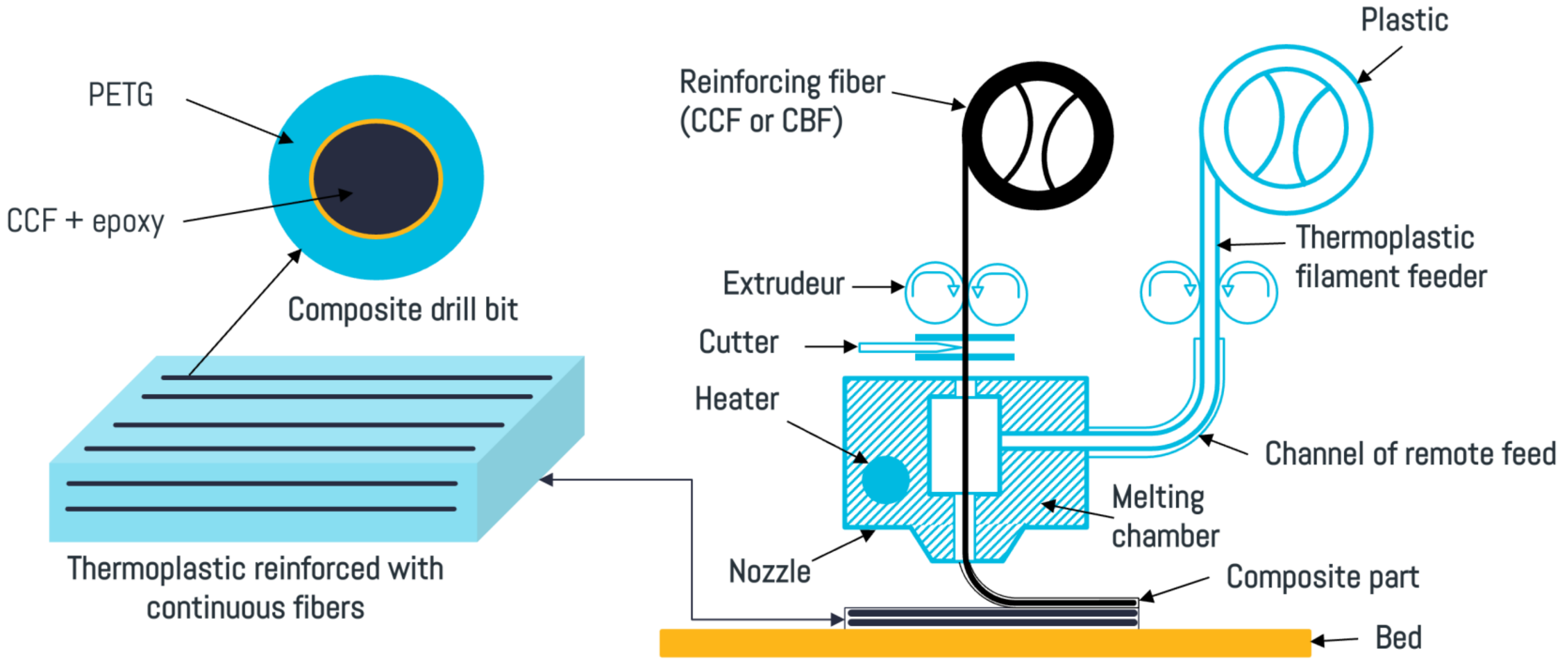
Some limitations of 3D printed CCFRCs :

- Mechanical performances remain restricted by the fiber orientation within the printing layers
- Low strength of inter-layer bonding

➡ **Optimize the printing parameters to gain maximum mechanical performances**

What criteria should be considered?

