Investigating the Effectiveness and Stability of Conformal Cooling Channels in Injection Moulds

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Abstract
This paper examines the integration of conformal cooling channels into micro injection moulds using advanced techniques such as Selective Laser Melting (SLM) to improve production efficiency while reducing operating temperatures. It takes into account the essential characteristics of stability. The study aims to carry out pressure studies using simulations to evaluate the impact on the mould.

1. Introduction

Micro injection moulding is a precise manufacturing method that is cost-effective and capable of handling high-volume production [1]. It is widely used across various industries due to its ability to produce small parts with high accuracy. Its effectiveness is closely linked to several factors. Temperature, which includes both mould and melt temperatures, and holding pressure are critical determinants that affect the dimensional characteristics and mass of the resulting parts [2]. The industry has traditionally used cooling channels, often created through drilling, to aid in heat dissipation from moulds and regulate plastic moulding temperatures. These channels are simple and effective, making them a preferred option for many applications. However, further improving injection moulding processes requires innovative approaches beyond conventional methods. Therefore, Selective Laser Melting (SLM) could be used. It is a form of metal 3D printing that enables the creation of intricate and customised mould geometries. The efficiency of injection moulding processes can be improved through the optimisation of cooling channels [1]. This paper investigates aspects beyond temperature considerations, such as pressure resistance.

2. Methodology

Injection moulding is a process in which a hot liquid polymer is injected into a mould under high pressure. In this case, the Babyplast 6/10 PT injection moulding machine is used. This limits the volume of the mould and the cooling channels. In this study, an injection mould for a filter system was evaluated. The filter system selected for this study was provided by project partner BBI [3]. **Fehler! Verweisquelle konnte nicht gefunden werden.** shows the filter system built from three different components. It consists of a cover, spacer and filter membrane. The filter membrane determines the use of the system. In contrast to traditional cooling channels with a greater diameter and distance to the mould, which are drilled from the outside, a mould with conformal channels that follow the contours of the part was designed to achieve more efficient cooling. Further research was carried out to simulate efficiency and temperature. Based on preliminary work, the pressure is evaluated here, to verify whether the pressure affects the shape of the channels and the mould.

The conformal cooling channels are shown in Figure 2. The channels have a diameter of 0.5 mm and a wall thickness close to the design guidelines of the metal printer manufacturer One Click Metal [4]. These dimensions are crucial for our work as we will be using the MPrint+ printer from One Click Metal to print the prototype in further research. The design was also influenced by the ejector pins. The tool was designed and simulated for pressure stability in Solid Works.

