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Experimental investigation of the manufacturability of a very fine optimized venting system using a combination of SLM and EDM

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Abstract

Tool making in injection molding is significantly influenced by the requirements of the plastics processing industry. The profitable production of increasingly individualized end products requires increasingly higher process speeds, low reject rates and long tool life. The venting of an injection mold is an important element to avoid damage to the injection molded part as well as unattained mold fillings. There are different strategies for this purpose, which are mostly based on limited local insertion of venting channels, e.g. by micro holes in uncritical areas or by placement in ejector elements. The challenge is the required size of a venting gap, which depends mainly on the melt viscosity. Another strategy is the use of venting inserts made of sintered metal. They require regular maintenance due to time and material-dependent filling of the pores and are associated with corresponding operating costs. It should also be noted that where a venting element is provided, effective temperature control is generally not possible.

The new venting technology involves integrating the finest possible primary venting canal network directly into the 3D-printed mold insert. This procedure offers the possibility to bring a near-contour cooling closer to the venting system. The experimental investigations concentrate on the producibility of the smallest possible air vents. The vents consist of a large number of hollow cones arranged in an array with their tips aligned with the inner contour of the tool. After the SLM process, the tips of the hollow cones are still closed and are only opened by the subsequent EDM process to finish the inner contour. The experimental results show the minimum size of the vent holes and their dependence on the cone angle, as well as the dimensional accuracy of the hollow cones as a function of the component orientation in the building space.

High Performance Tools, Injection molding, Ventilation

1. Introduction

In the plastics processing industry, increasingly individualised end products have to be produced profitably. This means that demands are increasing not only in terms of quality, but also in terms of geometries, surface design and material and resource efficiency.

While conventional approaches using classic manufacturing methods such as milling, drilling, wire-cutting or EDM are reaching their physical and economic limits, 3D printing and its high level of design freedom offer huge potential to improve the performance of tools significantly and at the same time save costs in manufacturing [1]. This includes, in particular, an improvement in the temperature control of the tool through new types of cooling concepts as well as a reduction in manufacturing effort and costs through integral design, i.e. the combination of individual components in a monolithic part.

When polymeric plastic mass is injected into the injection mould, a gas bubble appears in the moulding cavity at the end of the flow path. This gas bubble essentially consists of contaminated air and vaporised polymer mass from the injection moulding process. When the polymer mass is completely squeezed out by the injection pressure or the holding pressure, the gas bubble is compressed and finally escapes at high temperature and pressure through the parting line or the moving elements of the injection mould. This can lead to undesired damage or defects and the product may be broken.

The current state of the art venting technology, which allows localised optimal mould venting and thus fast mould filling, has reached its limits with complex products, especially when processing reactive plastics or very filigree geometries [2]. The venting of an injection mould is an important element to avoid damage to the injection moulded part as well as unachieved mould filling. Toolmakers use for example micro-holes in non-critical areas or place ejector elements in such a way that they contribute to venting. Vent inserts made of sintered metal are also used [3]. Due to time and material-dependent clogging of the pores, they require regular maintenance and involve corresponding operating costs [4].

However, the design freedom of additive manufacturing offers much better possibilities for this. Improved venting systems can be integrated directly into the additively manufactured inserts.

The necessary size of a venting gap depends essentially on the requirement as to whether the melt is allowed to flow into the vents or not. In the case of surfaces with high quality requirements, the vents must not show on the component surface. In this case, the gap widths are generally between 5 µm and 10 µm, with maximum values up to 20 µm [5]. The exact value depends on the melt viscosity of the used plastic. It should be noted that where a conventional venting element is provided, effective temperature control is in many cases not possible [4].

2. Functional design

The presented integration of the venting technology will only become possible with the use of additive manufacturing technologies. Later, it should be possible to bring venting and cooling closer together, which is not possible with conventional approaches. This will enable a more uniform and targeted temperature control of the injection moulds.