- Maximize tensile strength in the fiber direction
- Improved inter-layer bonding strength



Composite fiber co-extrusion technology

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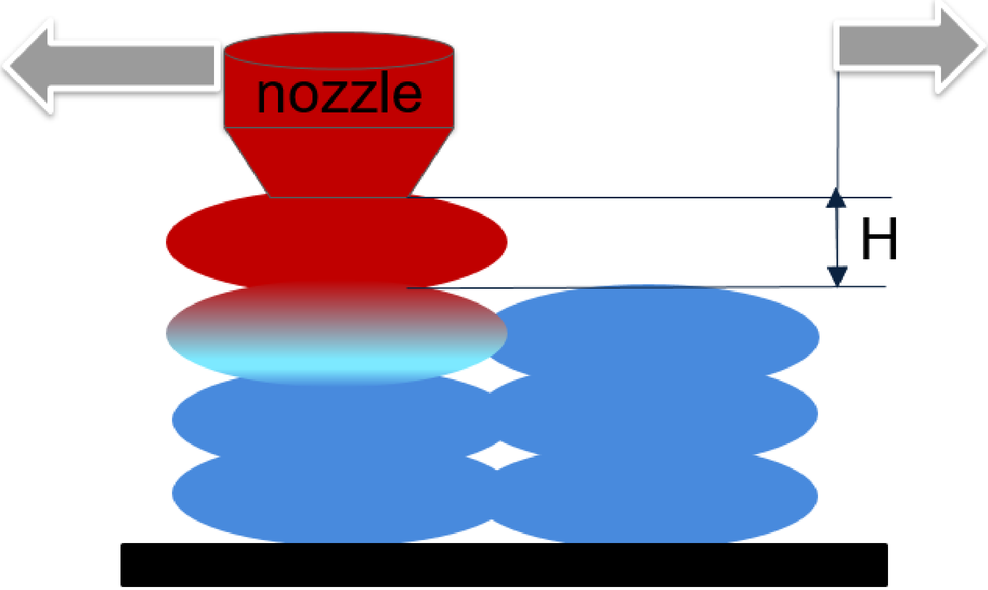
INTRODUCTION

What parameters need to be optimized?

Effect of nozzle temperature

- Variation in thermal history
- Improvement of flowability
- Enhanced impregnation of CCF in matrix PETG
- Improvement of molecular mobility facilitating interdiffusion across the interface

