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Analysis of mould design affecting the filling behaviour of an injection moulded micro part

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Abstract

Plastic micro injection moulding technology has been developed to fulfil the needs of mass production of micro components. This work presents a mould design of a simplified version of a micro optical medical part. The micro part includes micro features that could lead to the formation of weld lines during the filling stage. In order to produce high quality injection moulded micro parts, the influence of mould design, in terms of runner and gate systems, on the filling behaviour will be investigated. The filling of the micro part will be studied by analysing the position and orientation of weld lines formed around the micro features as flow markers. The mould design will then be optimized in order to enhance the filling capability of the process in future works.

Keywords: micro injection moulding, weld line, filling, micro part,

1. Introduction

Micro injection moulding processes have to be optimized in order to ensure the required product quality at the micrometre level. Particularly in the field of medical micro components, the stringent requirements of part dimensions lead to a large number of requirements in terms of design of the mould and the process itself. A critical aspect of the process is the achievement of a complete filling of the micro cavity. Therefore it is important to understand the relationship between the mould design and the filling of the cavity in order to obtain high quality micro parts.

In this investigation, the small dimensions of the micro part lead to a difficult characterisation of the filling behaviour using conventional methods (i.e. short shots method). During injection moulding of cavities with complex features, the latter can cause a separation of the polymer melt front during the filling of the cavity. The flow-fronts that join after separation form imperfections observable as weld lines. Weld lines are affected by mould design, process conditions and injected material. The characterisation of the filling behaviour will be investigated using an approach based on weld lines measurements, which act as flow markers of the melt flow development on the surface of the micro part [1, 2]. An accurate and repeatable measurement method based on optical microscopy and similar to other methods applied in previous studies [3] will be employed to describe orientation and position of characteristic points located on the weld lines.

2. Part and mould design

The micro part to be replicated is a small (sub-millimetre overall dimensions) medical component for an optical sensor (cf. Fig. 1). It has a shape similar to a hollow cylinder with critical features in the micrometre range. Its complex geometry leads to a challenging mould design. In order to include the same filling challenges but to avoid a complex mould design during the first investigations, a simplified version of the real micro part (cf. Fig. 2), with a flat shape but the same critical features and dimensions will be employed. Therefore, the geometry is obtained by dividing the real micro part vertically along its axis, unfolding and spreading it to a flat shape.

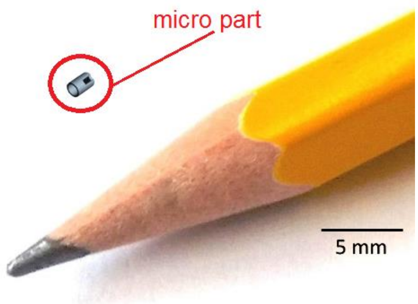

Figure 1. Surgical micro part in comparison with a pencil

A particular aspect of the micro part is the three windows (micro features of the same size) that lead to the separation of the polymer melt during the filling of the micro part and consequently to the formation of weld lines (cf. Fig. 3).

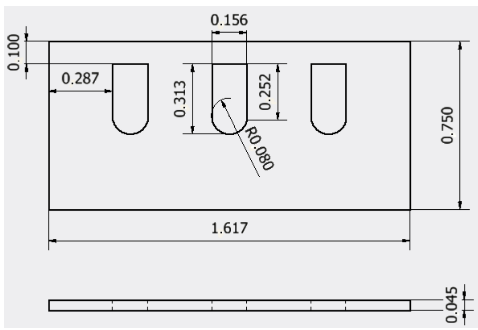

Figure 2. Simplified version of the real micro part containing the three windows (dimensions in mm)

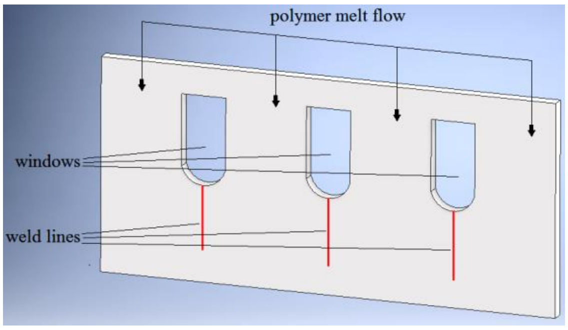

Figure 3. Expected weld lines in correspondence with the three windows

Three different changeable mould inserts were designed (cf. Fig. 4). Each one has the same micro part cavity but different runner and gate system. The aim of this differentiation is to evaluate the effects of runner and gate geometry on the filling behaviour of micro parts through the analysis of weld lines. Runner and gate systems have about the same volume (V) but different area-to-volume ratio (A/V), due to changes of length, depth and slope of the cavity surface.

