European Society for Precision Engineering and Nanotechnology (euspen), 18th International Conference, Venice (Italy), 4th-8th June 2018

Prediction of micro-sized flash using micro-injection moulding process simulations

F. Baruffi[1], M. Calaon[1], G. Tosello[1]

[1] Technical University of Denmark, Department of Mechanical Engineering, Kgs. Lyngby, Denmark

Abstract

Micro-injection moulding process simulations can be important to substantially reduce experimental and quality assurance efforts [1-2]. In this study, the usage of process simulations for the prediction of the size of the flash affecting a three-dimensional polyoxymethylene (POM) micro component is discussed. A 3D multi-scale mesh was used to discretize the geometry of the one-cavity micro mould. The venting channel was included into the model in order to simulate the flash formation as a virtual short-shot. Simulations were run with Autodesk Moldflow Insight 2017® and results validated comparing numerical results with experimental observations. A 3D focus variation instrument was used to measure the flash on moulded parts. Four injection moulding process parameters were tested to validate the numerical model with respect to process settings variation. Flash size was generally overestimated by simulations. However, both real and numerical results agreed on the signs and magnitudes of the effects of the investigated process parameters, demonstrating that simulations are a helpful tool for process optimization in the micro-scale.

Case study

- Objective ⇒ **prediction of micro-sized flash defect using injection moulding process simulations**
- Flash generated by the need of a venting channel for repeatable part filling
- Volume = 0.07 mm³, mass = 0.1 mg