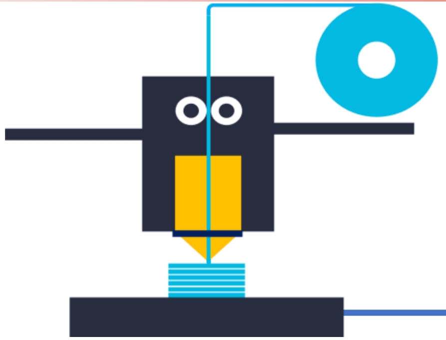


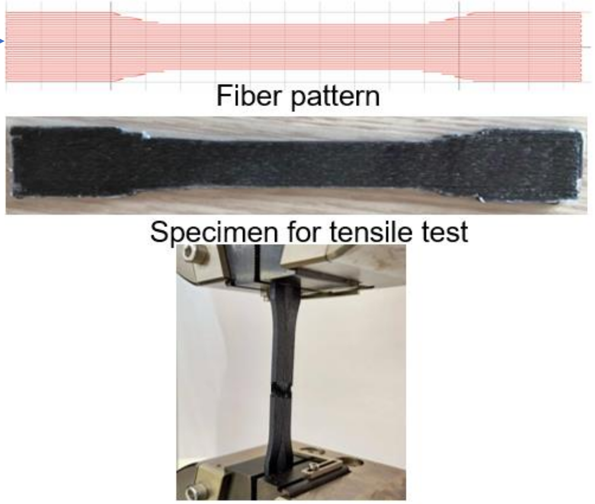
Effect of layer height

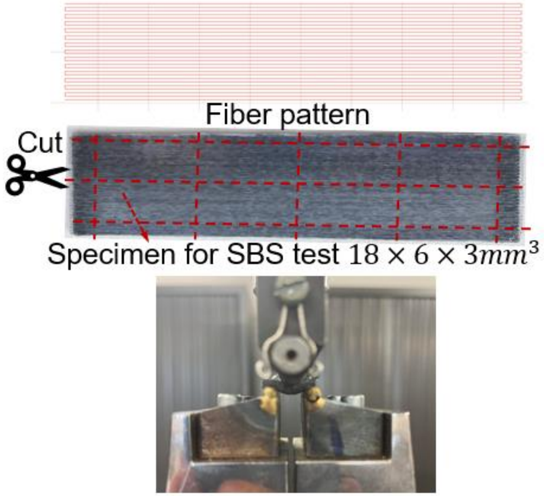
- Modified of carbon fiber content in 3D printed composite parts
- Variation in contact pressure between nozzle and deposited material
- Reduced interlayer voids
- Enhanced interlayer bonding

METHODOLOGY

3D printing of samples







Analysis methods:

- Analysis of variance (ANOVA) was performed to determine the significance of the studied parameters in order of influence on the mechanical performance.
- The response surface method (RSM) was used for the prediction of the mechanical performance as a continuous function of the studied parameters:

$$Y = \beta_0 + \sum_{i=1}^{N} \beta_i X_i + \sum_{i=1}^{N} \beta_{ii} X_i^2 + \sum_{i \neq j}^{N} \beta_{ij} X_i X_j + \varepsilon$$

Run	Variables		Responses	
	T_n(°C)	H(mm)	Tensile strength $\sigma(MPa)$	ILSS (MPa)
1	220	0.36	412.61±4.41	22.78±1.24
2	240	0.36	413.44±12.83	24.15±0.23
3	260	0.36	435.82±4.09	26.47±0.53
4	220	0.4	381.45±18.59	22.71±051
5	240	0.4	391.70±4.34	23.21±0.60
6	260	0.4	408.07±8.29	24.95±0.35
7	220	0.5	324.84±6.33	20.41±0.23
8	240	0.5	330.21±7.91	20.70±1.06
9	260	0.5	377.50±20.05	21.25±0.87

