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Rapid Tooling for Injection Moulding Project

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Introduction

Injection moulding is one of the most widely used manufacturing processes. It can be used to produce a large quantity of parts with high accuracy and quality very quickly. The process involves melting polymer granules to the point where they flow like a liquid, then injecting them into a mould tool cavity. This is carried out at high pressure which is maintained until the polymer cools, taking the shape of the mould cavity. The variety of parts manufactured in this way are vast, ranging from small medical devices right the way through to tables and wheelie bins.

The initial design and manufacture of the mould tool is traditionally a time consuming, expensive and an often problematic process. With the recent advancements in additive manufacturing technology and materials it is now feasible that mould tools can be manufactured by 3D printing creating significant cost savings.

The aim of this project was to investigate the viability of using 3D printed tools for short production runs or as a design testing iteration for a full metal machined tool. Of particular interest was to investigate stereolithography (SLA) resins which offer excellent strength and thermal properties as well as metal powder bed fusion (MPBF) printed steel tools.

Objectives

- Compare surface finish of parts injected from moulds of different materials.
- Determine maximum injectable parts from a mould using various injection materials.
- Perform design iterations to improve the cooling and heating affect by designing adding conformal cooling channels to mould tool.
- Where possible reduce cost of tool insert manufacture.
- Optimise injection moulding parameters for rapid tooling application.

Figure 1 – Simple block cavity with mould deformation

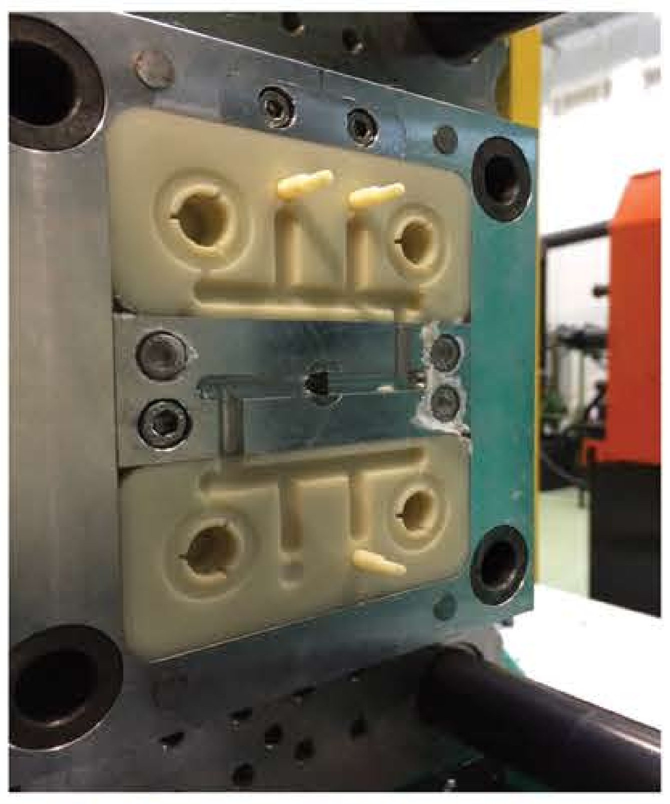

Figure 2 – Tool insert with complex geometry

Methods

Instead of printing the entire mould tool only the cavity relevant geometry was printed as a tool insert (see Figure 1 and 2 above). As it was suspected the SLA materials would perform worse than the printed metal inserts they were investigated first.

- A simple stepped block cavity tool insert was designed and printed in a variety of SLA materials at LPE's advanced manufacturing centre in Belfast (See Figure 1).
- The tools inserts were then tested at APT's campus in Athlone.
- The printed tool inserts were analyzed to determine which SLA materials had the best resistance to thermal and pressure strains.
- The next step was to design and print a more complex demonstrator tool insert, one with thin walls and complex geometry. This was then printed with the most successful SLA material (See Figure 2).
- This new tool insert was then tested at APT's campus.
- Tool insert design improvements were investigated using mould flow analysis. An advantage of additive layer manufacturing is that conformal cooling channels can be incorporated into the design of the print that would otherwise be impossible to manufacture. These channels were designed to help create more evenly distributed cooling which helps reduce the cycle time and increased the longevity of the tool (See Figure 3 below).
- The next part of the investigation was to compare the SLA printed inserts to metal PBF steel inserts and also to a CNC machined tool insert from tooling steel for benchmarking purposes.
- The new tool inserts were tested at APT.
- The investigation concluded with analysis of the longevity of the tool inserts, as well as analysis of the surface finish and the quality of injection moulded components.

