POLYOXYMETHYLENE FLOW ENHANCEMENT USING THE ROUGH SURFACE INJECTION MOULD CAVITY

PETR FLUXA, MICHAL STANEK, MARTIN OVSIK, ADAM DOCKAL

Tomas Bata University in Zlin, Zlin, Czech Republic

DOI : 10.17973/MMSJ.2020_06_2019018

fluxa@utb.cz

Injection moulding is a manufacturing process which is suitable for high-volume production of polymer parts. These products are final and do not require any additional operations. The quality of the final product is significantly affected by the surface of the mould cavity. This paper reveals the influence of cavity surface roughness and technological parameters on the flow length of polyoxymethylene (POM) into the mould cavity. These results indicate that costly finishing methods used for working of mould cavities can be replaced with less expensive manufacturing methods. Furthermore, it might be possible to shorten the time necessary for the production of the injection mould.

KEYWORDS

Injection moulding, polymer fluidity, surface roughness, polyoxymethylene, rheology

1 INTRODUCTION

Injection moulding is a polymer processing technology which has seen swift progress, and at this moment, it is used for the majority of produced plastic parts. Injection moulds are complex tools made by various materials and machined by different manufacturing operations. These tools, however, are able to produce final parts and no further operations are necessary.

Polymer granules are fed into a hopper of n injection mould. After this, the material is forced forward into the heated barrel by the rotating screw. The polymer melt is homogenized and heated to reach the desired temperature. At this moment, the cyclic injection moulding process is commonly divided into several stages: filling, packing, cooling and ejection of the final part. The most time demanding section is cooling, on the other hand, filling is the most important stage during the cycle. This stage is rapid and also the most complicated process, which results in the final part condition.

Furthermore, the quality of the product is based on the mould cavity surface roughness. On account of this, finishing operations are used for machining the mould cavity, including runners. These technologies, such as grinding and polishing, are expensive and time consuming. Comparative costs of different manufacturing processes are shown on Fig. 1. As can be seen on the figure, machining costs steeply escalated with decreasing surface roughness values.

In this paper, the influence of injection pressure and surface roughness of the mould cavity on the flow length are discussed. The question is how flow length of polymer melt changes using the mould cavity with different surface roughness values and if it is necessary to use costly finishing operations in all cases.

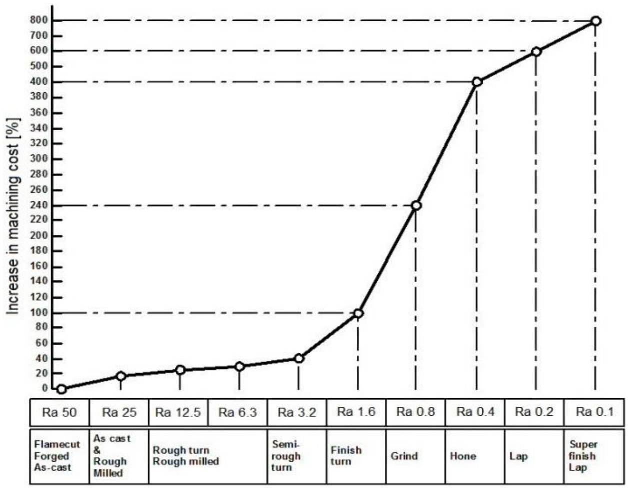


Figure 1: Comparative costs of different manufacturing processes

2 EXPERIMENTAL

2.1 *Tested material*

Polyoxymethylene POM (FORMOCON FM090) was chosen for the fluidity test. This polymer is commonly used thermoplastic with high stiffness and exceptional dimensional stability. Melt temperature during the experiment was 190 °C for all testing samples. In addition, POM absorbs moisture, which can cause many defects on the final product. For this reason, the drying unit Arburg Thermolift 100-2 was used to dry plastic granulate and to feeding the injection machine.

2.2 *Injection mould*

Injection moulding technology was used for preparing all testing samples. The special injection mould was made to realize this experiment. This mould was designed for easy manipulation when changing testing plates.

