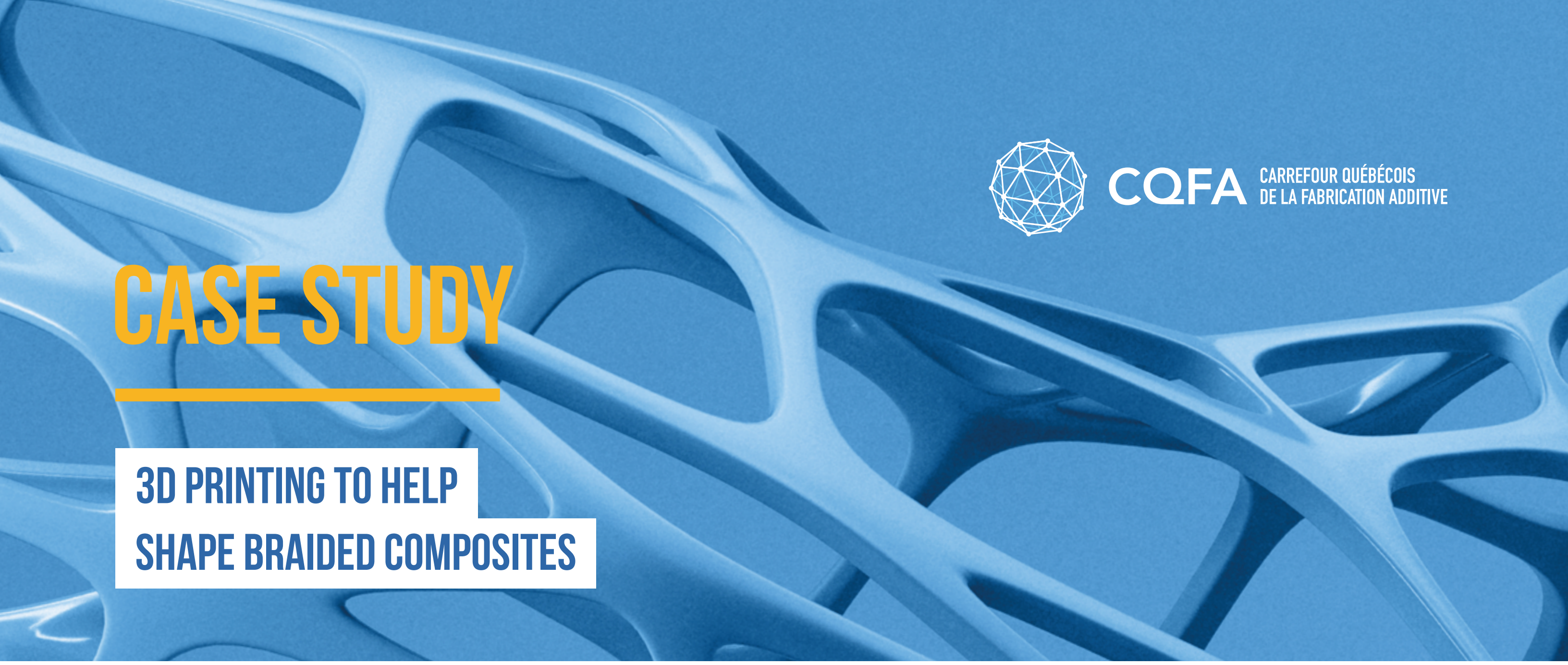

CQFA CARREFOUR QUÉBÉCOIS DE LA FABRICATION ADDITIVE

CASE STUDY

3D PRINTING TO HELP SHAPE BRAIDED COMPOSITES

Project duration

April 2018 to October 2021

Partners

Laboratoire de Structures de Fibres et Composites Avancés (labSFCA, Polytechnique Montréal), Centre Technologique en Aérospatiale (CTA), CTT Group (gCTTg), SphèreCo Technologies Inc.

Materials

Acrylonitrile butadiene styrene (ABS) and polyetherimide (or PEI plastics)

Processes

Fused deposition modelling (FDM)

Application fields

Aeronautics

OBJECTIVES

To 3D print prototype tooling for robotic braiding assistance and for resin vacuum infusion moulding, that would use to develop aeronautical parts.

BACKGROUND

Commercial aircraft are currently made with several composite components. The aircraft's structural composite parts are made from carbon fibres bonded by a polymer matrix. To produce these parts, the fibres are first assembled with an organized woven reinforcement. This reinforcement is then draped over the tooling before transferring a liquid polymeric resin to impregnate the carbon fibres. Heat treatment is then used to cross-link or solidify the resin. Each stage of this process is validated through the production of parts in an effort to maintain their quality, repeatability and performance while ensuring passenger safety. These validations require tooling that can cause development costs to balloon. The four project partners therefore joined forces to develop a composite aircraft fuselage frame. The objective was to reduce tooling and prototyping costs with 3D printing.