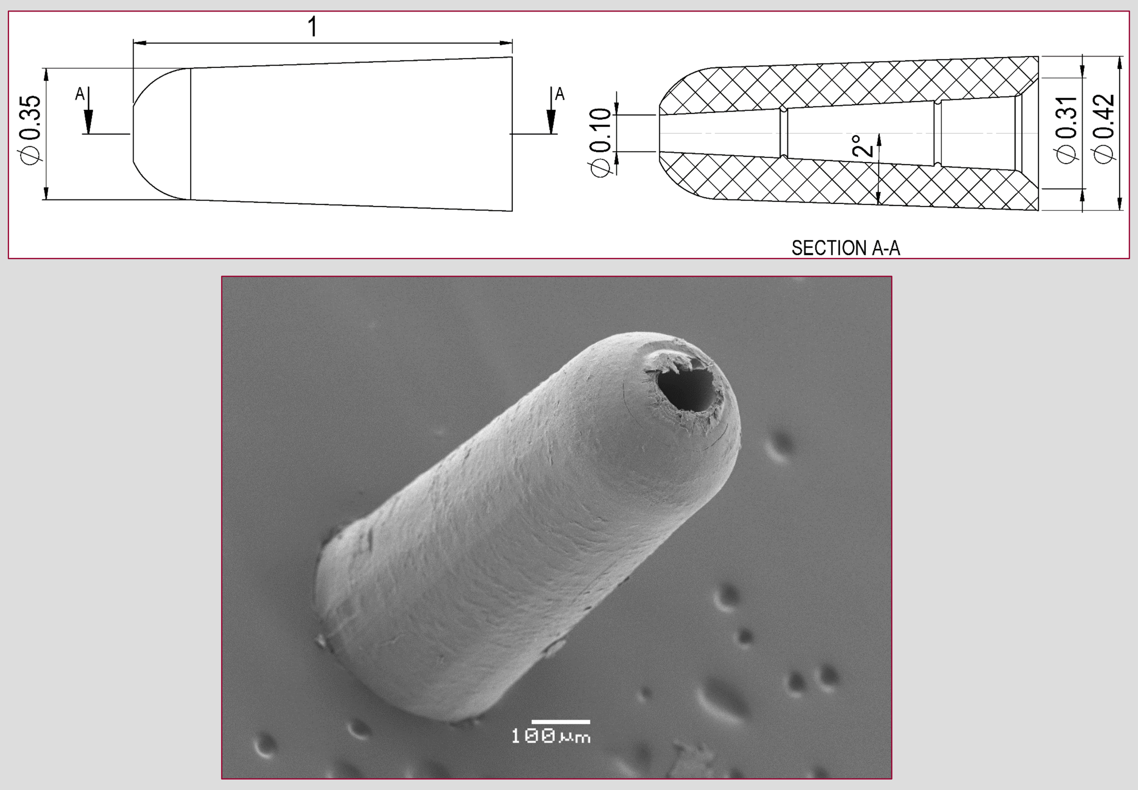

Figure 1. Geometry of the part with nominal dimensions in mm (top) and SEM image of it (bottom).

Experimental setup

- The effects of 4 process parameters on the flash size measured by the flash area A_{flash} were investigated
- µIM machine: Wittmann-Battenfeld MicroPower 15
- Material: high-flowability Polyoxymethylene (POM)
- Single-cavity insert machined by µEDM
- Three-plate mould enabling automatic separation of gate from the part
- Design of Experiments (DoE):
  - 2^4 full factorial with 5 replicates (Table 1)
- Measurement of A_{flash} performed with a focus variation microscope:
  - Magnification: 20×
  - Lateral digital resolution: 0.44 µm

Process parameter	Low level	High level
Melt temperature [°C], T_{melt}	200	220
Mould temperature [°C], T_{mould}	100	110
Holding pressure [bar], p_{hold}	250	500
Injection speed[mm/s], v_{inj}	150	350

Table 1: Experimental moulding conditions.

Simulation setup

- Autodesk Moldflow Insight (ASMI) 2017® was used for the numerical analysis
- The model comprised part and feed system (Figure 2)
- A multi-scale 3D mesh was applied:
  - 300 µm element size on the sprue
  - 20 µm element size on the venting channel
  - Total of 10^6 tetrahedrons
- Mathematical models:
  - Flow ⇒ 3D Navier-Stokes equations
  - Rheology ⇒ Cross-WLF model
  - Thermodynamics ⇒ Tait model

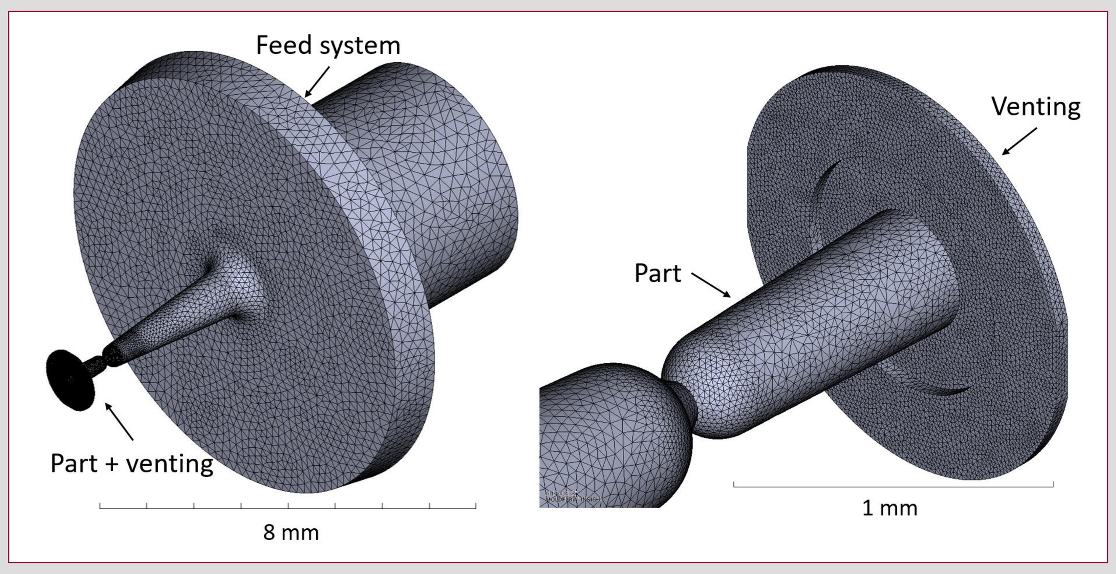

Figure 2. Meshed model.

