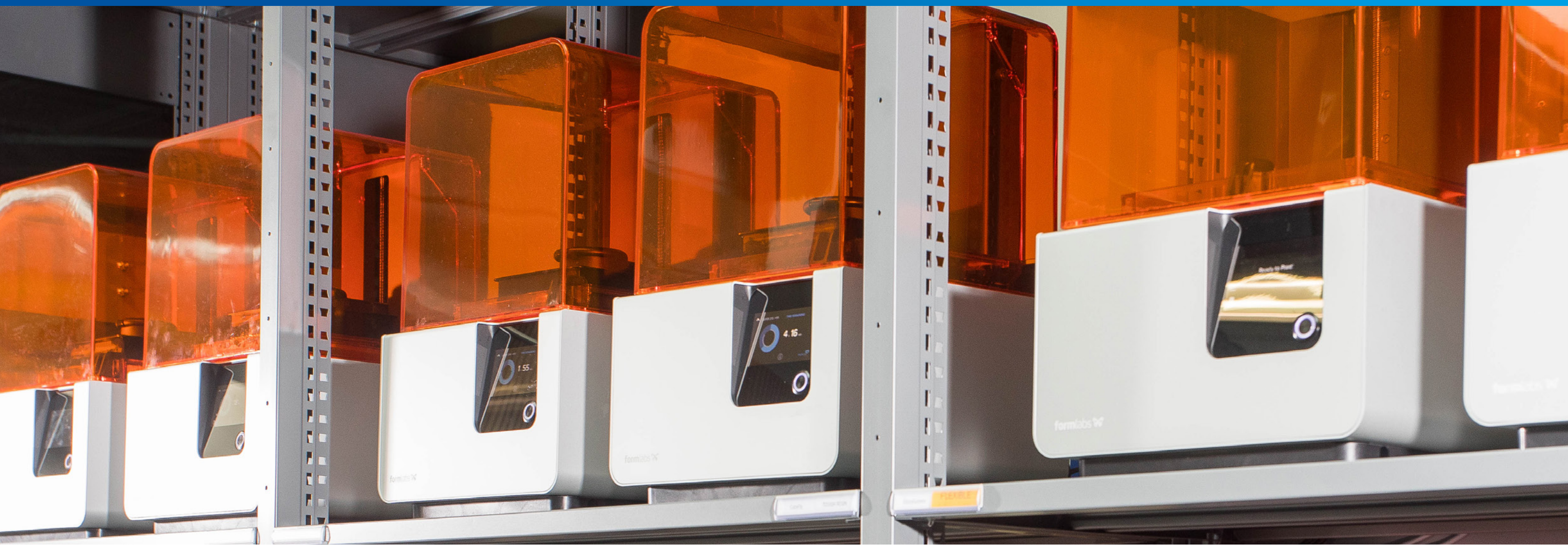
Design and Prototyping Group
Case Study

Batch volume cost reduction strategy for additive manufacture



Engineers within the University of Sheffield Advanced Manufacturing Research Centre's (AMRC) Design and Prototyping Group (DPG) have developed a cost reduction strategy to batch produce additive manufactured components. This is compared against traditional manufacturing techniques.

Challenge

Additive manufacture (AM) has the potential to disrupt conventional processes for the production of polymer components. AM doesn't require tooling and is now able to produce complex geometry components in relatively high volumes. The project challenge was to identify and create a cost reduction strategy suitable for AM which would reduce the manufacturing cost per part when compared directly with injection moulding. The initial brief specified selecting a component suitable for AM using the Stereolithography (SLA) system Formlabs Form 2 machines. The DPG developed a solution for producing high volume AM polymer components using a part stacking and nesting technique, maximising the build volume available within the Formlabs Form 2 machines.

SLA process

SLA machines produce polymer AM components using a vat polymerisation process using a laser to cure solid isotropic parts from a liquid photopolymer resin (Formlabs 2019). The SLA Form 2 machines work with the build platform lowered into the resin. The UV laser then draws a cross section of the part which hardens the resin. The part is built in layers until complete. Post processing involves the part removed from the Formlabs resin tank then transferred into an isopropyl alcohol (IPA) solution and agitated removing any uncured resin. After washing, the part is placed into a post-curing unit with a turntable exposing the part to light and heat, improving overall strength.

