Conformal Cooling

Case Study

A case study into the theory analysis of a 2 impression tool.

We believe that using this method of manufacture for a plastic injection mould tool has many advantages, particularly in increasing production, sustained & improved quality of the component being manufactured alongside a reduction in environmental impact.

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2 imp assembled moving half

Figure 1 - 2 imp. cap mould

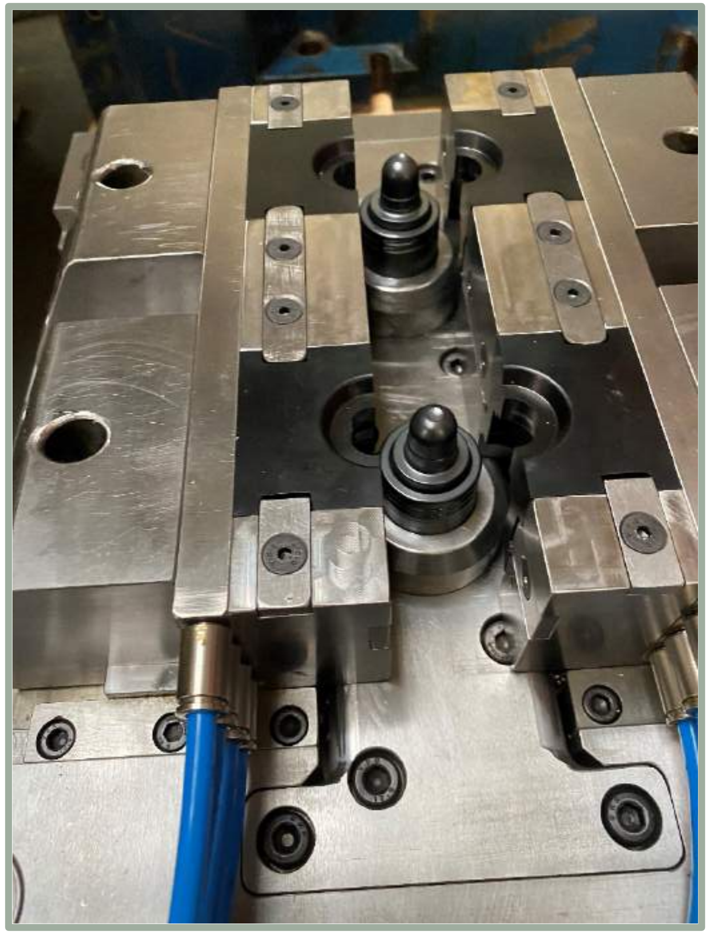

Figure 2 - 2 imp. cap mould

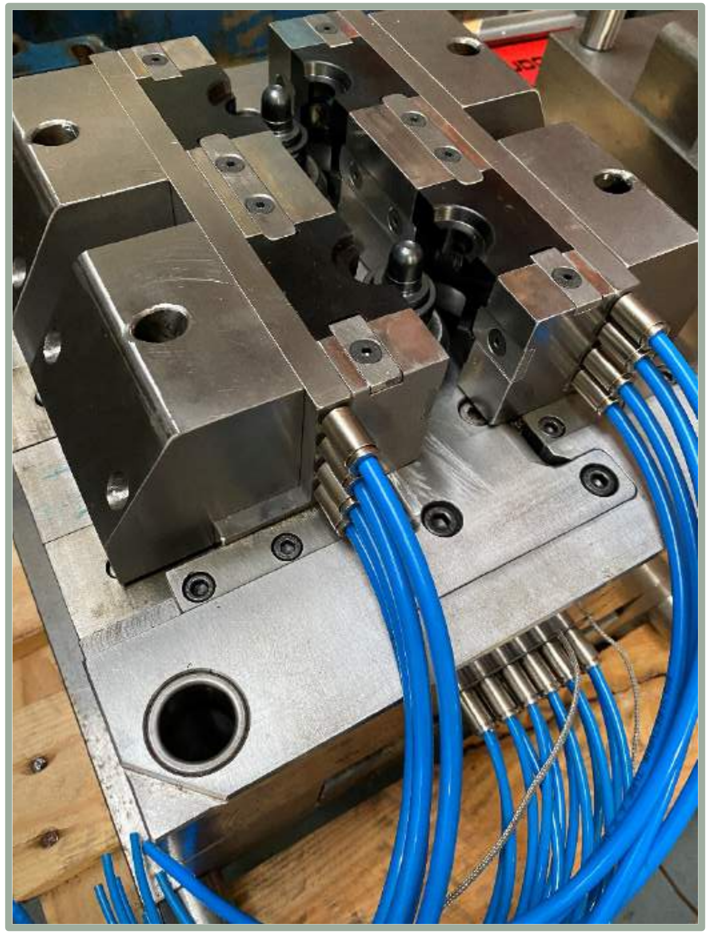

