Two-component injection moulding simulation of ABS-POM micro structured surfaces

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Abstract

Multi-component micro injection moulding (µIM) processes such as two-component (2k) µIM are the key technologies for the mass fabrication of multi-material micro products. 2k-µIM experiments involving a miniaturized test component with micro features in the sub-mm dimensional range and moulding a pair of thermoplastic materials (ABS and POM) were conducted. Three dimensional process simulations based on the finite element method have been performed to explore the capability of predicting filling pattern shape at component-level and surface micro feature-level in a polymer/polymer overmoulding process. Flow front predictions are compared with experimental results using the short shots technique over the whole miniaturized component and within the surface micro structures.

1 Introduction

Multi-component micro injection moulding (µIM) is the key replication technology for high precision manufacturing of multi-material micro products. One of the key challenges in multi-component µIM technology is the achievement of a full surface replication of the first component when moulding the second polymer. This aspect is particularly critical when dealing with increasingly small shot sizes (typical mass of micro moulded components is in the range of 10^1-10^2 mg) as well as micro structured surfaces with features in the range of 10^0-10^2 µm. To understand the polymer flow advancement characteristics when moulding a polymer melt over a miniaturized polymer component with a micro structured surface, two-component (2k) moulding experiments and corresponding three-dimensional finite element µIM simulations were carried out. The possibility of producing multi-material micro plastic parts depends on the availability of a high accuracy injection machine, an optimized moulding process and high precision micro tools specifically developed for micro multi-material applications. The use of simulation for injection moulding process/product/mould design is a powerful tool which can be used up-front to avoid costly tooling modifications and reduce the number of mould trials. However, simulation accuracy needs to be verified to assess the validity of results obtained in the specific multi-material µIM process configuration.

2 Experimental

Sequential two-component µIM was executed during the present study. Process data were gathered and used to establish a reliable simulation methodology suitable for the 2k µIM parts. Parts were moulded on an injection moulding machine equipped with a Ø18mm reciprocating screw adapted to micro injection moulding applications. The first shot material was polyoxymethylene (POM BASF Ultraform H2320 004, Tmelt = 200 °C) and the second shot was acrylonitrile butadiene styrene (ABS Dow Magnum 3416 SC, Tmelt = 260 °C) (Figure 1). A mould with interchangeable micro cavity inserts has been manufactured in order to mould first a 12.5x12.5 mm^2 micro structured POM component and after to overmould such component by ABS short shots until complete filling of the two-component micro cavity (Figure 2).

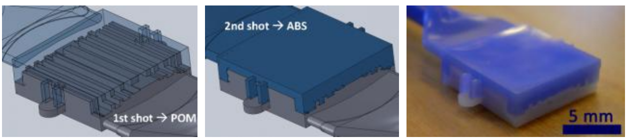
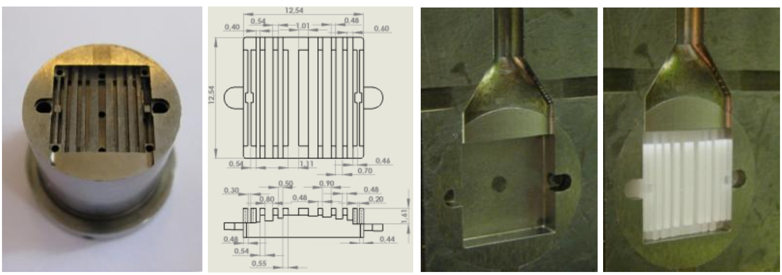


Figure 1: Two-component injection moulding of micro structured component.



(a) (b) (c) (d)

Figure 2: First shot: (a) micro structured tool, (b) part design; second shot: (c) tool cavity, (d) first moulded component inserted prior the 2k moulding cycle.

3 Simulation

2k µIM simulations were performed using the Autodesk Moldflow Insight software. Three-dimensional meshes of both first and second shot were prepared from a 3D CAD model of the full geometries, i.e. including runners, sprues, gates, components and their micro structured surfaces (see Figure 3). Segmentation of the models allowed to employ a course yet precise mesh for the feeding system (element edge length in the order of 500-1000 µm) and a finer mesh (element edge length of 100-200 µm) for the gate and the micro features, where high resolution analysis of shear rate and thermo-mechanical conditions of the polymer flow are required.