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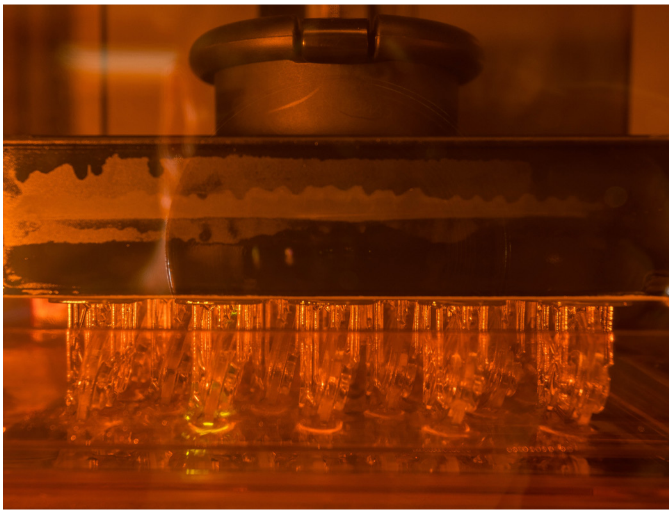
Solution

A generic cap was selected as the candidate component for the study. Its end-use function is to seal apertures within a composite part. The cap was chosen due to its small size and that it would be typically volume injection moulded rather than additively manufactured. The cap has an OD of 36 mm with a volume of 5.34 cm^3. A trial batch of caps were prepared using the Formlabs Form 2 software PreForm, with the caps oriented at a 25 degree angle allowing the maximum batch of caps to be positioned on the build platform. PreForm is a print preparation software used in conjunction with Form 2 AM machines, allowing users to prepare, orientate, apply supports and upload the files to the Form 2 machines ready for additive manufacture. An initial batch of 27 caps were trialled and produced taking under nine hours, including preparation, build and post-processing time.

A method was developed to vertically stack the caps, maintaining overall part quality and close fit part geometry whilst maximising the available build volume. The parts were nested to maximise the quantity that could be produced within the build envelope. Using PreForm, these nests were then duplicated to produce 90 caps in a single build. The caps were then additively manufactured using the Form 2 machines, followed by washing in an IPA solution and curing within the curing station. The final stage involved removing the breakaway supports manually and any excess support material needing to be trimmed down so as not to cause detriment to the overall part quality or function.



As part of this study, it was noticed that the caps nested further apart with more supports between the caps resulted in radial distortion. Reduction of length supports between the caps within the nest resulted in less distortion. To understand the part quality and dimensional accuracy, the caps were inspected using a CT scanner. These scans highlighted that the caps tended to overfill during AM causing the part to be oversized. The cap geometry was measured with 98% of the cap being within 0.30 mm of the nominal value. The Form 2 machine ran the 90 cap build with the addition of preparation, build and post processing time in just over five days.

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Material properties AM vs Injection Moulding

The caps were produced using Formlabs clear resin (predominantly acrylic compound). The injection moulded material could use a comparable material of acrylic. The injection moulded component may typically present with a witness line and potentially flash but could have a high polish. The AM components retain support touchpoints which can be removed using an abrasive for a smooth finish. To improve the appearance further, an acrylic cleaner and microfiber cloth can be used for a well-polished transparent part.

The table identifies the mechanical properties of the materials for both processes:

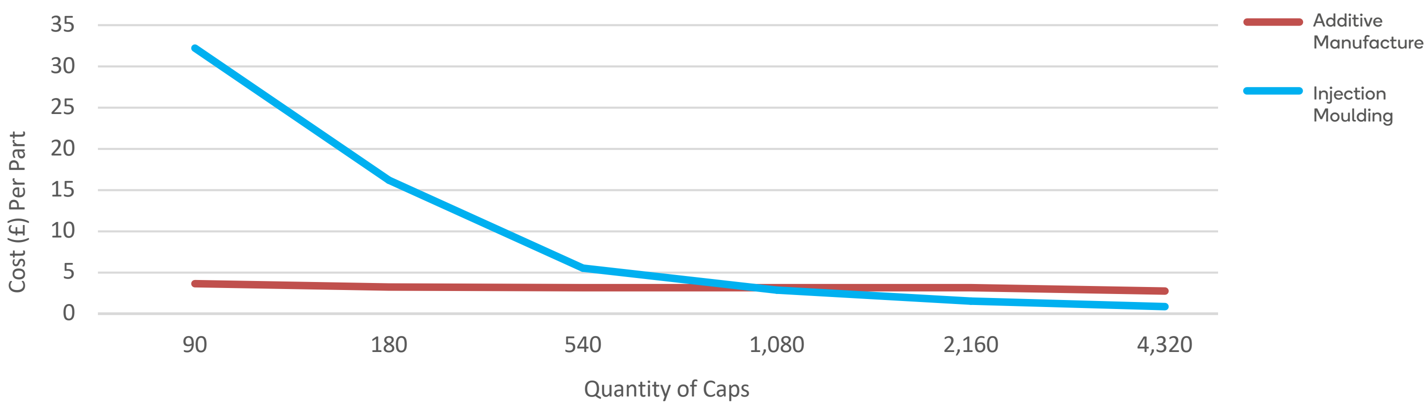
	Injection Moulding	Additive Manufacture
Ultimate Tensile Strength (MPa)	64.9	65
Elongation at Failure (%)	10.1	6.2
Flexural Modulus (GPa)	2.9	2.2
Deflection Temperature at 0.46 MPa (°C)	97.2	73.1