Figure 3 - 2 imp. cap mould

Figure 4 - 2 imp. cap mould

Fixed half with 2 drop hot runner

Figure 5 - 2 imp cap tool

Figure 6 - showing 2 imp cap tool

Mould tool in the press for first trial

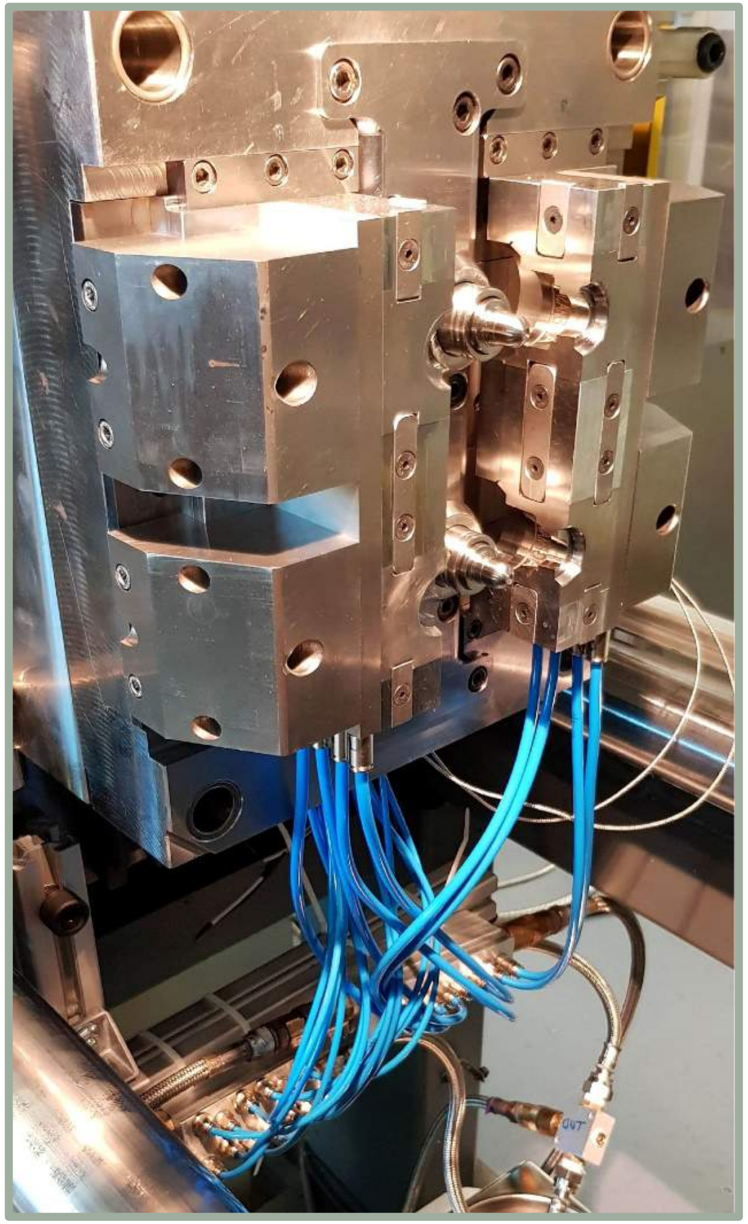

Figure 7 - MH tool in press

Figure 8 - FH in press Fanuc 100T

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Figure 9 - Thermocouple fitted to core

Measuring the core temperature

Figure 9 shows the thermocouple in position through the centre of the core, enabling the core temperature to be monitored in the centre of the moulding.