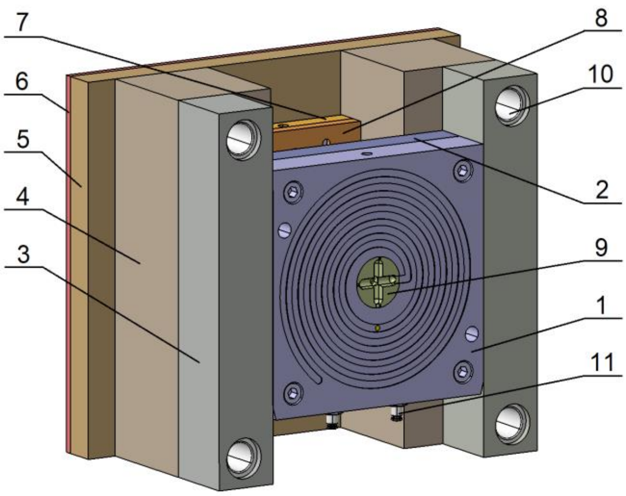


Figure 2: Core side of the injection mould
1 - testing core plate, 2 - backing plate, 3 - riser, 4 - spacer block, 5 - clamping plate, 6 - heat insulation board, 7 - ejector backing plate, 8 - ejector front plate, 9 - sprue puller insert, 10 - guide bush, 11 - hose nipple

Fig. 2 shows the core side of the testing injection mould. The core and backing plate are fixed by 2 riser bars. The core plate includes a coolant circuit to control the mould surface temperature. The mould surface temperature was set to 80 °C. On account of this, the insulation plate was used to avoid thermal conduction to the injection machine.

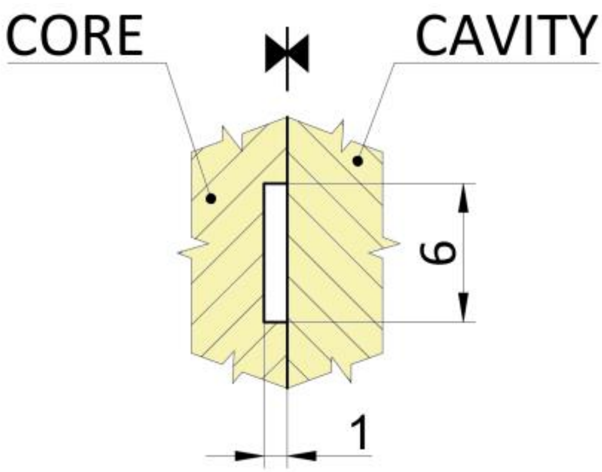


Figure 3: Cross section of the mould cavity

The core plate contains a spiral suitable for fluidity testing. A cross section of this spiral can be seen on Fig. 3. The maximum possible length of a testing sample is limited by the length of the spiral channel of 2000 mm.

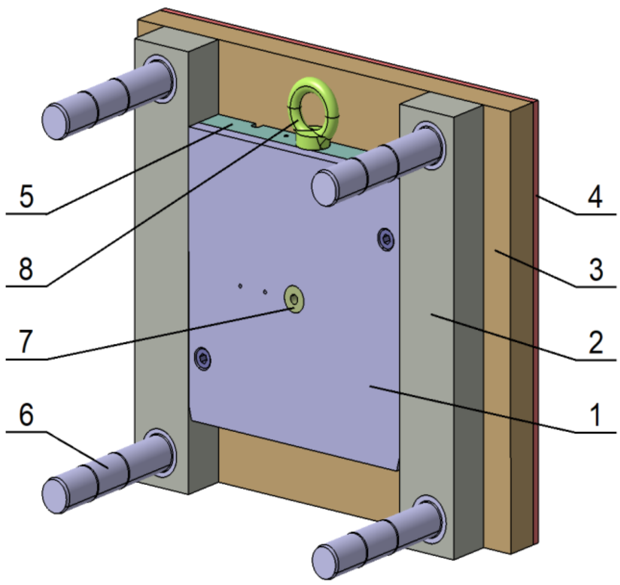


Figure 4: Cavity side of the injection mould
1 - testing cavity plate, 2 - riser, 3 - clamping plate, 4 - heat insulation board, 5 - backing plate, 6 - guide pin, 7 - sprue, 8 - lifting eye bolt