Results

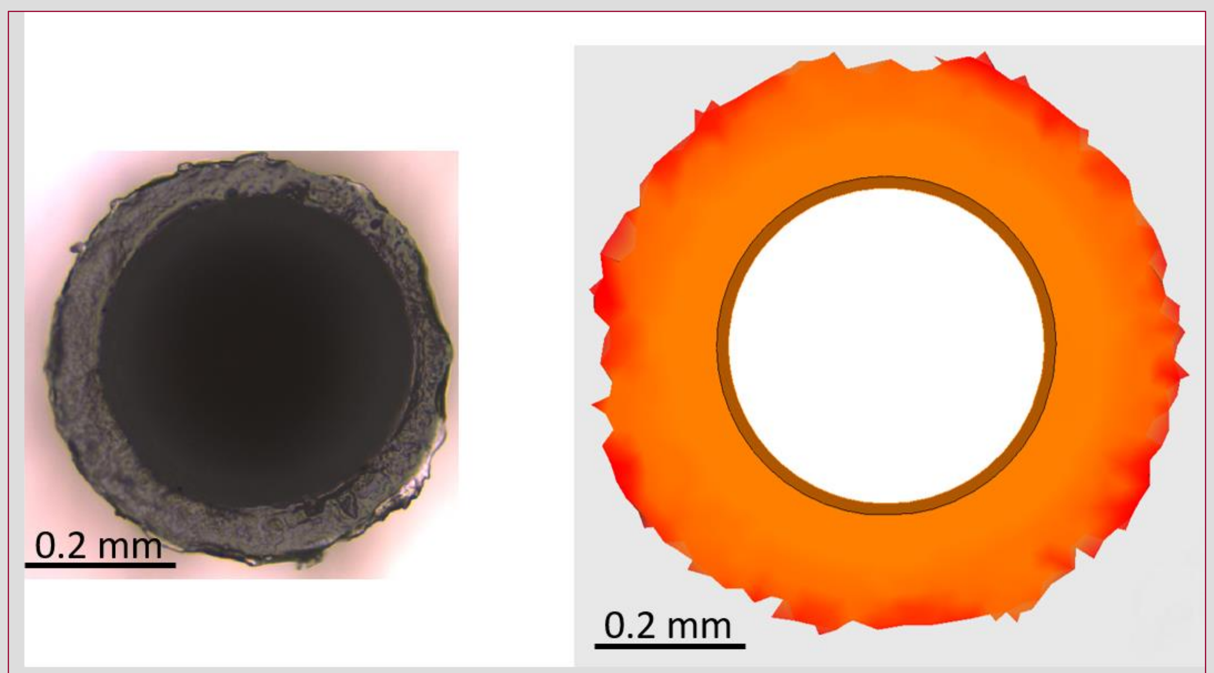

Figure 3. Real flash on the part (left) and simulated flash (right).

- Real flash size was always smaller than simulated one (factor of 2)
- Discrepancy due to underlying model simplifications such as neglecting surface roughness

- Increase of four variables led to an increase of flash size due to polymer melt rheology
- The numerical model was capable of predicting the signs of the effects
- The magnitudes of the effects, i.e. the slopes in the main effects plot, were very similar in the two cases
- Effects of v_{inj} and T_{mould} were the best predicted