Side movers and cores before ceramic costing

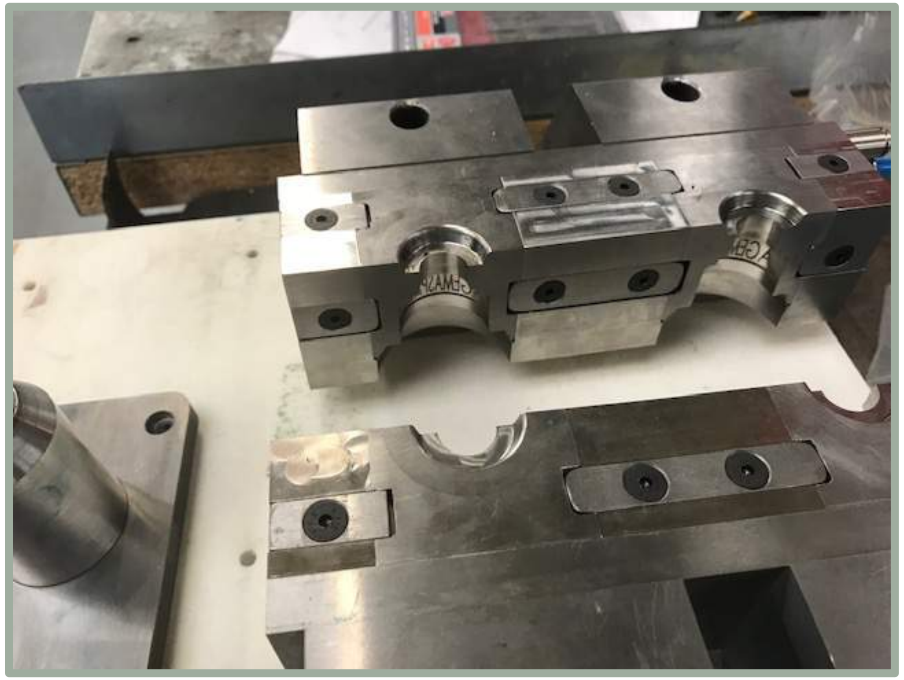

Figure 10 - Side mover splits

Figure 11 - The cores

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Figure 12 - Parts on the build platform

Parts on build platform

Parts shown on build platform before removal by wire erosion.

Figure 13 - Set of sectioned inserts

Conformal Cooling

Figure 13 shows the components with the 2 cores sectioned to show the cooling channels in the inner and outer cores.

Figure 14 - The manifold

Manifold

This shows the manifold that sits below the 2 cores with the individual feeds to 2 separate spirals that run around the surface of the impression.

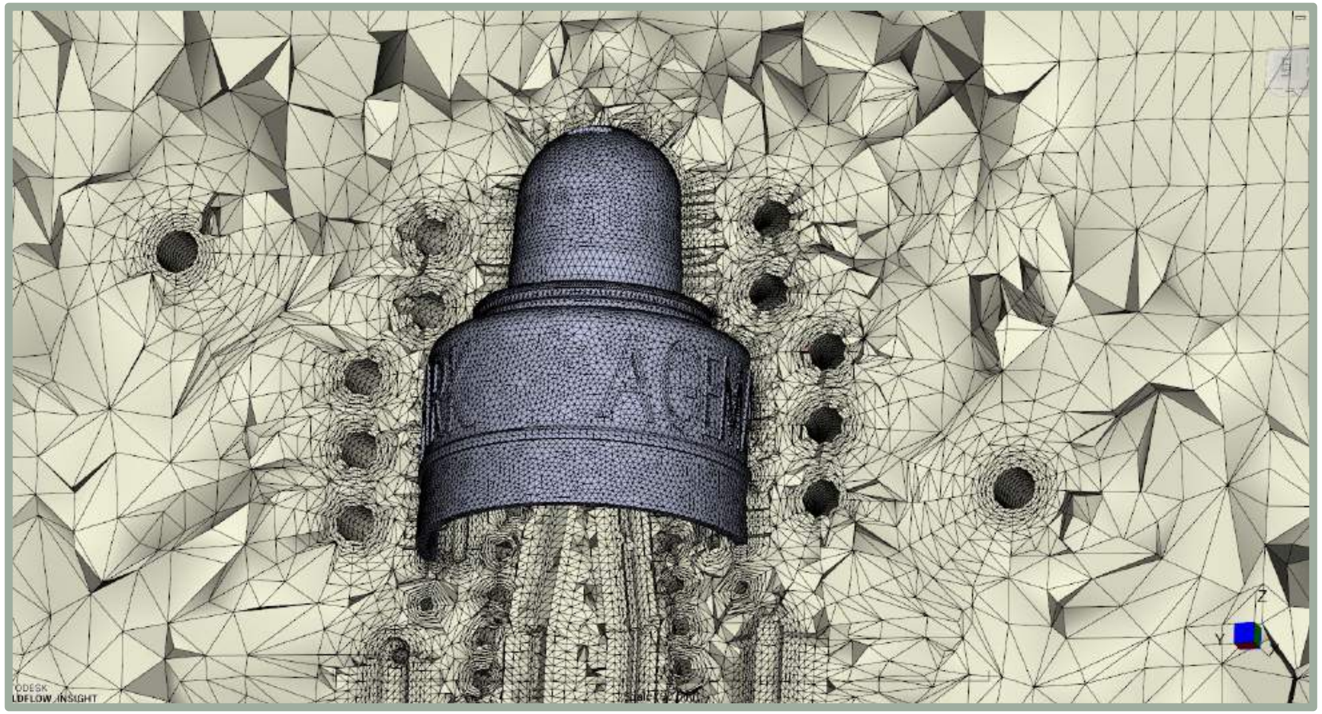

Figure 15 – A close-up of the mesh detail around the part

Build mesh

The final stage is to build the tool mesh, allowing prediction of thermal behaviour during the moulding process.