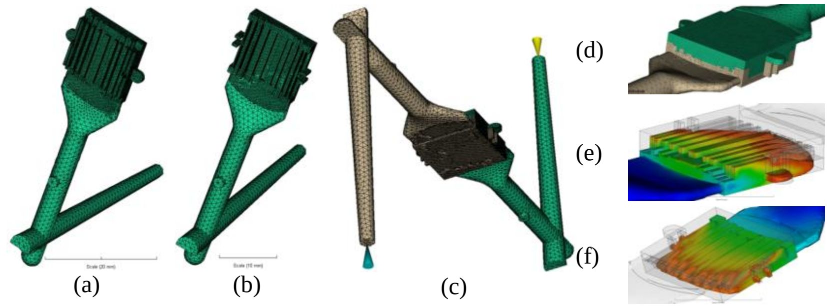


Figure 3: (a) 1st and (b) 2nd component meshes; (c)(d) combined 2k micro part mesh; (e) 1st material (POM) and (f) 2nd material (ABS) cavity filling.

Process settings in the simulation were implemented taking into account actual processing conditions for both 1st and 2nd moulding shots. A particular aspect to consider is the implementation of the injection speed in the simulation filling control settings as it is defined in the injection moulding machine [1]. For the present case, an absolute ram speed vs. time setting was employed (max. injection speed = 45 mm/s).

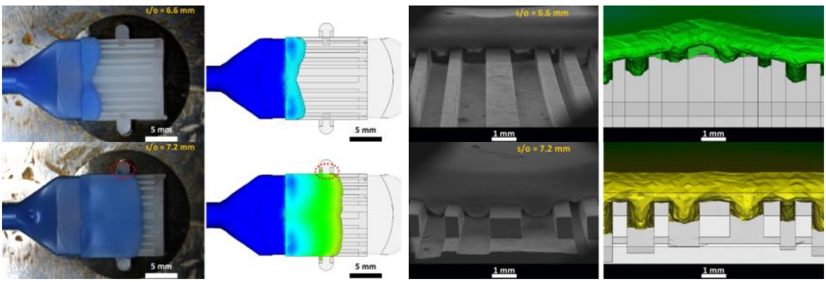


Figure 4: ABS short shots at 6.6 mm and 7.2 mm switch-over point overmoulding the POM component. Comparison of flow front position during filling between experiments and simulations: on the component (left) and on the surface micro features (right).

The validation study was conducted by comparing the flow front shape prediction of the second polymer during filling the 2nd shot cavity. Short shots of ABS overmoulding the POM micro structured component were moulded by applying different switch-over points at increasing stroke lengths. The corresponding injection speed profiles were recorded by the injection moulding machine control unit, and subsequently implemented in the simulation software. Agreement of flow front shape predictions with experiments was verified at both dimensional levels (on the component and on the surface micro structures) (see Figure 4).

4 Conclusion

A two-component micro injection moulding process and its simulation have been established. Flow front pattern was caracterized at both millimetre (i.e. component) and sub-mm (surface micro structure) levels. Multi-material process simulation results in terms of flow pattern at both dimensional scales were verified. The analysis confirms the critical importance of: (1) a complete modelling of the component in all its parts (runner, sprue, gate, part, micro structured surface) for accurate geometrical and volumetric representation of the moulding (especially for miniaturized and micro parts, which can have a rather small volume as compared with the full moulding); (2) a high accuracy 3D mesh of all details of the component through the whole dimensional range from the millimetre to the 10^0-10^1 µm scale; (3) correspondence of the simulation process set-up parameters with those encountered during experiments. The established validation methodology allows obtaining an improved flow front shape simulation accuracy in multi-material micro injection moulding.

Acknowledgements:

This paper reports work undertaken in the context of the project "Hi-Micro" (High Precision Micro Production Technologies, http://www.hi-micro.eu/), Task 1.2 "Micro Injection-Moulding Oriented Product Design". Hi-Micro is a Collaborative Project supported by the European Commission in the 7th Framework Programme (Grant agreement no: 314055).

References:

[1] G. Tosello, F.S. Costa, H.N. Hansen (2011) High Accuracy Three-dimensional Simulation of Micro Injection Moulded Parts, 11th International Conference of the European Society for Precision Engineering and Nanotechnology (euspen), 23-27 May 2011, Lake Como (Italy), pp.15-19.