CQFA CARREFOUR QUÉBÉCOIS DE LA FABRICATION ADDITIVE

CASE STUDY

ROBOT-ASSISTED ADDITIVE MANUFACTURING OF MULTIFUNCTIONAL COMPOSITES

Project duration

Ongoing since early 2018

Partners

Safran Group (France), Ariane Group (France), Canadian Space Agency, NanoXplore, MEKANIC, Solaxis, NRC

Materials

Carbon fiber-reinforced thermoplastics (PEEK, PEI, Nylon, PLA), Thermosets (filled epoxy).

Processes

Fused Filament Fabrication (FFF), Extrusion-based 3D printing (Direct-ink writing)

Application fields

Aerospace, Transportation, Energy

OBJECTIVES

Multifunctionality of parts (e.g., enhanced acoustic and mechanical properties), Automation, Manufacturing complex and more performant parts, Reducing cost and weight, Rapid manufacturing of large parts.

BACKGROUND

Additive manufacturing (AM) allows the layer-by-layer fabrication of parts featuring complex geometries that usually cannot be achieved using conventional manufacturing methods (e.g., injection molding). This technology provides design freedom, reliability and cost-effectiveness (e.g., no capital investment when starting a new production). Various industries, including aerospace and transportation, have taken major steps towards incorporating AM technologies, mainly Fused Filament Fabrication (FFF), relying on thermoplastics into their activities (e.g., manufacturing custom components, part repairs). The current activities of the aerospace industry are focusing on using AM to manufacture tooling, fixtures and some limited parts. This industry is also exploring the use of AM for the manufacturing of customized non-structural parts. Our goal at the Laboratory of Multiscale Mechanics (LM2) at Polytechnique Montreal is to manufacture large-scale industrially-approved parts featuring multifunctionality, shape complexity and lightweight by further development of AM technologies (i.e., FFF and extrusion-based direct-writing of thermosetting materials).

THE CHALLENGE

Commercial 3D printers designed for the industry are offering large build envelope (up to 914 × 610 × 914 mm3) while choices of material filaments are still very limited. Moreover, this current AM technology largely operates in a closed-source environment: the users cannot modify the printing parameters and the materials are provided only by the printer manufacturer at a very high cost. The open-source FFF process is currently in the early stage of development with several important issues to be solved such as: (1) limited availability of commercial high-performance thermoplastic filaments, (2) limited operating temperature not compatible with high temperature-resistant thermoplastics, (3) relatively weak mechanical properties of the printed parts when compared to the same parts obtained by traditional manufacturing processes, (4) relatively small printing envelope, and (5) very low production rates.

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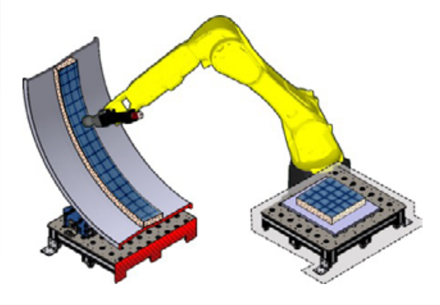

Robot-assisted non-planar additive manufacturing of multifunctional composites (Courtesy of Jean-Francois Chauvette)

THE SOLUTION

In collaboration with a large network of industrial partners, the LM2 research group at Polytechnique Montreal is developing new high-performance multifunctional composite materials and open-source additive manufacturing concepts for the creation of industrially approved parts. Our recent works have focused on rapid non-planar additive manufacturing of large composite structures and abradable acoustic coatings featuring high mechanical and acoustic performances for aerospace industry. Through an efficient mixing/manufacturing approach, we formulated and fabricated printable filaments of reinforced high temperature-resistant thermoplastics (i.e., PEEK, PEI) with excellent mechanical properties comparable or exceeding those of commercial products. These materials are being used for 3D printing of geometrically optimized sandwich structures aiming to achieve multiple functionalities such as lightweight, highly improved sound absorption efficiency and high mechanical performance in aircraft engines or composite lunar rovers. On the manufacturing side, we developed a customized 6-axis robot-assisted printing platform for rapid non-planar additive manufacturing of large sandwich panels using our developed composite formulations (see Figure). A hydraulic-operated multi-nozzle printing head, designed in collaboration with MEKANIC, is also mounted on the robot arm to perform the high-speed deposition of epoxy-based abradable materials on non-planar complex surfaces (e.g., engine fan case).

BENEFITS/RESULTS

The 6 Degree-of-Freedom additive manufacturing process developed by the team allows full control of the composite's orientation in 3D space, improve their out-of-plane properties, and accelerate the overall process productivity. The high-performance thermoplastic composite materials and the cost-effective additive manufacturing strategies (when compared to the industrial printers) developed here will provide a workable option for 3D printing fabrication of large parts for the aerospace industry. The printing platform enables nonplanar printing of large parts or coatings when our multinozzle is mounted. The epoxy-based materials were designed to be printable in the multi-nozzle (i.e., 26 nozzles) for their rapid direct deposition (e.g., 220 mm/s) and to achieve multi-functionality (i.e., lightweight, acoustic and abradable). This very recent printing platform represents the next evolution in automated deposition of abradable materials, currently being applied manually or by thermal spraying methods, allowing greater control of the coating geometry and adding other functionalities to the deposited coatings for future aircraft engines. Finally, the LM2 team develops new slicing methods for processing of CAD data required for the fabrication of parts directly on nonplanar surfaces (e.g., engine fan case).

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