The small geometries and complex nature of the cooling channels required a high resolution mesh which resulted in the use of 8.9 million elements and took over 5 hours to calculate.

Defined process Conditions

For the melt and mould temperatures, the manufacturer's recommended moulding conditions were used, but the top end melt temperature of 230 °C and the bottom end mould temperature of 30 °C were used to try and minimize cycle times. The packing pressure was set at 80% of the peak filling pressure and switchover was set at 99%.

Figure 16 - Fill time result

The calculated fill time was just over 0.7 seconds, and was identical for each part, This resulted in a maximum shear rate of approximately 10 000 s·1 and could be comfortably made shorter to achieve shorter overall cycle times.

Figure 16 – Fill time result

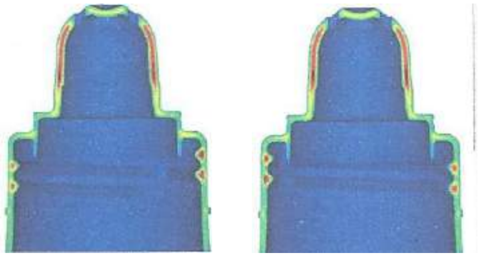

Figure 17 – Time to reach ejection temperature

Cooling Channels

Figure 18 shows the layout of cooling channels within the mould.

