

Additive Manufacturing of Wholly Thermoplastic Composites

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Research Project: Processing Conditions Required to Generate Wholly Thermoplastic Composites for Use in Additive Manufacturing

Research Objective: Synthesize TLCP reinforced nylon composite filaments using dual extrusion for use in 3D printing, optimize 3D printing process for maximal mechanical properties of composite, and compare the properties of the 3D printed composite to those of injection molded TLCP reinforced thermoplastics.

Materials

TLCP reinforcement material (Thermotropic Liquid Crystalline Polymer), also known as Vectra B950, is an aromatic copolyesteramide. Regular nylon is used as the matrix material.

Procedure

TLCP reinforced composite has been widely used in different application due to their lightweight, high strength and stiffness, chemical resistance and great recyclability [1-8]. In this work, TLCP reinforced nylon composite has been developed for using in 3D printing process. TLCP reinforced nylon filaments were generated using dual extrusion, a process by which two single crew extruders are used to individually process two plastics at their optimal processing temperature and pump them directly into a T junction in which a reinforcement material is dispersed throughout a matrix material via a static mixer, then extruded out of a nozzle and cooled in a water bath. Different pumping speeds were controlled via individual gear pumps connected to each extruder. Pump speeds were adjusted to produce 20 wt% TLCP/nylon composite. The filament was then collected and prepared for use in 3D printing.

Using a Pulse 3D printer, TLCP reinforced nylon filament was used to produced tensile bars at several different processing temperatures. Temperatures between 250 and 270°C were used at a bed temperature of 80°C to compare the effect of printer nozzle temperature on the mechanical properties of the composite. Other printing parameters were 0.6 mm diameter nozzle 20 mm/s printing speed, 0.2 mm layer height, and 100% infill.

Injection molded parts were prepared with pelletized 20 wt% TLCP/nylon filament. Plaques were molded that can be cut into tensile bars in both the transverse and flow direction. Injection molding parameters were a barrel temperature of 260°C and mold temperature of 60°C.

Results

The effect of printing temperature on the mechanical properties of the 20 wt% TLCP/nylon composite was determined. [9-17] Figure 1 and 2 show both an increasing tensile modulus and strength with print temperature. This is likely due to higher temperatures giving the polymers more time to diffuse and entangle with each other, leading to greater interlayer adhesion. The highest temperature tested, 270°C, yielded the greatest mechanical properties, improving pure nylon's tensile modulus and strength by 240% and 50% respectively. The mechanical properties of the 3D printed composite were compared to those of injection molded composite.

The injection molded TLCP/nylon composites were significantly weaker than their 3D printed counterparts, as can be seen on table 1. The 3D printed composites were much stiffer at nearly double the tensile modulus of injection molded composites (3.6 and 8.1.GPa for injection molded and 3D printed composite, respectively). Significant improvements in tensile strength were also noted, at 61.3 MPa for injection molded composites and 75.2 MPa for 3D printed composites. The mechanical improvements can be attributed to fiber length. When TLCPs are injection molded, the fibers can break down and only form longer fibers in the parts of the mold where higher extensional forces are present, but otherwise the fibers remain short or form other non-fibrous shapes. In the 3D printed parts, the filament contains continuous fibers of TLCP throughout, allowing continuous reinforcement throughout the whole printed part.