THE CHALLENGE

The composite fabric, also known as fibrous reinforcement, is made using a braiding machine that interweaves carbon threads to shape a three-dimensional braid. The threads are deposited on a moving mandrel through a braiding machine using a 6-axis robot. But the mandrel's design creates challenges in terms of its size and mass. The alignment of sections must be perfect and free of surface defects to avoid damaging the deposited carbon fibres. The tooling used to manufacture the vacuum infusion composite also creates challenges. Process temperatures reach 180°C. The tooling's mechanical strength must be guaranteed under these conditions. Another challenge involves the tooling's thermal expansion control (α_{therm}); it can induce deformations in the manufactured part because the polymers' α_{therm} is greater than that of metals. Attention is given to any possible dependence between the printing orientation and the tooling's α_{therm}. In addition, the polymer tooling interface must be inert to the part's consumables and materials, here the infusion resin. The final challenge involves the temporal evolution of the tooling's geometric integrity.

3D PRINTING TO HELP SHAPE BRAIDED COMPOSITES

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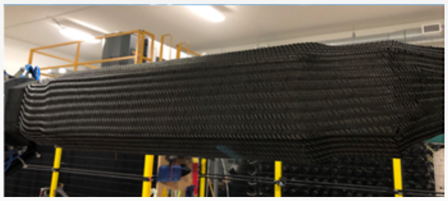

Figure 1 – 3D printed ABS mandrel covered by a carbon fibre braid.

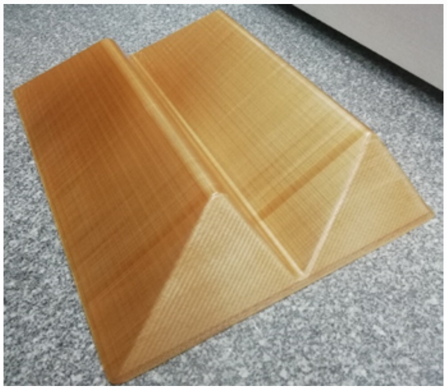

Figure 2 – 3D printed PEI mould for the vacuum infusion moulding of Z-section parts.

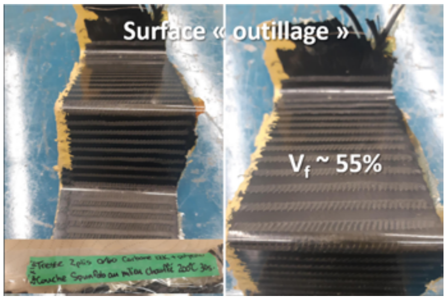

Figure 3 – Example of a Z-section composite part, preformed and moulded through vacuum infusion.

THE SOLUTION

ABS was chosen as the printing material for the multi-part braiding mandrel. Bolted metal rods were incorporated along the mandrel's main orientation to reinforce its mechanical bend resistance, bracing it against the robotic arm. The mandrel was also manufactured with a partial fill to limit mass and printing times. For the infusion tooling, the use of PEI allowed moulding at temperatures of 180°C without compromising the mould's structural integrity. A 30% volume fraction, grid type filling was used. Printed samples were produced to detect any dependence between their α_{therm} and their print orientation or fill fraction. Surface preparations were conducted on the area that comes into contact with the composite part. This involved sandblasting and the use of a PTFE adhesive film. This film provides the mould with a low-adhesion surface and a physicochemical barrier between the resin and the PEI. Finally, the tooling was measured before and after its use through a coordinate measuring machine (CMM) to ensure the mould's geometric integrity during the many heating and cooling cycles involved.

BENEFITS/RESULTS

The ABS mandrel helped braid the fabrics with different three-dimensional preform architectures. Figure 1 shows this mandrel covered by a carbon fibre braid. The mandrel accelerated the braiding's development at a low cost and with short printing times. The PEI mould, shown in Figure 2, was used to make eight composite parts by vacuum infusion. No dependence was observed between the printing orientation and the α_{therm}. The tooling's CMM measurements confirmed geometric integrity throughout its use. The tooling's surface preparation, shown in Figure 3, provided the moulded parts with a satisfactory finish. 3D printed tooling shows a great deal of potential when prototyping and moulding a small series of composite parts by infusion. The main advantages involve short manufacturing time and design flexibility.

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