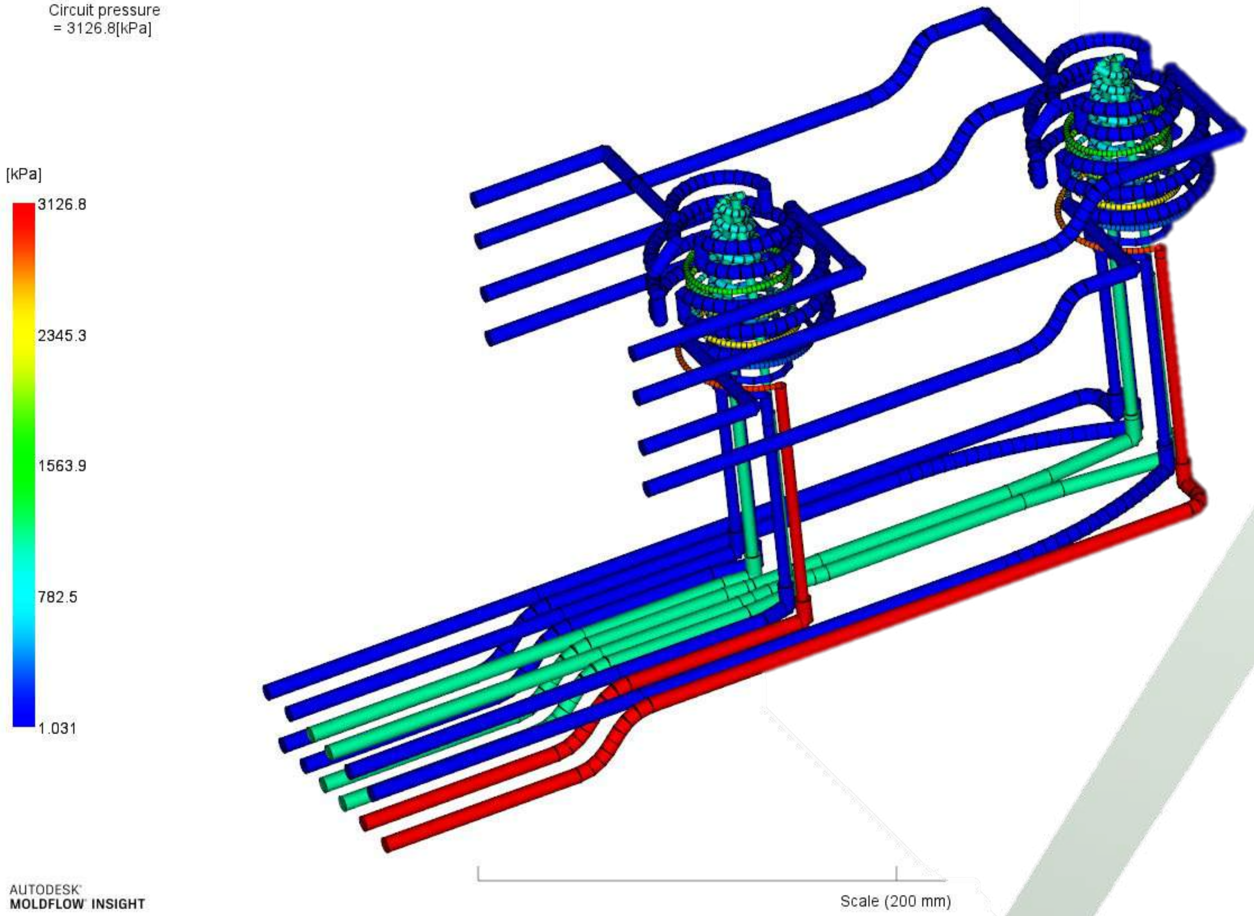

Figure 18 – Cooling channels layout within the mould

Time to reach ejection temperature

The time to reach ejection temperature was calculated at 3.7 seconds for the core region near the tip of the cap, and with a total cycle time of 5.8 s (including mould open time). This was viewed as an encouraging result as the current process has a cycle time in the region of 8s.

The analysis calculates the steady state temperature of the tool. i.e. the temperature field that develops for an extended moulding process, rather than simply considering a single cycle. The tool elements hit a peak temperature around 50°C, but this soon decays towards the target value during cooling. It is interesting to note that the cooling performance of the core is better than that outside the part for this projection, which is aligned with the split plane of the side actors and therefore contains no cooling channels.

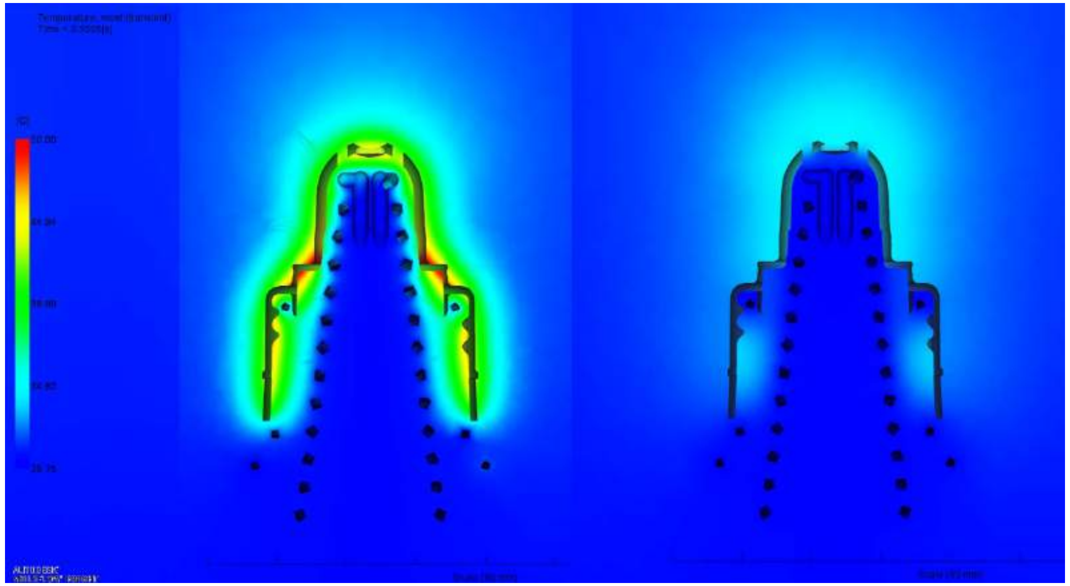

Figure 19 – Tool surface temperature at end of fill 0.9s (left) and start/end of cycle 5s (right)

Thermal Camera Images

With the tool cycling consistently in fully automatic mode, after a period of two hours, the surface temperature of the part and tool was monitored in the process using the thermal imager.

Part and core temperatures during mould cycle

The results were encouraging, showing no long term heat build up in the core manifold, and a product surface temperature of 50 °C which is lower than expected, and can be seen in an ejected part.