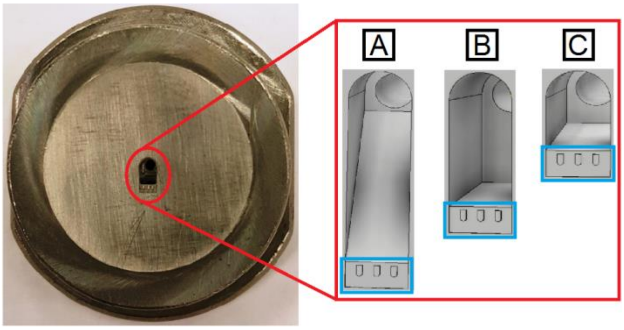

Figure 4. Changeable mould inserts with different runner and gates systems (A, B, C) for the simplified micro part (highlighted in blue)

The tooling process is carried out on a five axes milling center (DMG Sauer Ultrasonic 20 Linear). The micro injection moulding machine (Desma FormicaPlast 2K) that will be used to perform the experiments consists of a two-phase piston injection unit and a pneumatic injection drive. The first phase refers to a heated plasticization zone with a vertically positioned piston while the second one to a horizontally positioned piston for precision injection of the melted polymer material. The material chosen to perform the experiments is uncoloured POM N23200035. This is a thermoplastic polymer with extremely low coefficient of friction and sliding wear when mating with smooth metal surfaces.

3. Weld line formation and measurement

The condition to obtain an ideal straight weld line in simultaneous correspondence with a window is that the flow-fronts fill the micro part in a uniform and synchronised way from both sides (cf. Fig. 5a), until they meet each other. However, the small dimensions of the windows and the 45 µm part thickness could easily lead to a non-uniform filling of the part. It can occur that the polymer melt flow-front of one side fills the micro cavity faster than the flow-front on the other side. Furthermore, a small region may remain unfilled.

In this case, the point where the two melt flow-fronts meet each other might be displaced in forward direction (cf. Fig. 5b) and the weld line could have a different orientation with respect to the ideal case. The filling behaviour will be investigated by analysing position, length and orientation of the weld lines via optical measurements, which represents an alternative and clear method to evaluate the melt front development in the micro cavity. The orientation is determined considering the angle α between the actual and the ideal weld line. The length, the first and last points of a weld line are determined considering a local reference coordinate system positioned on the first point of the ideal weld line.

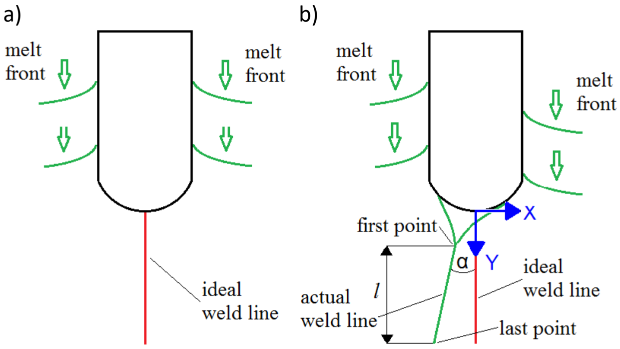

Figure 5: Formation of an ideal (a) and a possible actual (b) weld line

4. Summary and outlook

The mould design for the analysis of the filling behaviour of a micro part through weld line measurement has been presented. Changeable mould inserts with different runner and gate systems were designed with the aim to evaluate the effects on the filling behaviour.

The mould design is not the only factor influencing the filling of the micro-cavity, since it also depends on the micro-injection moulding process parameters setting. The next step will be to employ a design of experiment in order to characterise the relationship between the filling behaviour of the micro part and the process parameters for every changeable mould unit. Injection speed (V_{inj}), melt (T_{melt}) and mould (T_{mould}) temperatures will be varied in order to determine their influence on the position, length and orientation of weld lines. Process parameters will be adapted according to the values recommended by the manufacturer of the polymer material and to research results from previous studies. Injection moulded micro parts will be manufactured and each of them measured multiple times for every different changeable mould insert and process parameters setting. It is expected that high values of injection speed and mould temperature lead to a forward movement of the first point of the weld lines and to longer weld lines due to a reduced viscosity of the polymer melt.

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References

[1] Hasnaes F B, Tosello G, Calaon M, Elsborg R and Hansen H N, 2015, Weld line optimization on thermoplastic elastomer micro injection moulded components using 3D focus variation optical microscopy.

[2] Xie L, Ziegmann G, 2010, Effect of gate dimension on micro injection molded weld line strength with polypropylene (PP) and high-density polyethylene (HDPE), *Int. J. of Advanced Manufacturing Technology* **48**, 71-81.

[3] Tosello G, Gava A, Hansen H N and Lucchetta G, 2010, Study of process parameters effect on the filling phase of micro-injection moulding using weld lines as flow markers, *Int. J. of Advanced Manufacturing Technology* **47**, 81–97.