CQFA CARREFOUR QUÉBÉCOIS DE LA FABRICATION ADDITIVE

CASE STUDY

DEVELOPING HIGH PERFORMANCE POLYMERS (HPP) FOR ADDITIVE MANUFACTURING OPTIMIZATION BY FUSED POLYMER FILAMENT DEPOSITION (FDM)

Project duration
2019 and 2020 (18 months)

Partners
Fonds de recherche du Québec – Nature et technologies (FRQNT)

Materials
High performance polymers (HPP)

Processes
Fused Deposition Modelling (FDM)

Application fields
Aeronautics

OBJECTIVE

Creating high performance filament using high performance polymers (HPP) to provide good interlayer adhesion and mechanical properties that are superior to those of base materials.

BACKGROUND

3D printing by fused filament deposition (FDM) is a layer-by-layer manufacturing process used to produce parts with a high level of complexity that would normally be unattainable through traditional manufacturing processes like injection moulding. This particular 3D printing process is the most widely used on the market due to its simplicity, low cost and wealth of available materials. It can create prototype and functional parts quickly and at low costs, while avoiding the design and manufacturing steps involved with production tooling.

THE CHALLENGE

When compared to parts obtained through traditional processes like injection molded, parts printed using FDM technology show inferior and anisotropic mechanical properties (uneven along the printing axis), particularly due to insufficient interlayer adhesion. These parts often reveal inadequate dimensional characteristics due to shrinkage and warping, especially when manufacturing larger parts. These constraints severely restrict the use of FDM for high technology applications, including those associated with the aeronautics sector. A number of strategies have been used to limit these HPP-related effects, many of which show tremendous potential for the aeronautics sector. HPPs (PEI, PPS, PEEK, PSU, PPSU, etc.) are well known in the plastics sector due to their exceptional thermal, thermomechanical and mechanical properties, all of which points to the short-term adoption of these polymeric materials for certain applications, especially those involving metal parts. These materials are not yet widely used in FDM, as they require printing processes and formulations that are adapted to the constraints of additive manufacturing.

This could be achieved by the following: 1) Optimizing the FDM process printing parameters for HPPs; 2) Limiting shrinkage by incorporating low linear thermal expansion coefficient fillers into HPPs; 3) Increasing interlayer adhesion by optimizing printing parameters and implementing innovative new technology.

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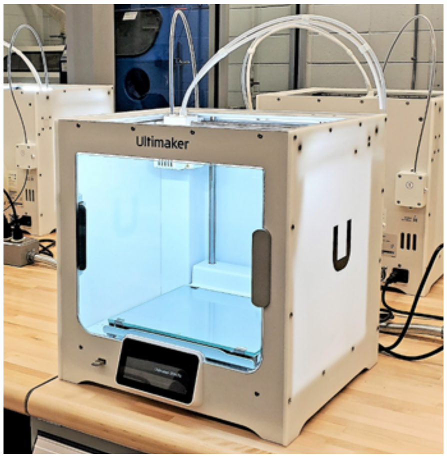
COALIA laboratory



COALIA laboratory

THE SOLUTION

To reduce the thermal expansion coefficient (TEC) in polyphenylene sulphide (PPS), carbonaceous fillers were selected, as well as inorganic fillers with a low thermal TEC. Certain fillers even had a negative TEC. The fillers were then incorporated and dispersed into the polymer matrix using a twin screw extruder.

Samples were compression molded from the resulting pellets to produce standardized samples, which were then used to perform thermal (differential scanning calorimetry-DSC and thermogravimetric analysis-TGA), mechanical (tensile and Izod impact) and thermomechanical (dynamic mechanical analysis-DMA) characterization tests. A rheological study was also conducted using the melt flow index (MFI) to compare the viscosity of the various mixtures in a molten state. The thermomechanical analysis apparatus (TMA) was also used to study the evolution of the linear thermal expansion coefficient (TEC) for the various mixtures produced.

In parallel, 3D printing filaments with diameters of 1.75 mm (± 0.05 mm) were manufactured using a single screw extruder. These will be used for 3D printing trials on an AON-M2 printer manufactured in Quebec.

BENEFITS/RESULTS

One of the fillers studied was selected for its ability to reduce the resulting mixture's TEC by roughly 30%; its use could therefore reduce shrinkage, delamination, plate separation and warping during printing.

The next phase of the project will involve 3D printing trials with comparative parts using the new formulation. The parts' mechanical properties will be analyzed and the resulting hypothesis will be verified to precisely establish whether or not the various mixtures help reduce shrinkage, delamination, plate separation and warping during printing.

CONTACT

COALIA
671 Frontenac Boulevard West, Gate 7C
Thetford Mines, QC, G6G 1N1
418-338-6410
Andro Vachon
avachon@cegepthetford.ca