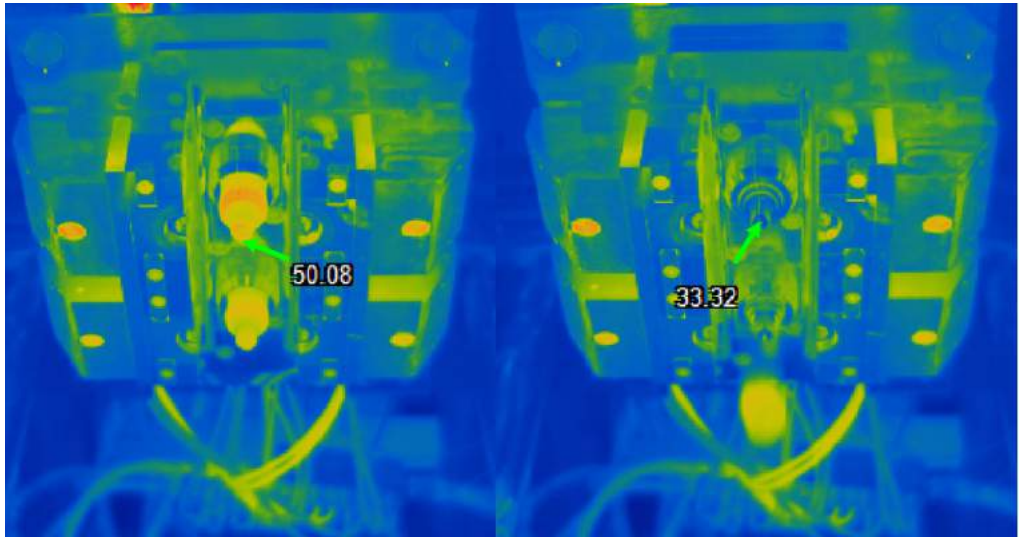

Figure 20 – Temperature within the mould during cycle

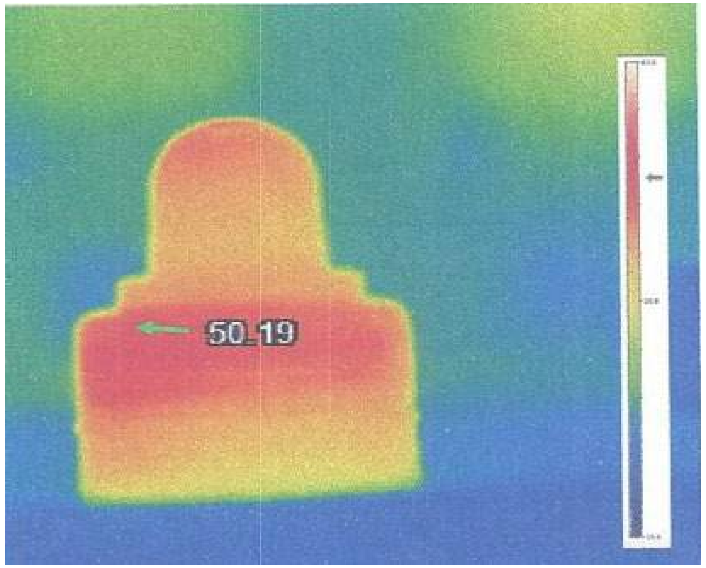

Figure 21 – Temperature within the mould during cycle

Part Inspection

Visually, the parts produced using the process settings looked very good, with no obvious signs of deformation or sink marks. There was also no evidence of flash.

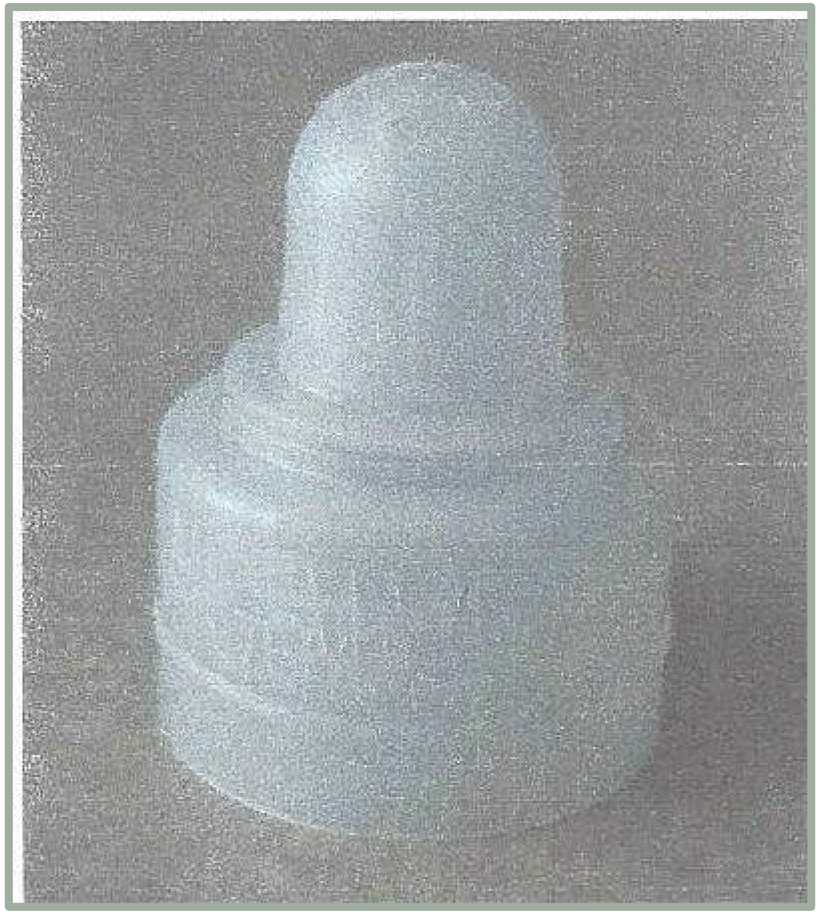

Figure 22 – Physical part

CT Scan Data

For a more rigorous part inspection, the moulded products were inspected using a Nikon 225XT XRay CT machine. This machine can build full volumetric images of components and can be sued for geometric characterisation and identification of internal defects such as voids. The resolution of the scan depends on the component size, but a part like the cap component will typically have a voxel resolution of 5 µm. A single scan takes approximately 4 hours and reconstruction and processing a further 2 hours.