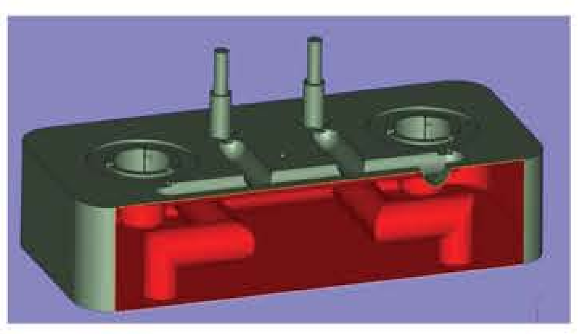

Figure 3 - Example of conformal cooling

Injection Materials Tested: Polypropylene (PP), Polycarbonate (PC), Nylon (PA), High Density Polyethylene (HDPE), Low Density Polyethylene (LDPE)

Results

It was found that the ceramic filled resins achieved the best results of the SLA materials. In fact the they surpassed expectations in terms of heat resistance and longevity of tool insert life. The other SLA resins did not perform so well as the surfaces of tools made in these resins blistered and deteriorated quickly (see Figure 1).

The ceramic filled resin also performed well with more complex geometry. However it was evident that the mould need another design iteration to allow quicker processing and avoid heat related warp age issues.

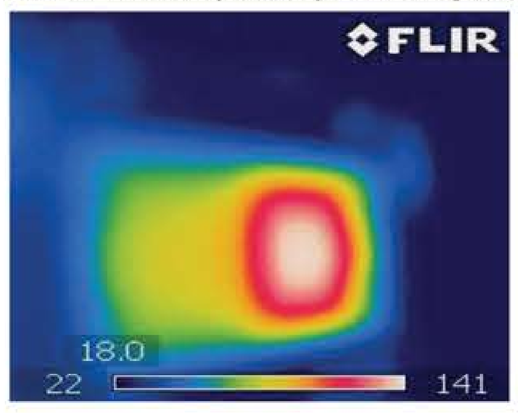

Figure 4 - Pre conformal cooling

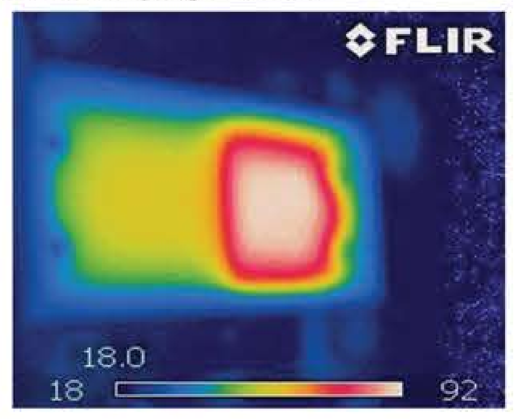

Figure 5 - Post conformal cooling

Conformal cooling channels significantly reduced the heat build up in the moulds during the injection process (see Figure 3 for an example). Figure 4 is a thermal image of a mould without conformal cooling and shows surface temperatures of around 140°C. Compare this to Figure 5 which had conformal cooling channels and you can see a reduction of almost 50°C. This means the cycle time can be reduced and more parts can be produced in a shorter time frame. Being able to add conformal cooling channels to the mould is an invaluable addition to the injection moulding process and serves two main purposes. Firstly it allows a mould to be cooled down between shots and secondly it provides a method of heating a mould for more abrasive polymers so as not to shock the material when it is shot.

Figure 6 - Stereolithography

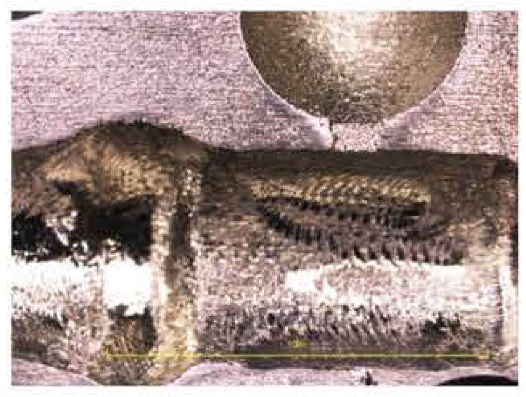

Figure 7 - DMLS

Figure 8 - CNC

Figures 6, 7 and 8 above show pictures of the tool inserts cavity under a microscope. It can be seen that the Stereolithography and CNC cavities had a smooth surface finish, whilst the DMLS cavity had a slightly rougher finish. This roughness in the finish of the DMLS tool caused the parts to stick to the cavity upon ejection. This issue could be offset with more time spent finishing and polishing the cavity to achieve a smoother surface finish.

For all three tools insert the moulds were able to produce +500 runs. However it should be noted that the gate on the stereolithography insert broke under the high shear stress so a number of work arounds had to be developed to combat this issue.