If the openings of the venting system are not small enough, high surface roughness caused by the SLM process [6] can accelerate clogging of the channels by plastic residues and deposits. Furthermore, long channels with a constant diameter also have a greater tendency to clog. The 10 µm to 20 µm already mentioned cannot be achieved with the use of selective laser melting alone [7].

Based on this consideration, now cone-shaped openings for venting will be printed in the tool insert (Figure 1).

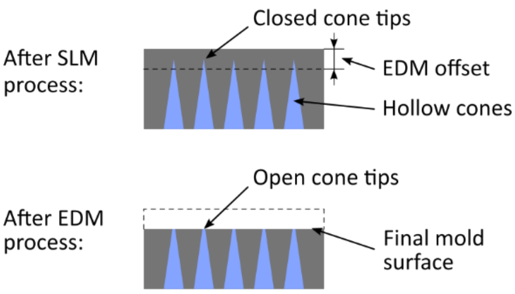

Figure 1. Illustration of the vent opening depending on the machining steps

These hollow cones are positioned that their tip points in the direction of the inner contour of the tool. In addition, a processing offset is necessary for the EDM process. After the SLM process, the tips of the hollow cones are still closed. Then after the EDM process, the necessary material was removed and the final surface of the mould is created and the cone tips are open. The positioning and the cone shape allow to control the opening diameter properly.

3. Experimental realisation

Preliminary investigations showed that conventional machining processes are not capable of producing such small openings, as they easily become clogged during machining. This problem also occurred when making a cut through the SLM-produced test specimens.

The investigation of the cone geometry was difficult in the area of the cut edges, as the milling process partially closed the areas marked in Figure 2a. The cone tip uncovered by deburring and the resulting cut edge in Figure 2b distort the characteristic created by the SLM process. The cone surface shown in Figure 2d also appears very rough regardless of the edge characteristic. Further measurements will describe the surface roughness in more detail.

The diameter of the opening at the cone tip is 100 µm in the CAD model in order to obtain a statement as to whether a hole is created with the used process parameters. The cone tips were visible but not open on the surface of the part after the SLM process. In the design of a final tool insert, the cone tip is then modeled in such a way that no unnecessary amount of material has to be removed in the subsequent EDM process. The mechanically post-processed cone tip in Figure 2c has a diameter of approx. 200 µm.

With an idealized cone tip, it is possible to produce significantly smaller openings by material removal. Depending on the shape of the cone tip created in SLM and the accuracy of the EDM process, there will be corresponding limitations.

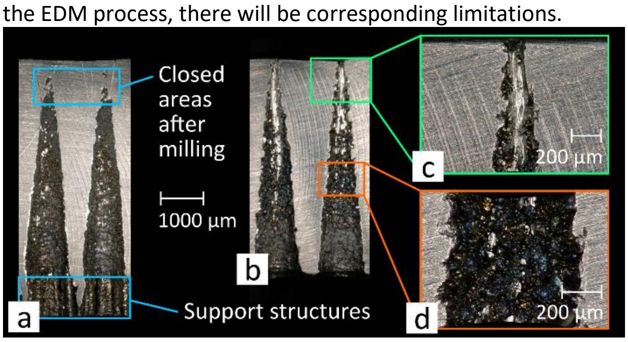

Figure 2. Microscope examinations of the SLM specimens

Accordingly, the roughness on the tool surface and in the cone tip has an influence and should be as low as possible. An optimization of the SLM parameters will show which minimum opening sizes will be possible.

4. Summary and outlook

Cone-shaped vents with EDM finishing have the potential to produce significantly smaller opening sizes than would be possible with constant diameter vents in SLM. The surface roughness is decisive for the smallest possible openings. There are several aims when choosing the cone parameters. A small angle reduces the sensitivity of the opening dimensions to the material height removed by the EDM process. At the same time, it also increases the number of hollow cones that can be placed on a defined surface. Small angles increase the risk of clogging the vent openings.

For a significant increase of the cross-sectional area of the openings, this principle can also be transferred to a prism-shaped opening geometry. The opening would have the shape of a long and very thin slit on the surface. In this case, more air can be exhausted per time. Further investigations will show the technical limits and prove the advantages in the application.

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