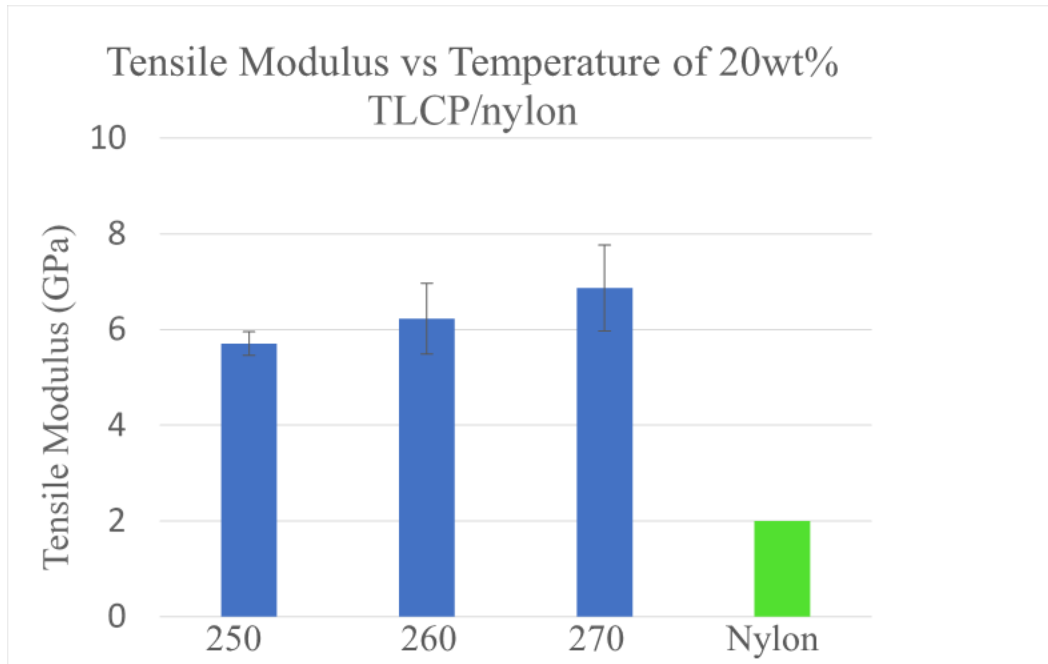


Figure 1. Tensile Modulus of 3D printed TLCP/nylon at different printing temperature

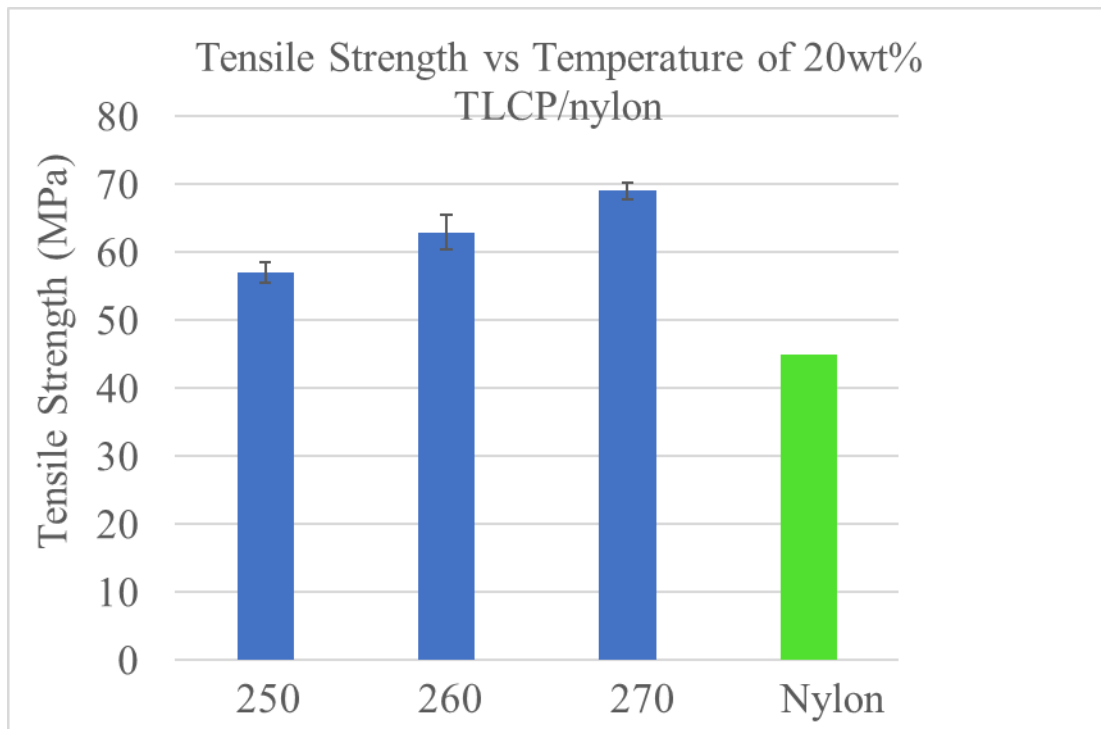


Figure 2. Tensile strength of 3D printed TLCP/nylon at different printing temperature

Table 1. Tensile properties of 3D printed TLCP/PA material and injection molded counterpart

Samples Properties	Injection molded 20wt% TLCP/PA	3D printed 20wt% TLCP/PA
Tensile Modulus (GPa)	3.6±0.13	8.1±0.6
Tensile Strength (MPa)	61.3±2.3	75.2±5.6

Conclusion

20 wt% TLCP/nylon composites were prepared via several processing techniques and their mechanical properties were tested. Filaments exhibiting continuous TLCP fibers produced via dual extrusion showed excellent properties when used to create 3D printed parts at an optimal printing temperature of 270°C. The injection molded parts showed less favorable mechanical properties, mostly due to discontinuous and broken-down fibers.

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