The cross section of the component shows excellent wall thickness symmetry and little evidence of the classic warpage that would normally be seen when moulding using small cores. Excellent wall thickness control and circularity of the component and highlights the quality of the detail at the tip of the cap.

Scan Data

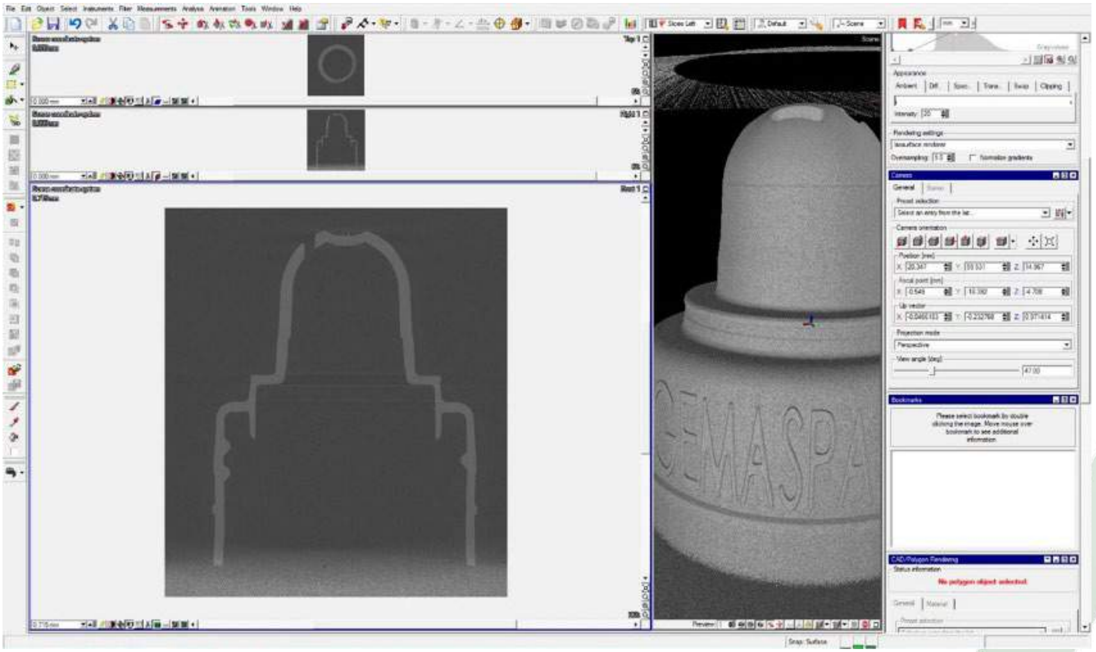

Figure 24 – Wall section scan

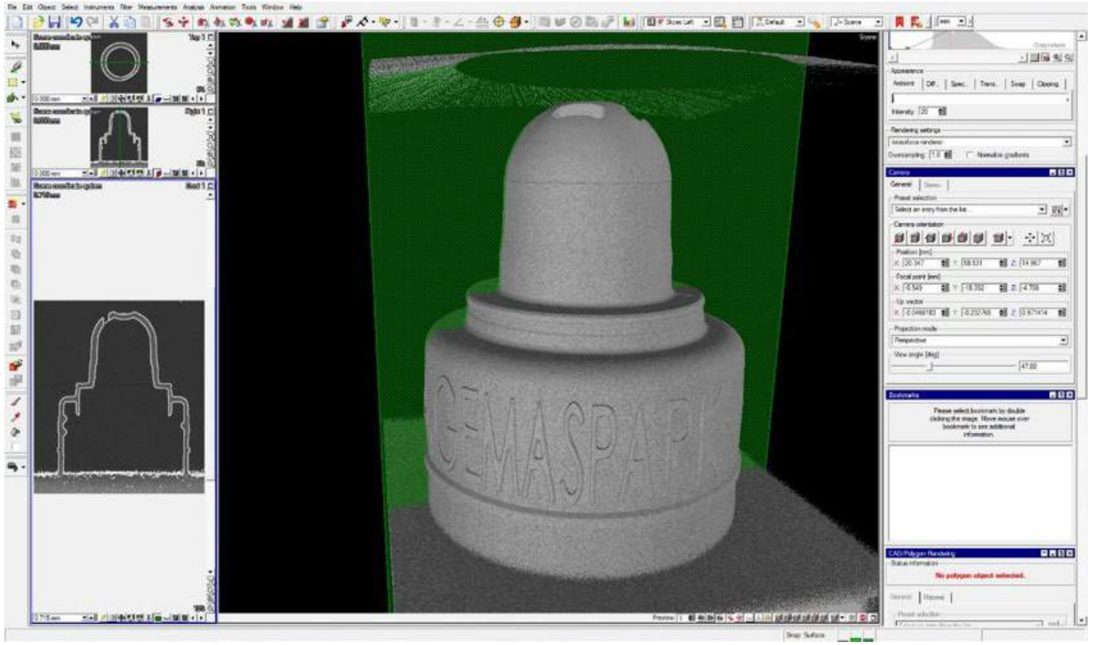

Figure 23 – scan of wall section

Cross section view

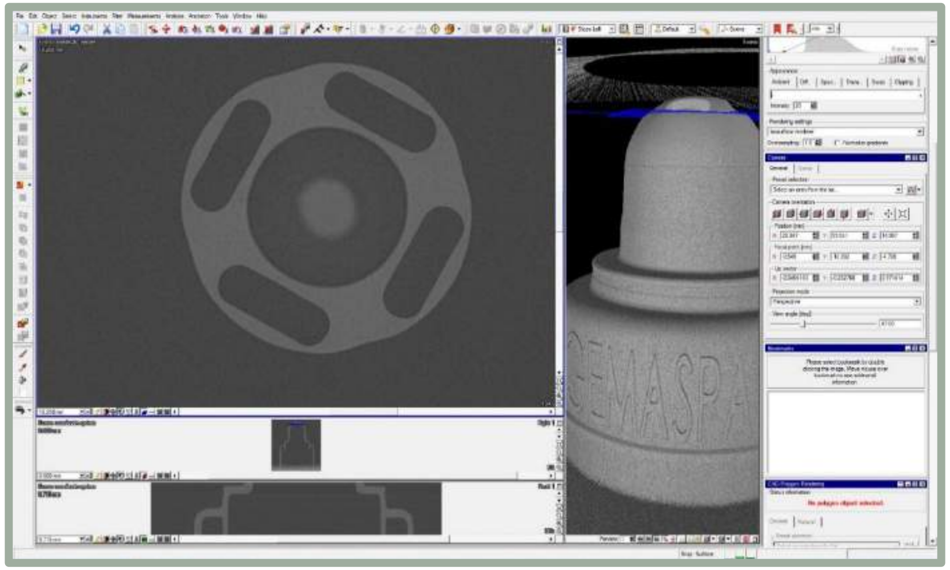

Figure 26 – Cross section view

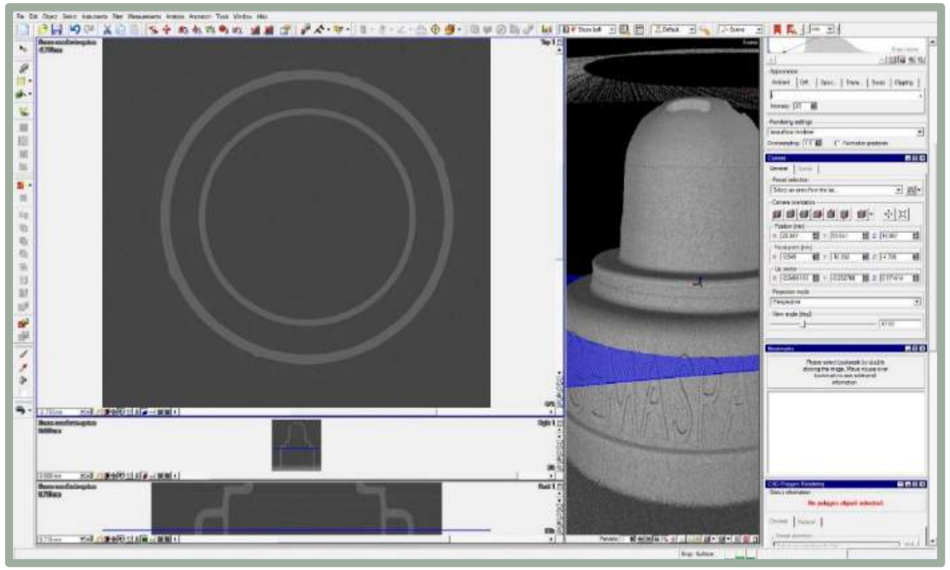

Figure 25 – Cross section view