High Accuracy Three-dimensional Simulation of Micro Injection Moulded Parts

G. Tosello[1], F. S. Costa[2], H. N. Hansen[1]
[1]*Department of Mechanical Engineering, Technical University of Denmark*
[2]*Autodesk Inc, Moldflow R&D Center, Australia*

guto@mek.dtu.dk

Abstract

Micro injection moulding (µIM) is the key replication technology for high precision manufacturing of polymer micro products. Data analysis and simulations on micro-moulding experiments have been conducted during the present validation study. Detailed information about the µIM process was gathered and used to establish a reliable simulation methodology suitable for µIM parts. Various Simulation set-up parameters that have been considered in order to improve the simulation accuracy: injection speed profile, melt and mould temperatures, 3D mesh, material rheology, inertia effect and shrinkage prediction. Quality factors investigated for the quantitative comparisons were: short shots length, injection pressure profile, moulding mass and flow pattern.

1 Introduction

The use of simulation for injection moulding design is a powerful tool which can be used up-front to avoid costly tooling modifications and reduce the number of mould trials. Experimental validation studies are an important tool for establishing best practice methodologies for use during analysis set up and the development of new products.

The accuracy of the simulation results depends on many component technologies and information. Therefore, accurate process calibration was performed both to provide quality input data for simulation set-up and to obtain reliable output data for results validation.

2 Experimental

The possibility to produce micro plastic parts depends on the availability of high accuracy micro injection machines, optimized moulding processes and high precision micro tools. A micro moulding machine (FormicaPlast 1k, i.e. one-component, from DESMAtec), provided with a two-plunger plasticizing/injection unit (see Figure 1), was employed during the experiments (injection piston diameter = 3 mm, plasticizing piston diameter = 6 mm) [1].

In-line process monitoring of mould temperatures, melt temperatures, injection piston speed and positions was carried out during the experiments and implemented in the simulation. Measured mould temperatures were 51.8±0.3 °C at the injection plate and 45.0±0.1°C at ejection plate. Melt temperature was set at 220°C and measured at 223.7±0.1°C. Injection profile was set with a constant speed of 100 mm/s through the whole piston stroke length of 12 mm. Average injection speed was measured at 99.7 mm/s with a standard deviation of 1.1 mm/s over the whole 12 mm range of piston stroke length and a production batch of 20 cycles. Piston speed was measured at 12 different stroke lengths: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 mm. Cavity injection time to fill a complete part was 120 ms.

The tool was a two cavity mould as shown in Figure 2, with a part thickness of 1 mm, width ranging from 1.5 mm to 3 mm and a part length of 12 mm. The whole moulding including the miniaturized sprue, two runners and two parts had a weight of 91.3±0.3 mg (see Figure 2). At the set injection speed of 100mm/s, short shot experiments were performed at 9 different injection times of 40, 50, 60, 70, 80, 90, 100, 110, 120 ms (where the flow front reaches the gate after 40ms and produces a full part after 120ms, see Figure 3). A mass repeatability (i.e. 1σ standard deviation) between 0.2 and 0.4 mg was obtained for each series of short shots experiments. The moulding experiments were performed using a BASF Ultraform H2320 004 POM material. The material viscosity was determined using a capillary rheometer to verify the accuracy of the material characteristics in the software database.

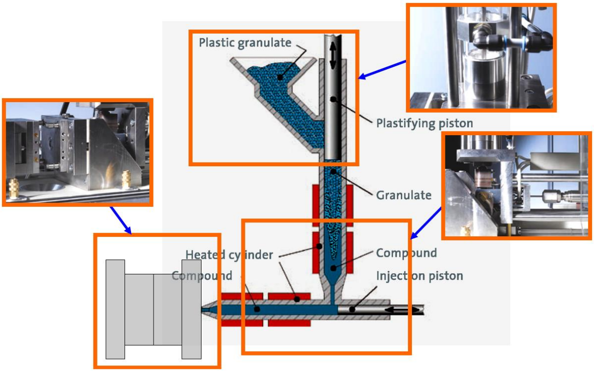

Figure 1: µIM machine structure: two-piston (plasticizing and injection) unit, miniaturized hopper, micro mould, metering and injection chambers [1].