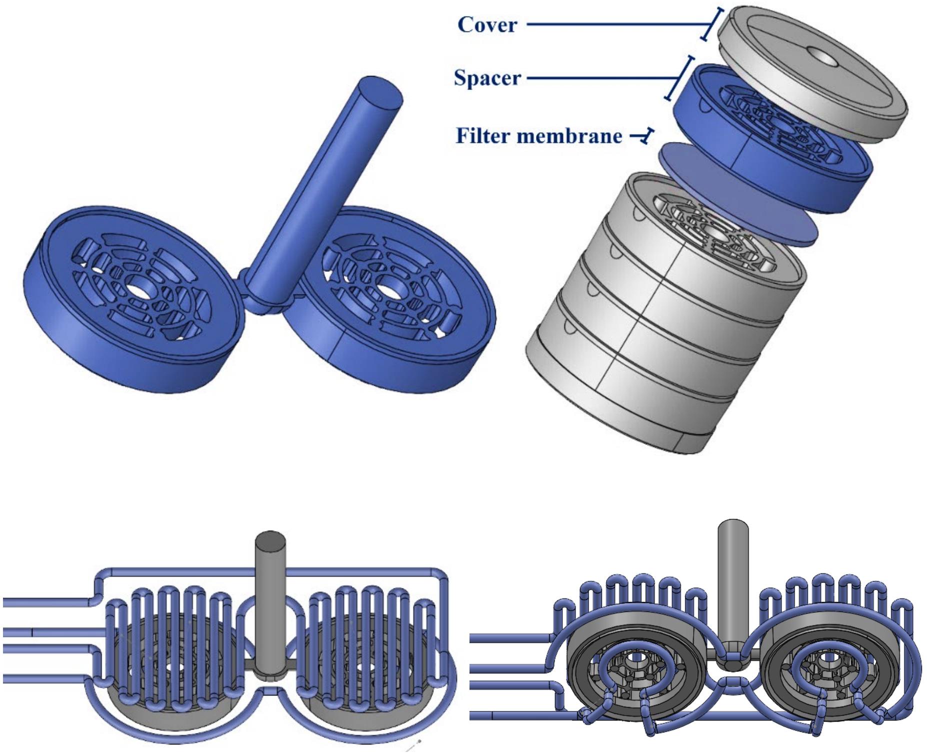

Figure 1: Part with conformal cooling channels (blue) top view and bottom view. Channel diameter 0.5 mm in Solid Works.

To evaluate the effect of pressure in the mould on the channel shape, a pressure simulation was performed using Solid Works.
Pretesting with the Moldex3D software for plastic injection moulding was used to evaluate the performance of the mould. The efficiency was increased, and the temperature of the mould was reduced by using conformal channels compared to traditionally manufactured channels. A maximum sprue pressure of 42.7 MPa was identified in this pre-test. The simulation evaluated whether the mould could withstand in any circumstance using 42.7 MPa and the injection moulding machine's maximum pressure (2030 bar = 203 MPa) [5]. The tool consists of two parts, the cover and the ejector block. Both have conformal channels with different designs. As shown in Figure 3, pressure is applied to the mould surfaces inside the cavity.

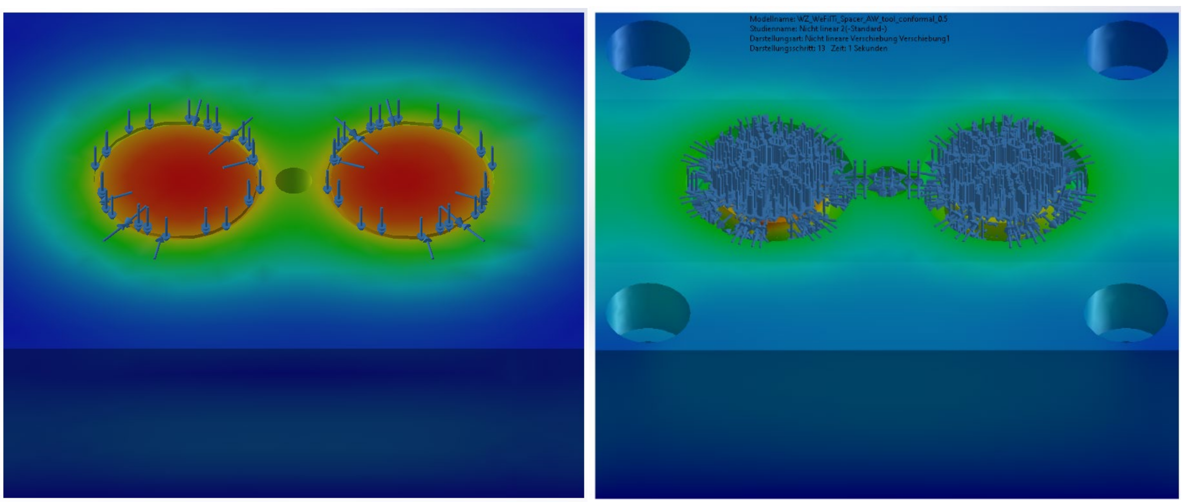

Figure 2: Pressure on the injection mould. Cavity (cover block) on the left and core (ejector block) on the right.

3. Results and Discussion

Through presimulation and pretesting, these conformal cooling channels have been shown to reduce temperatures compared to conventional channels. The decrease in temperature improves cycle times and enhances the overall efficiency of the moulding operation and can have an impact on warpage and product quality. That highlights the importance of the conformal cooling method. The use of these channels has increased mould efficiency by approximately 30%. This increase can be attributed to several factors, such as more uniform cooling across the mould and reduced energy consumption.