RESULTS

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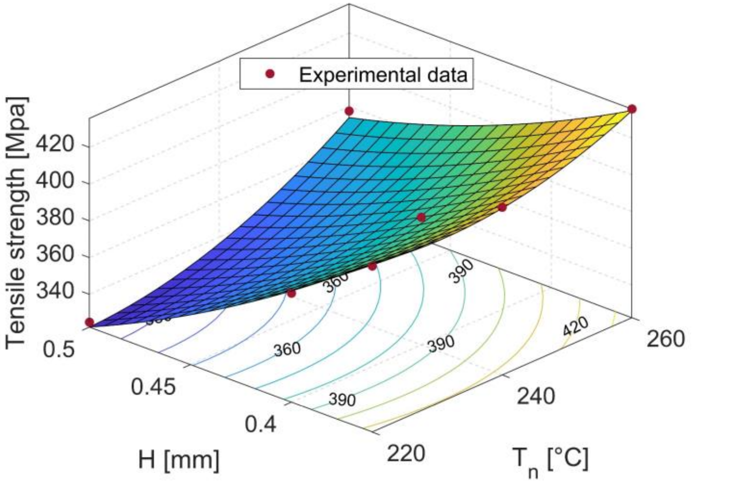
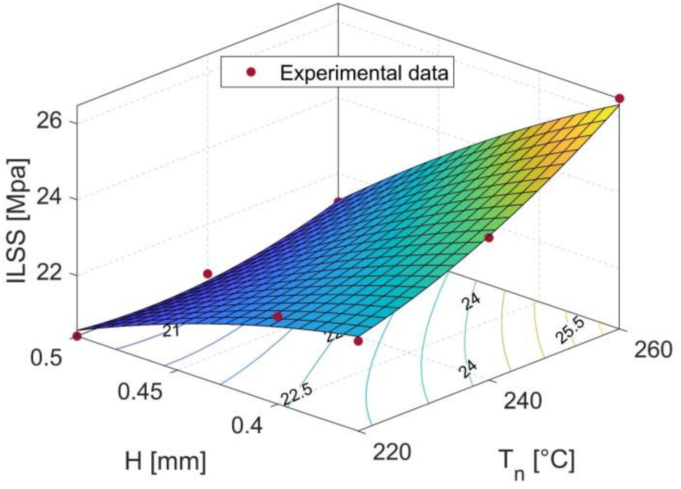
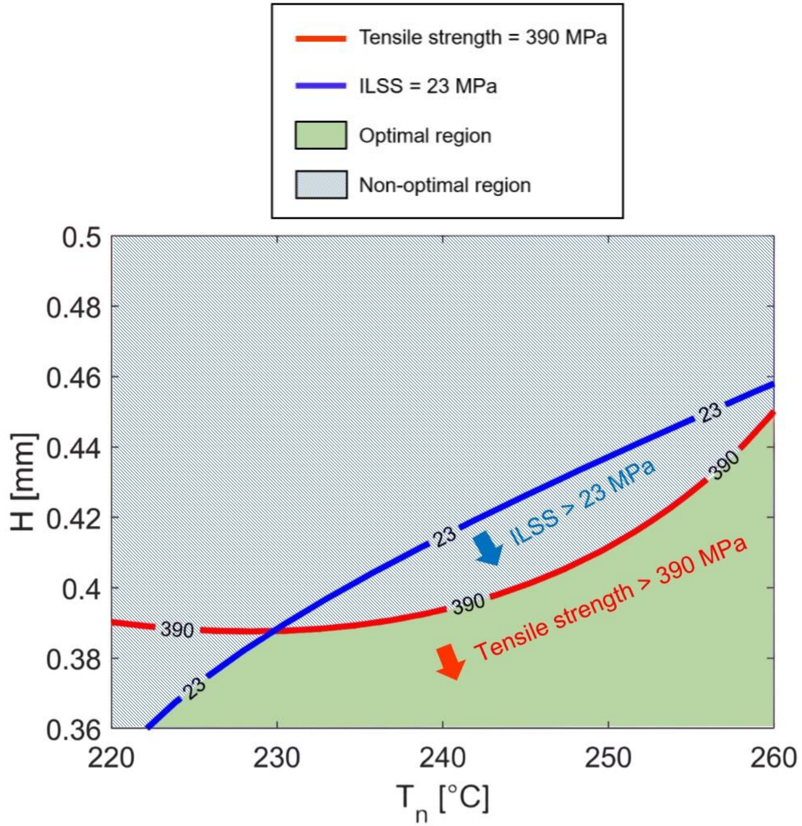
Response surface of tensile strength



Response surface of ILSS





Design of multi-response optimization

ANOVA for tensile strength

Source	DF	Adj SS	Adj MS	F-Value	p-Value	Remark
T_n(°C)	2	6059.4	3029.7	12.61	0.004	Significant
H(mm)	2	27063.2	13531.6	56.32	<0.001	Significant
$T_n \times H$	4	1101.1	275.3	1.15	0.367	Insignificant
Error	18	4324.7	240.3			
Total	26	38548.4				

ANOVA for ILSS

Source	DF	Adj SS	Adj MS	F-Value	p-Value	Remark
T_n(°C)	2	39.953	19.9767	19.81	<0.001	Significant
H(mm)	2	111.779	55.8895	55.41	<0.001	Significant
$T_n \times H$	4	10.643	2.6607	2.64	0.05	Insignificant
Error	36	36.311	1.0086			
Total	44	198.686				

CONCLUSIONS

- The nozzle temperature and the layer height have a significant impact on the tensile strength and the interlaminar shear strength of the 3D printed continuous carbon fiber-reinforced PETG composites.
- Optimal range of values for the nozzle temperature, and the layer height were determined satisfying the requirements for the mechanical performances of the 3D printed composites using RSM.

THANK YOU

Do you have any question ?