Conclusions

The results from this project show that rapid tooling using Stereolithography and MPBF is a viable and advantageous method for either producing short production runs or as an intermediate step in the design of a full metal machined tool. However both the SLA and MPBF tool insert have their limitations, being that of gate strength and printed surface quality respectively. This project has been a great success and valuable knowledge has been gained by both LPE and APT. LPE have since used this knowledge to print a number of insert tools for customers.

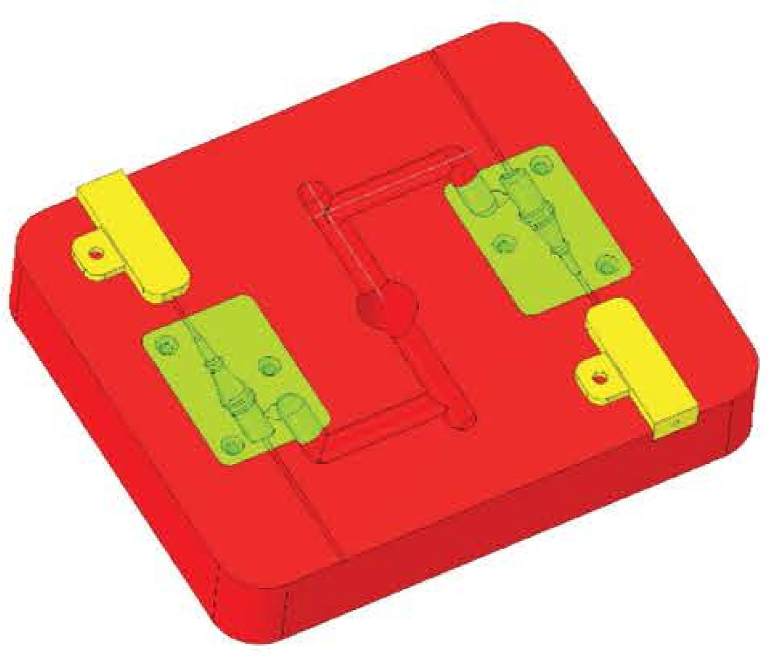

Figure 9 – Insert tools

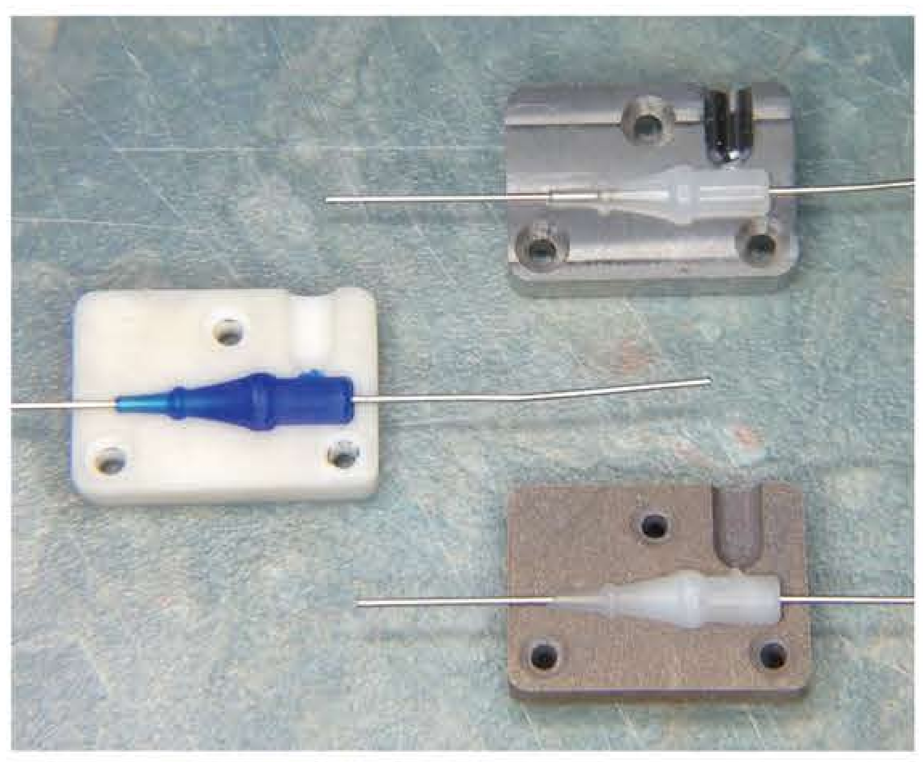

Figure 10 – Inserts for comparison

Figure 11 - Mould flow analysis identifies air traps

Acknowledgments

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