To ensure the structural integrity of these moulds with conformal cooling channels, it is imperative to subject them to pressure simulation. This is necessary to recreate the conditions that will be generated during injection moulding. These tests provide crucial insights into the mould's ability to withstand the forces exerted during moulding operations. The pressure tests showed some interesting results in Figure 4, which displays the pressure tests conducted at a significant 42.7 MPa and illustrates the response of the two blocks of the tool. The diagram presents the results of the pressure tests in a colour-coded format, with displacement (URES) a range up to $4.2 \cdot 10^{-3}$ mm. Despite the significant pressure applied, the mould demonstrated remarkable resilience and remained largely unaffected by the load. However, closer inspection revealed different levels of deformation across the mould. The pressure test diagram shows that the surface and central regions of the cavity exhibited more dislocations, as indicated by the presence of intense red and orange colours. In contrast, the cooling channels show less degrees of deformation, as evidenced by the lighter shades of green and blue.

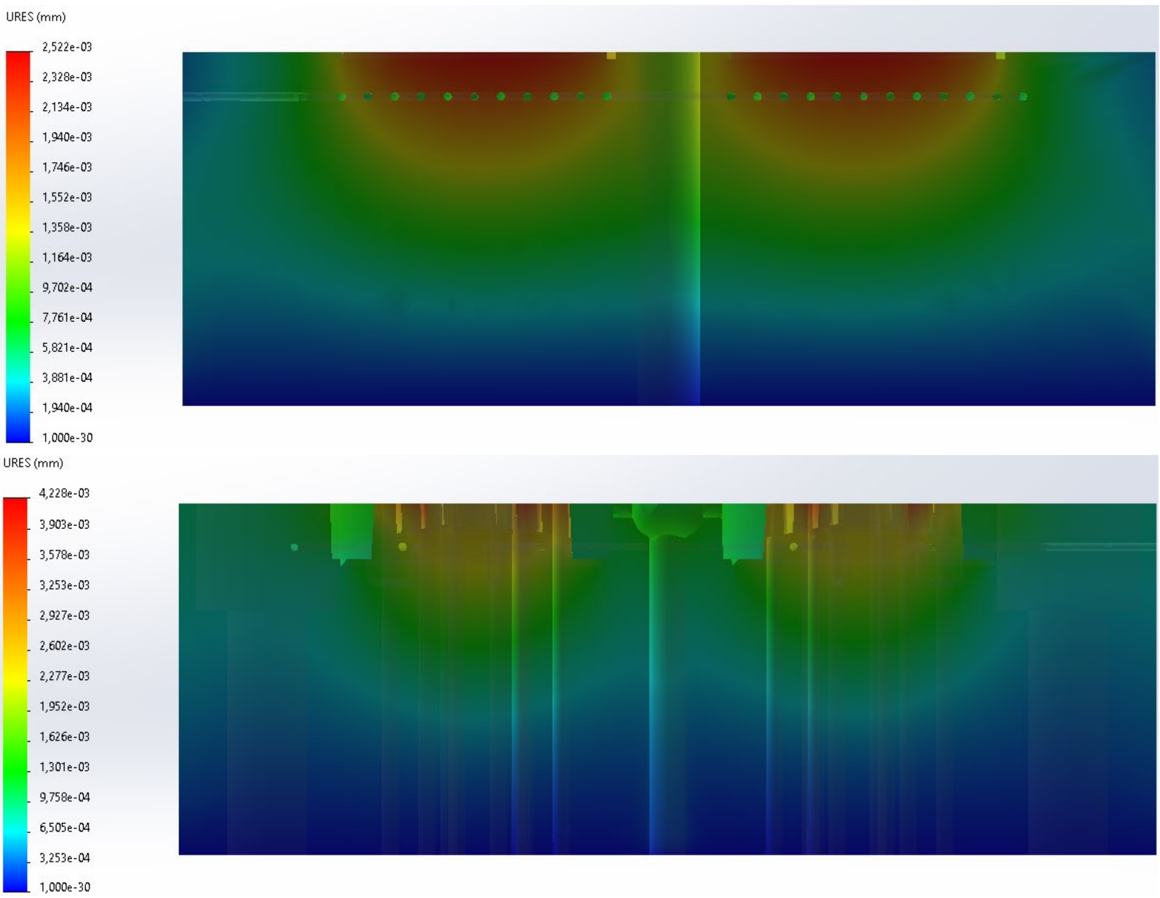

Figure 3: Colour-coded diagram of the sectional view of the pressure simulation with a 42.712 MPa cover block (top) and ejector block.

Moreover, the study highlights the range of deformation experienced by the mould under varying pressure conditions. Specifically, at 203 MPa, the range of deformation increases by approximately ten times compared to lower pressure levels, shown in Figure 5. The mould was found to be unaffected by pressure during the injection moulding process, demonstrating its ability to resist such pressures with minimal deformation.