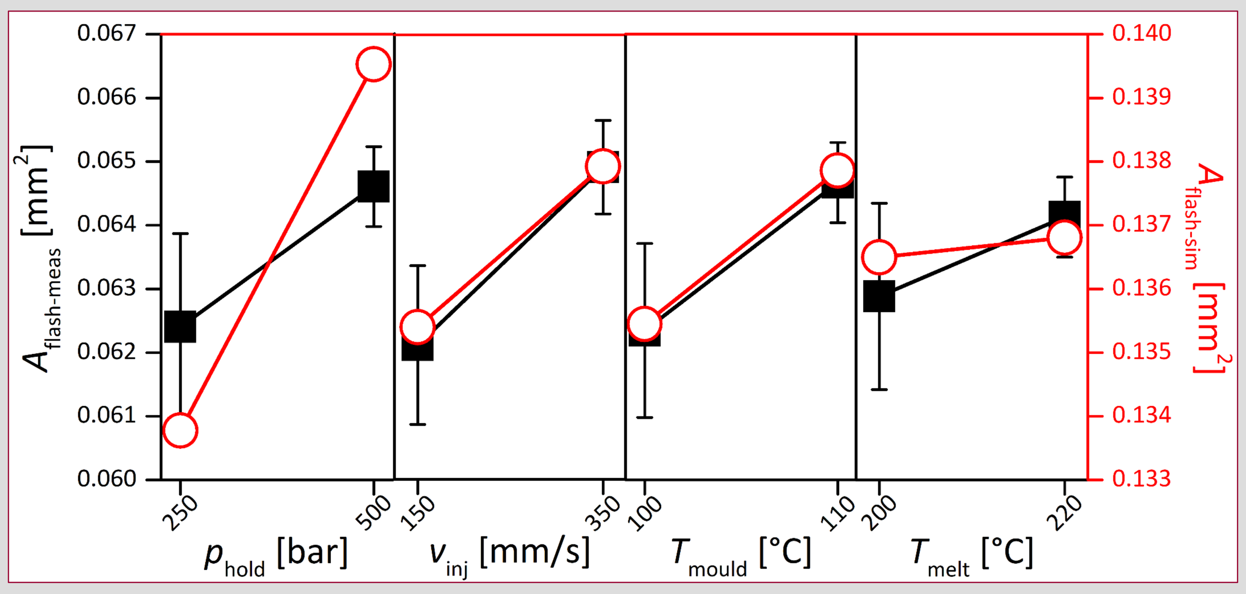

Figure 4. Main effects plot of flash area for experiments $A_{flash\text{-}meas}$ (in black) and simulations $A_{flash\text{-}sim}$ (in red). Note that the scales for the two sets of results are different but the shown ranges are equal. Interval bars represent the standard errors of experimental data.

Conclusion

Flash size on micro moulded parts was characterized by the flash area measured using a focus variation microscope. Injection moulding simulations were run and the flash was visualized as a virtual short shot. Experimental and numerical results were compared over a range of process parameters. Results showed that simulations overestimated the flash size affecting the produced parts. However, the effects of the process parameters was well predicted by the numerical model, being the slope signs of the main effects plot analogous. The magnitude of the effects was also similar, particularly for mould temperature and injection speed. This proved that injection moulding simulations can be a valuable tool for product/process optimization when flash minimization is the objective.

References

[1] G. Tosello, F. S. Costa, and H. N. Hansen, "Micro Injection Moulding High Accuracy Three-dimensional Simulation and Process Control," Proc. Polym. Process Eng. 11, pp. 1–14, 2011.
[2] L. Wang, Q. Li, W. Zhu, and C. Shen, "Scale effect on filling stage in micro-injection molding for thin slit cavities," Microsyst. Technol., vol. 18, no. 12, pp. 2085–2091, 2012.

Acknowledgements

This research work was undertaken in the context of ***MICROMAN*** project ("Process Fingerprint for Zero-defect Net-shape MICROMANufacturing", *http://www.microman.mek.dtu.dk/*). MICROMAN is a Marie Skłodowska-Curie European Training Network supported by Horizon 2020, the EU Framework Programme for Research and Innovation (Project ID: 674801).

µMAN
Process Fingerprint for Zero-defect Net-shape MICROMANufacturing

THE FRAMEWORK PROGRAMME FOR RESEARCH AND INNOVATION
HORIZON 2020