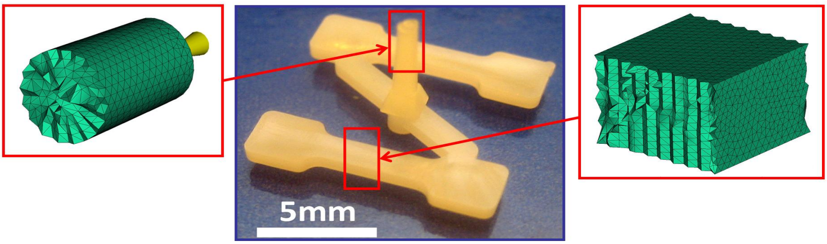

Figure 2: µIM part and mesh details (3D element size = 100µm, no. layers ≥ 10).

3 Simulation

Simulations were run and 3D analysis meshes were prepared using the Autodesk Moldflow Insight 2011-Service Pack 2 product (AMI 2011). From an IGES 3D CAD model of the geometry, a 3D volume mesh of tetrahedral elements was created (1’000’000 elements, see details in Figure 2). Micro moulding simulations were executed taking into account actual processing conditions implementation in the software. Accurate process control allows uncertainties and inaccuracies in the set-up phase of the simulation to be reduced. In particular, inputs regarding the filling control settings in the software were consistently defined by using a ram speed vs. position setting. From the experimental process monitoring, the actual piston velocity of 100 mm/s was used for the whole stroke length. An analysis sequence including filling, packing, cooling and warpage calculations was selected.

The validation study was based on the comparison of simulation results with accurate process/product measurements. The simulation results were validated on the basis of injection pressure, short shots flow front pattern, short shots mass and short shots length comparisons (see Figure 3 and Figure 4).

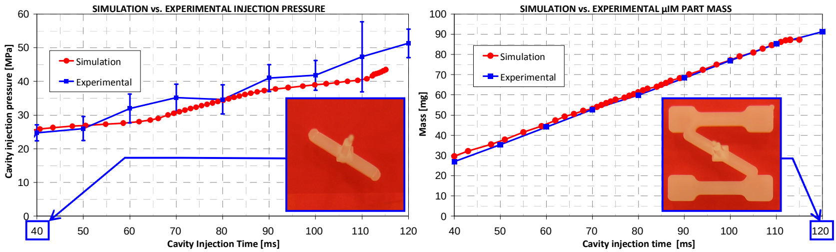

Figure 3: Simulation vs. experimental comparisons: injection pressure at injection location (left), micro moulded parts mass (short shots and full part)

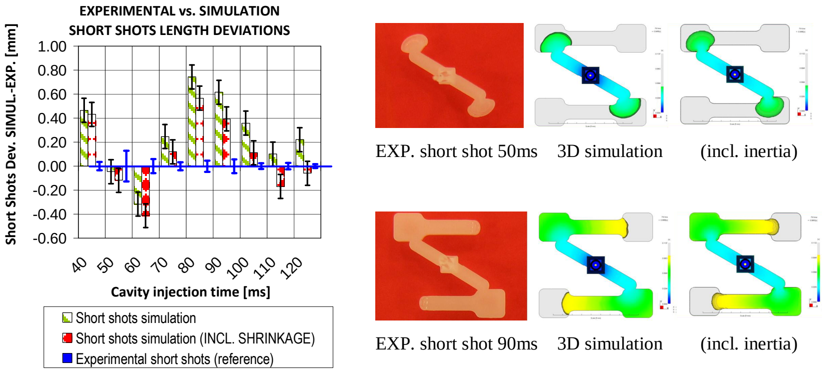

Figure 4: Simulation optimization: effect of shrinkage on short shots length deviation (left) and of inertia on flow front pattern prediction (right).

4 Conclusion

A repeatable and calibrated process including accurate measurements of the micro moulded parts is required to perform a reliable validation of µIM simulation. The simulation methodology established allowed the attainment of an accurate simulation in terms of cavity injection pressure, short shots mass, length, and flow front shape.

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References:

[1] G. Tosello, H.N. Hansen, P. Guerrier (2010) Process Condition Monitoring of Micro Moulding Using a Two-plunger Micro Injection Moulding Machine, 7th Int. Conf. on Multi-Material Micro Manufacture (4M/ICOMM 2010), Bourg en Bresse and Oyonnax (France), 17-19 November 2010, Research Publishing, ISBN:978-981-08-6555-9, doi:10.3850/978-981-08-6555-9 138, pp.283-286.