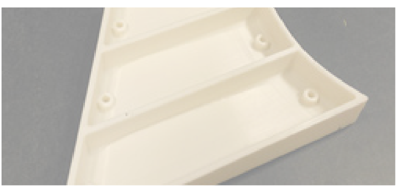
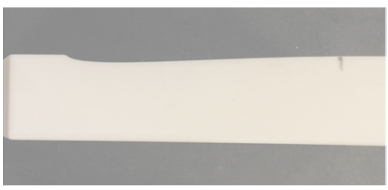
AMRC
Design and Prototyping Group

Case Study

The University Of Sheffield.
Advanced Manufacturing Research Centre
BOEING

Optimisation of FDM composite lay-up tooling for additive manufacture





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1 Summary

The AMRC Design & Prototyping Group designed and additive manufactured (AM) a suite of carbon composite lay up tools as part of a larger project. The tools were designed and manufactured quickly to produce a variety of components including upper and lower wing skins; the resulting carbon wing skins are located in position by adhesion to an AM frame. Initial CAD tool design (figure 1- 3) was created in approximately 1.5 hrs with minimal intent for AM design optimisation.

The initial AM tool design followed a somewhat traditional form with the two separate panels, one upper skin and one lower skin, each measuring approximately 400 mm x 400 mm x 50mm. Reinforcing ribs were added on the rear of each tool (figure 2) along with through-holes on flat faces to affix metallic strips aiding formation of desired return features (figure 1-2).

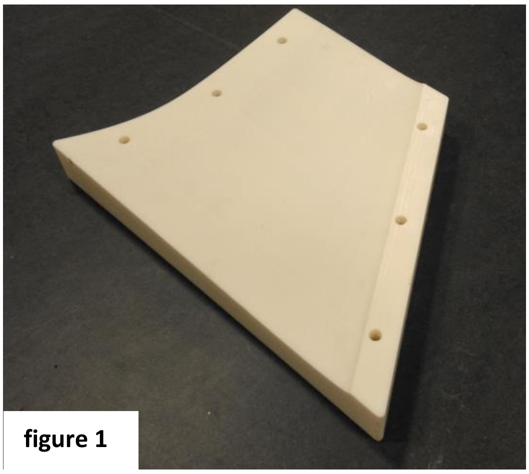

figure 1

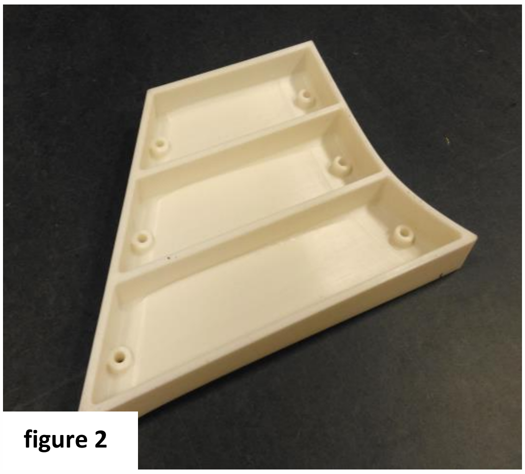

figure 2

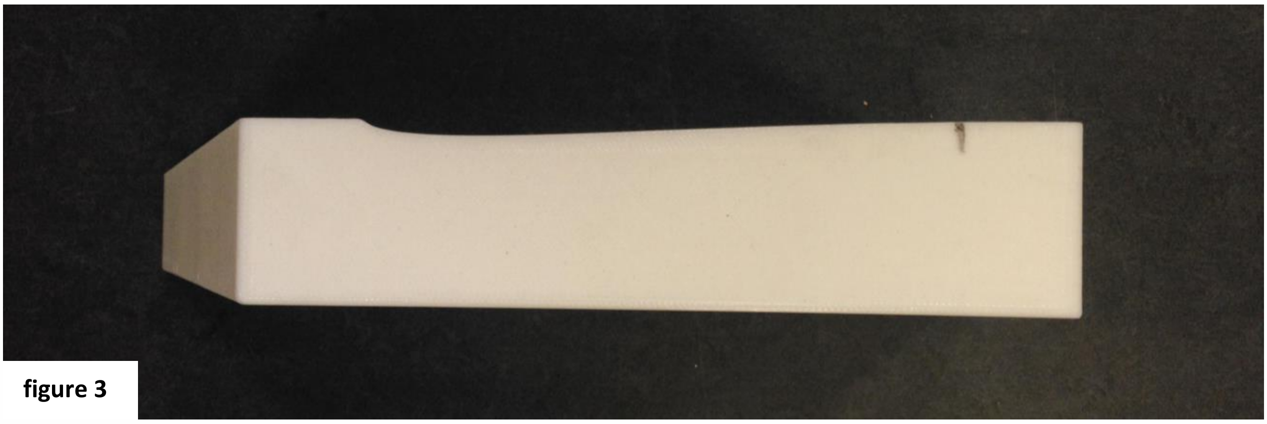

figure 3

2 Non-optimised manufacturing details for initial AM design – QTY X2 tools

- Print time: 74 hours 58 minutes
- Model material: 2,322 cm3
- Support material : 1,083 cm3
- Layer resolution: 0.254 mm
- Material type: ABS M30

CAD models are exported as STL file format before being processed through 'Insight' software associated with the Stratasys Fortus900mc production machine. The software introduces process parameters to the sliced STL in order to generate tool paths; importantly this data includes the width of deposited material bead. As with any process this knowledge is critical to the design phase and when implemented correctly both cost and time savings are significant:

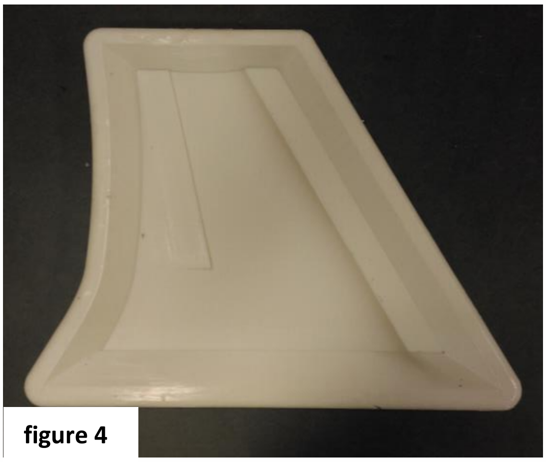

figure 4

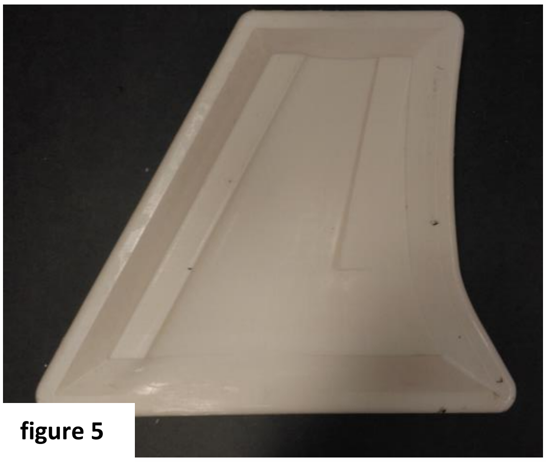

figure 5

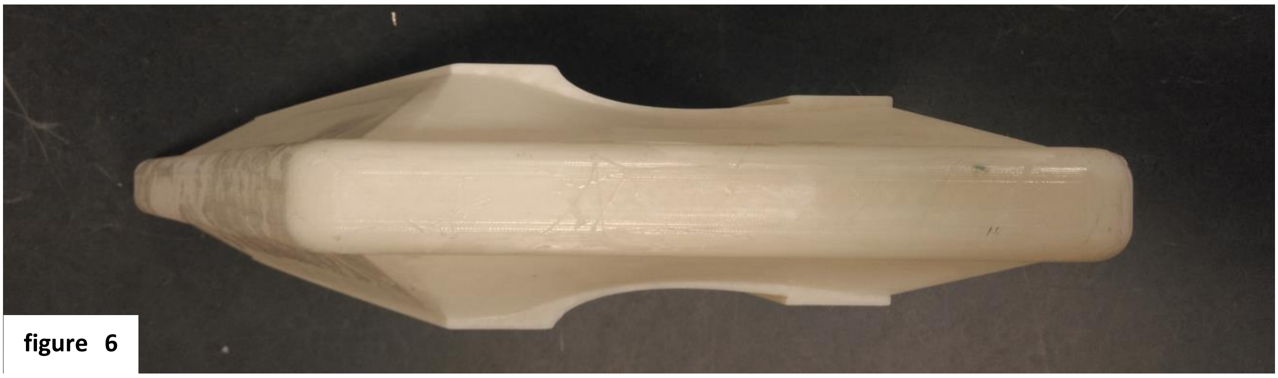

figure 6

3 Optimised manufacturing details for AM design with process knowledge - QTY X1 dual sided tool

• Print time:	40 hour 37 minutes	(45.8% decrease)
• Model material:	2,068 cm3	(10.9% decrease)
• Support material :	183.36 cm3	(83.0% decrease)
• Layer resolution:	0.254 mm	
• Material:	ABS M30	

The optimised tooling is intended to be larger than the original tool (figure 7) however by applying design for additive manufacture at the CAD stage the build time and overall material use was considerably reduced. Main alterations to the original design are as follows:

- Process information of toolpath deposit data that makes up the outer shell of the tool (contours) was used fed into CAD as a driving parameter.
- The tool was enlarged to introduce overhang areas to ease trimming (figure 4-5).
- Two layup moulds were merged into a single tool (figure 6).
- The interior of the tool was sparse filled (a non solid lattice interior).

Other design revisions include large radius edges to the tooling helping to eliminate punctures during the vac bag infusion process, and the sparse filled tool is light and manageable to use in contrast to traditional metallic alternative. Build orientation was with the height in the Z direction to ensure an optimum finish to the aerofoil form.

figure 7 - Comparison of the original tool (right), against the larger optimised version

Conclusion

This study demonstrates how build times for producing parts by AM can be significantly affected by a basic level of process knowledge, and that the resulting increase in productivity is almost directly attributed to design for AM.

Redesign of the tooling reduced build time by 45.8 per cent. The 83.0 per cent reduction in support material is mainly due to the removal of strengthening ribs, printing support material increases build time, but most of the additional time comes from the need to change heads between build material and support material for each layer. By filling the tool with a sparse lattice structure the mould strength was evenly and efficiently distributed throughout.

Tool face finish is an important factor as this is reflected in the final composite surface, although the tool was printed in the optimum orientation post process operations are still necessary but these operations have been minimised by foresight into FDM process capability.

Contact

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