



Abstract

PLA and PLA/CF tensile test specimens were fabricated with a FDM 3d printer and different printing parameters. Test showed that PLA/CF was superior in terms of yield stress, ultimate stress and young's modulus while PLA superior in fracture strain. These results show that there is a trade-off between strength and plasticity when carbon fibers reinforces in PLA.

Keywords : Additive Manufacturing; Carbon Fiber Reinforcement; Mechanical Properties

Introduction

PLA and PLA/CF are commonly used in FDM 3d printing [1]. Their mechanical properties are strongly influenced by printing parameters like temperature, speed, layer height and orientation [2, 3]. This study compares the tensile behavior of PLA and PLA/CF specimens which are produced under different printing parameters to evaluate the effect of carbon fiber reinforcement on raw PLA..

Materials and method

PLA and PLA/CF filaments (JamgHe, 1.75mm) were used to make tensile specimens (ASTM D638). PLA/CF contained 15-20% short carbon fibers. Specimen was designed in Solidworks and sliced in Bambu Studio and then printed on Bambu Lab X1 Carbon with 0.4 mm hardened steel nozzle. Printing parameters are temperature (200, 215, 230°C), speed(50, 75, 100 mm/s), layer height (0.1, 0.2, 0.3 mm) and build orientation (0°, ±45°, 90°). Using a Taguchi L9 design 9 sample sets were generated by Design-Expert for both PLA and PLA/CF. Tensile tests were performed by Santam STM-20 universal testing machine equipped with an extensometer. Table 1 shows sample sets designed by Taguchi L9 design. Figure 1 shows a sample of tensile test made with PLA.

Table. 1 Taguchi L9 design

Set	Temperature	Speed	Orientation	Layer Height
Sample 1	T1 (200 °C)	V1 (50 mm/s)	0°	0.1 mm
Sample 2	T1 (200 °C)	V2 (75 mm/s)	90°	0.2 mm
Sample 3	T1 (200 °C)	V3 (100 mm/s)	±45°	0.3 mm
Sample 4	T2 (215 °C)	V2 (75 mm/s)	±45°	0.1 mm
Sample 5	T2 (215 °C)	V3 (100 mm/s)	0°	0.2 mm
Sample 6	T2 (215 °C)	V1 (50 mm/s)	90°	0.3 mm
Sample 7	T3 (230 °C)	V3 (100 mm/s)	90°	0.1 mm
Sample 8	T3 (230 °C)	V1 (50 mm/s)	±45°	0.2 mm
Sample 9	T3 (230 °C)	V2 (75 mm/s)	0°	0.3 mm



Fig. 1 Tensile test sample made of PLA

Results and Discussion

Among the nine samples, the results show that PLA/Cf specimens provided higher values in almost every cases in term of yield stress, yield strain and young's modulus, while PLA showed advantage in term of fracture strain. That's because by adding carbon-fibers to PLA, fracture occurs earlier and causes PLA behave more brittle. On the other hand, it increases the strength of composite. Figure 2 shows the stress-strain curves of 9 samples of PLA and PLA/Cf for comparison. The blue curves indicate PLA and red curves indicate PLA/CF.

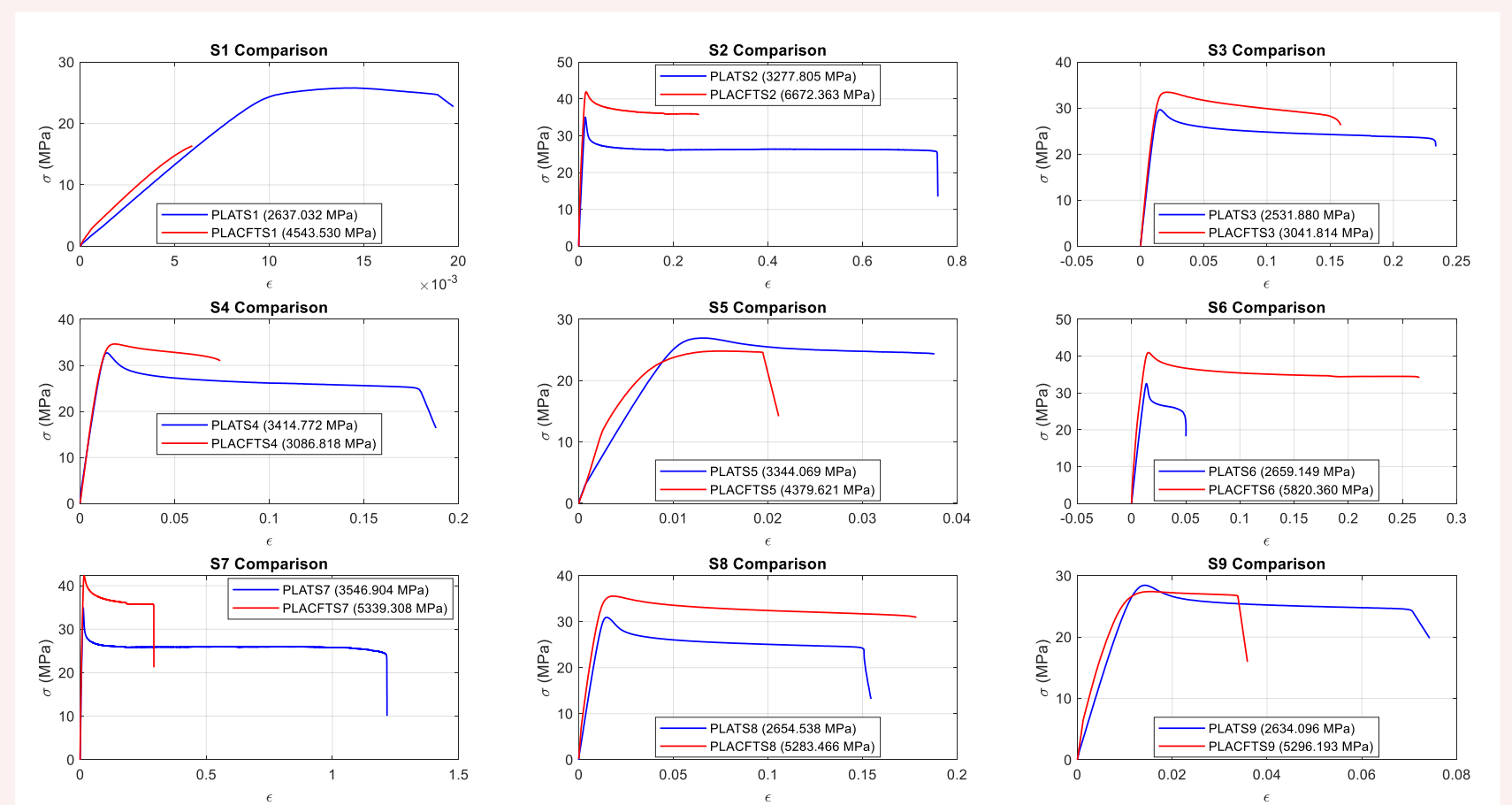


Fig. 2 PLA and PLA/CF Stress-strain curve comparison

Conclusions

Adding carbon fibers to PLA clearly changes material's behavior under tensile test. The composite (PLA/CF) turned out stronger and stiffer, showing higher yield stress, yield strain and Young's modulus in almost every case. However, PLA stretched further before breaking, which means PLA/CF is more brittle. In simple terms, PLA/CF is the better choice when strength and rigidity matter, while PLA is more suitable when flexibility and toughness are important. These results indicate that a trade-off happens between strength and plasticity by reinforcing carbon fiber.

References

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Approval