Composites Additive Manufacturing Technical Brief

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Introduction:

Additive manufacturing (AM), colloquially known as 3D printing, is a disruptive technology whose influence is becoming ever more prevalent as the associated technologies progress. While AM has most often been used for rapid production of prototypes, AM is shifting toward the production of end-use, multifunctional components for a wide variety of applications.

Composites are a class of materials well acknowledged for having high strength to weight ratios. As such, composites have been of significant interest for aerospace applications. The combination of composite materials with AM opens a variety of doors in terms of composite design. As AM technology advances and becomes more prolific, so too does composites based AM (CBAM).

CBAM technology is often performed using a polymer AM fabrication method, though this is not always the case. The details of these methods can be found in the polymer AM technical brief. This document describes a variety of CBAM technologies that are available for use to commercial and military entities.

Reinforced filament:

A common method of achieving composite reinforcement is the addition of fiber reinforcement to fused filament fabrication (FFF) filament. Some available reinforcement types are carbon fiber, glass fiber, carbon nanotubes, and aramid fibers. Filament vendors have been adding the reinforcement to a number of thermoplastic feed materials including acrylonitrile butadiene styrene (ABS), Nylon, Polycarbonate, and poly ether ether ketone (PEEK) among others. The addition of reinforcement has been shown to increase tensile strength and stiffness of resultant parts [1,2].

The increase in mechanical performance does come with some tradeoffs. Reinforced filaments will be costlier and often require different processing parameters for part fabrication. Additionally, it has been shown that the addition of carbon fiber reinforcement can significantly reduce interlayer fracture toughness [3], though this shortfall in fracture toughness may be partially rectified with proper control of processing parameters.

Vendors:

- 3DXTech
- Nanovia

Sources:

[1] Ning, Fuda, et al. "Additive manufacturing of carbon fiber reinforced thermoplastic composites using fused deposition modeling." Composites Part B: Engineering 80 (2015): 369-378.

[2] Zhong, Weihong, et al. "Short fiber reinforced composites for fused deposition modeling." Materials Science and Engineering: A 301.2 (2001): 125-130.

[3] Young, Devin, Nelson Wetmore, and Michael Czabaj. "Interlayer fracture toughness of additively manufactured unreinforced and carbon-fiber-reinforced acrylonitrile butadiene styrene." Additive Manufacturing (2018).

Markforged Continuous Fiber Reinforcement:

Markforged offers a number of FFF 3D printers that are capable of reinforcing plastic parts with continuous carbon fiber tows. This produces parts with mechanical properties far exceeding an unreinforced part. These gains in mechanical properties are sufficient to use the resultant parts in end-use and structural applications, including tooling. Markforged printers are available in industrial and desk top formats.

Link: Markforged.com

Cosine Additive:

Cosine Additive manufactures the AM1 FFF printer. Some features of the AM1 are a large build volume, filament or pellet fed FFF printing, and high temperature extrusion (up to 500° C). By taking advantage of these features, the AM1 has been used to produce tooling for layup and thermoforming, among other applications, by utilizing composite feedstock material. Additionally, the pellet feed feature is 10 times faster than filament feeding, making the AM1 capable of very quick prints.

Link: Cosine Additive

Continuous Composites:

Continuous Composites describes their manufacturing method as a "moldless, Out of Autoclave (OOA) manufacturing process.". Continuous Composites offers a method for printing a variety of continuous fibers including carbon fiber, fiberglass, Kevlar, fiber optics, copper and nichrome wire. The Continuous Composites printer consists of an extrusion tool head attached to a multi-axis robot arm.

The printing process itself acts as a combination of the FFF extrusion method combined with the resin curing aspect of stereolithography. The extruded fiber is covered with a thermoset resin which is immediately cured by a UV light source after leaving the tool head. This enables the printer to fabricate parts with completely horizontal overhangs with no support structures, a feature usually unachievable outside of some polymer powder-bed methods. By printing fiber optics and conductive wire, the Continuous Composites printer is capable of building in functionality to the composite parts.

Link: Continuous Composites

EnvisionTEC:

The Selective Lamination Composite Object Manufacturing printer (SLCOM 1) from EnvisionTEC fabricates objects from woven composite sheets. The sheets are impregnated with a thermoplastic resin and selectively laminated together in the desired object shape. There are a number of options to choose from for both the thermoplastic resin and the fiber reinforcement. Available resin options are PEEK, polyetherimide (PEI), and polypropylene among others. Options for reinforcement include fiberglass, carbon fiber, and Aramid fibers. The SLCOM 1 printer is intended for industrial use and could be of particular interest for aerospace applications.

Link: EnvisionTEC SLCOM 1

Impossible Objects:

The Impossible Objects CBAM printer fabricates composite parts from sheets of short chopped carbon fiber. Each layer of the part is composed of one chopped carbon fiber sheet. A wetting fluid is selectively sprayed onto the sheet according to the layer's cross-sectional area. A thermoplastic powder (e.g. Nylon, PEEK) is applied to the sheet, only sticking where the wetting fluid has been added. Excess powder is removed and the next sheet is placed on top of the previous one. After all layers have been printed, the stack of sheets is placed into a heated press to bond the layers together. Finally, the part is taken from the press and placed in a bead blasting cabinet where excess fibers are removed. This results in light composite parts with good mechanical properties, desirable for aerospace applications.

Link: Impossible Objects