University College Dublin
Ireland's Global University

School of Engineering

Department Materials Engineering

3D printing of continuous stainless steel wire composite parts

Alison Clarke

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Abstract

Additive manufacturing (AM) builds parts by adding a layer of material to a previous layer to make the desired shape, also known as 3D printing. Better known for printing polymers, but metal parts are also produced in this way. This project investigates if the 3D printing technique called fused filament fabrication, can be used to print a stainless-steel wire reinforced polymer composite. A fine stainless steel continuous wire fibre (SSF) is embedded into a polymer filament to making a composite filament, parts are then made by 3D printing without the use of extreme heat. Commercial SSF is only 14 microns, smaller than most human hair. A baby average hair diameter is 50 microns and an adult's 80 microns.

Most metal AM works by melting or sintering the raw material to the previous layer. Sintering is a heat treatment that bonds metal powder particles, lower than the melting temperature of the material. Raw material comes in two forms, a powder or wire, known as feedstock. Power AM is generally known as Powder Bed Fusion. Achieving more complicated and delicate shapes than in other manufacturing processes. It can be slow with a lot of waste and expensive specialist equipment is needed. Wire Arc Additive Manufacturing is mainly welding. Faster than PBF with low material waste and easily accessible, affordable equipment. Both powder and wire have high heat transfers that can damage the parts. Less well used than powder, up until recently, wire AM has only been a hot manufacturing process.

Wire is made in a similar way to making Play-Doh strings, by pushing it through a shape, called a die, but wire pulled through a much stronger die. To reduce a wires diameters, multiple dies can be set up one after another, but don't get down to SSF diameters of 14 microns. Made by a specialist wire drawing process, called 'bundle wire drawing', the company NV Bekaert SA designed and patented the process to make SSF [1].

3D printed polymers parts are relatively quick to make but have low strength. The polymer material is melted in the printing nozzle and extruded, now molten it sticks to the cooled previous layer, building a part. Research into combining polymers with other materials, such as carbon or metal, finds significant improvement strength and flexibility known as fused filament fabrication. Two methods to add the material are firstly by combining materials in the printer's extrusion head, and secondly by making a filament and then 3D printing. The second method will be used to make SSF composite filament.

Using a modified extruding machine, a composite filament is made with a polymer and SSF. The SSF is introduced into the molten polymer with a special nozzle, coating the SSF. Specialist microscopes and tests determine the structural and internal changes after being made, stretched in different directions, squashed, and broken. Potential for the composite parts is in textiles, automotive and marine applications.

[1] J. D. Baerdemaeker and J. Vleurinck, "An Introduction to Metal Fibre Technology," *Whitepaper*, pp. 1–9, 2017.