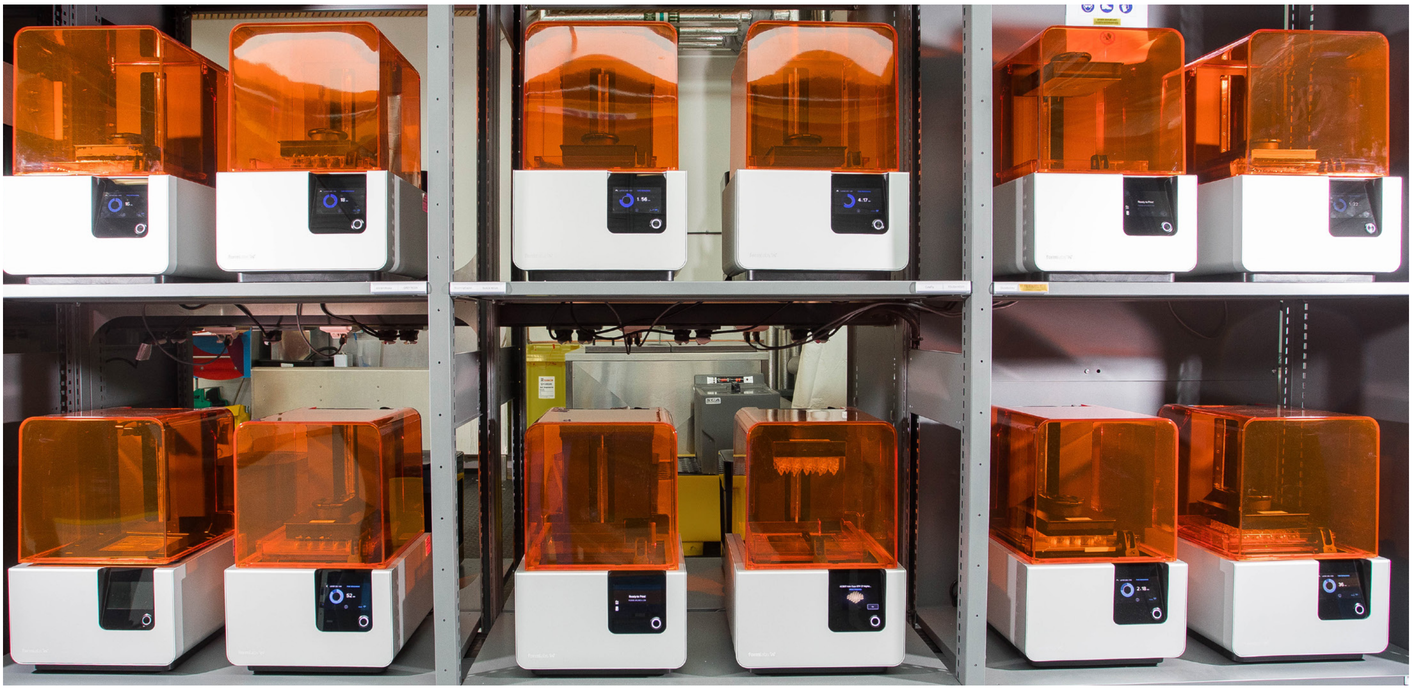
Cost saving benefit

The injection moulding process and cost calculations included the design, manufacture and polishing of the tool, and production of the parts. The AM calculations included the software preparation, build and post processing time, material and machine costs. This study identified that the production of 1000 caps in AM would have a lead time of 4 weeks using just one Form 2 machine, wash station and curing unit with the machine running at 90% capacity. This lead time could be reduced with the use of another Form 2 machine and associated equipment. Injection moulding the same quantity would take an estimated 4 weeks, this lead time would not be incurred every time parts are ordered.

The table below shows cost per part with the cost of the injection moulding tooling amortised. The cost per part when injection moulding in quantities of 1000 is £2.86 whereas the same quantity in AM would cost £3.16. This case study has outlined that to AM parts in quantities under 1000 is more cost effective when compared to the same quantity if injection moulded. This case study has identified that adopting the strategy of optimising the building techniques, there was a cost saving benefit.

Additive Manufacture vs Injection Moulding Cap Production Part Cost





Conclusion

This case study has shown that in this instance applying the stacking technique, AM is a more cost effective method of producing batch volumes of small components when compared to injection moulding. The scope of this case study was to compare one type of AM machine with injection moulding and one type of component geometry. AM is suitable and advantageous in this instance, but larger components or other types of AM equipment may differ in cost benefits.

AM enables the production of low quantity custom, complex shapes for a minimal cost when compared to injection moulding. Clearly the novel AM solution offers benefits in terms of fast turnaround, high accuracy parts. This solution could offer advantages to many companies looking for a cheaper alternative with this type of development in AM potentially disrupting existing manufacture technologies utilising this readily accessible technology.

Clearly the novel AM solution offers benefits in terms of fast turnaround, high accuracy parts. This solution could offer advantages to many companies looking for a cheaper alternative.

References

Formlabs., (2019). Professional 3D Printing Powered by Lasers [online]. Formlabs. [Viewed 15 March 2019]. Available from: https://formlabs.com/3d-printers/form-2/

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