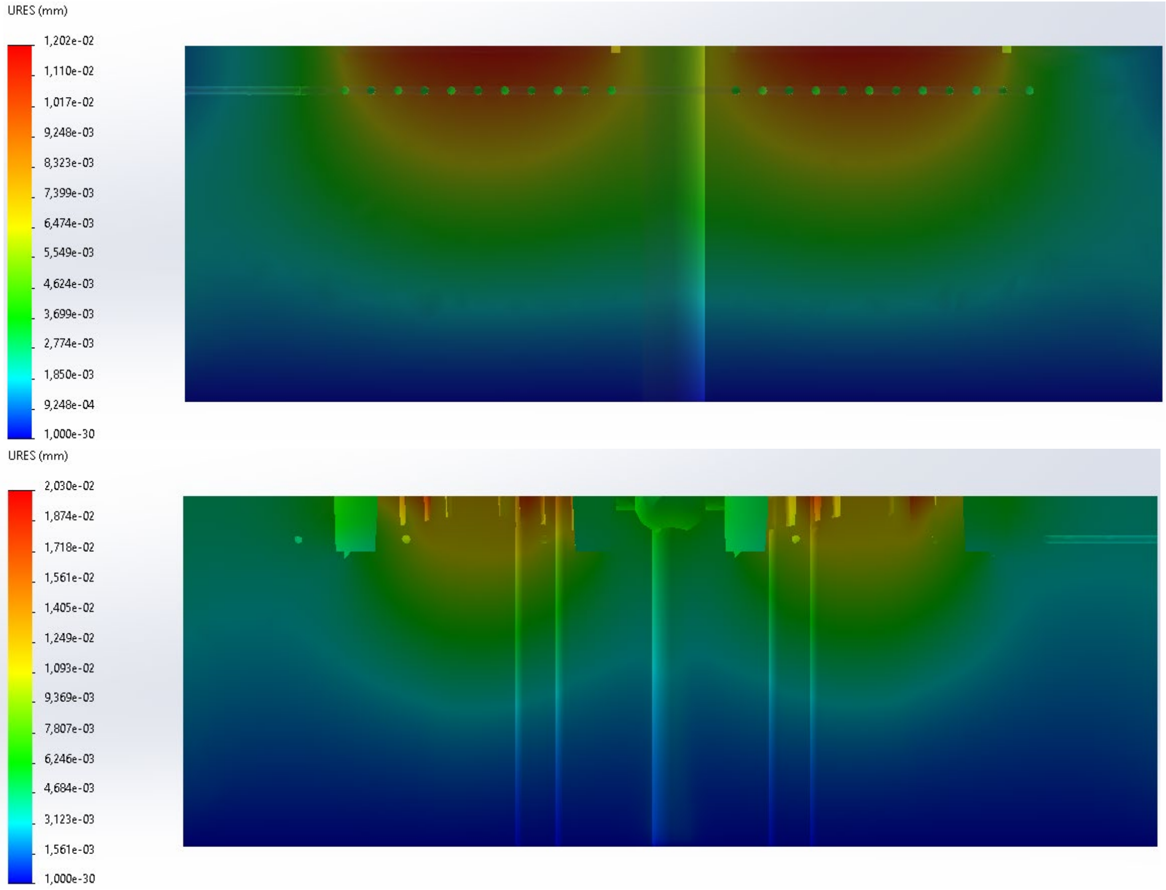

Figure 4: Colour-coded diagram of the sectional view of the pressure simulation with 203 MPa cover block (top) and ejector block (bottom).

4. Conclusion

In summary, the integration of conformal cooling channels has a significant impact on several aspects of the injection moulding process, including temperature control and overall efficiency. Thorough research and simulations in this study have demonstrated the ability of the mould to withstand significant pressure, suggesting that an additive manufactured mould could be viable for this specific application.

Further research to fully validate the durability of the tool over extended periods of use, long-term testing is essential. Endurance testing should be prioritized to ensure the mould's reliability in real-world production scenarios. Furthermore, the incorporation of lightweight design elements into the mould holds promise for further optimization to fully exploit the benefits of additive manufacturing. This approach improves mould structural integrity and offers distinct advantages for temperature control, efficiency and pressure distribution.

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