Fig. 4 presents the cavity side of the testing injection mould. The testing cavity plate and backing plate are fixed by 2 riser bars, similarly to the core side. In the same way, the cavity side includes the insulation plate. The testing cavity plate is attached by only 2 screws contributing to shorten the time needed to change the plate.

Eight different cavity testing plates were machined. In this case, four different manufacturing operations were used: milling, grinding, polishing and electrical discharge machining. These technologies are common in injection mould cavity production. Cavity testing plates are shown in Tab. 1 with surface roughness and a photo of their surface.

It is worthwhile to note, that testing cavity plates with different surfaces influence the final mould cavity by only about 43%. More obvious results could be obtained by using eight different core plates with the required surface roughness.

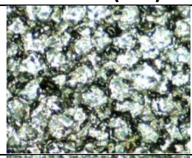
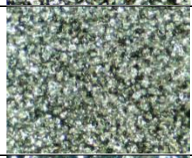
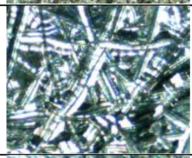
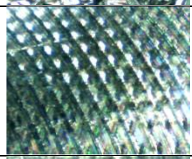
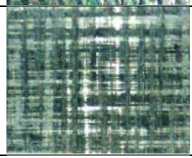
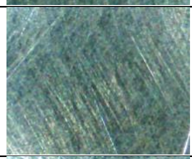
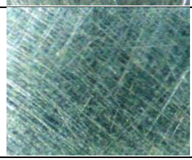
Manufacturing technology	Surface roughness Ra	Photo of the surface (50x)
Electrical discharge machining	12.74	
Electrical discharge machining	4.36	
Milling	5.01	
Milling	1.60	
Grinding	0.80	
Grinding	0.45	
Polishing	0.42	
Polishing	0.10	

Table1: Testing core plates surfaces

2.3 Injection machine

The testing samples were prepared using the hydraulic injection moulding machine Arburg Allrounder 470 C Golden Edition with the maximum clamping force of 1500 kN. Injection pressure values were set up from 200 bar to 800 bar.

Figure 5: Injection moulding machine Arburg Allrounder 470C

3 RESULTS AND DISCUSSION

Testing samples were prepared with a combination of 7 injection pressure values and 8 different cavity testing plates. Subsequently, 10 testing samples were measured for each combination. Box plot diagrams and line graphs with selected statistical values were used to demonstrate results.

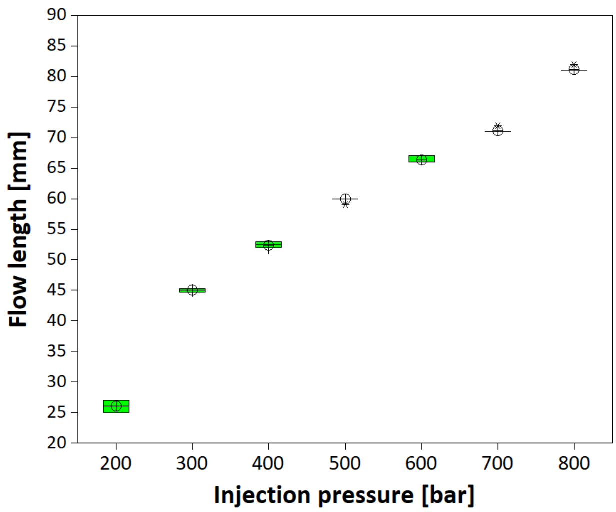


Figure 6: Flow length vs. injection pressure (testing plate Ra 0.8)

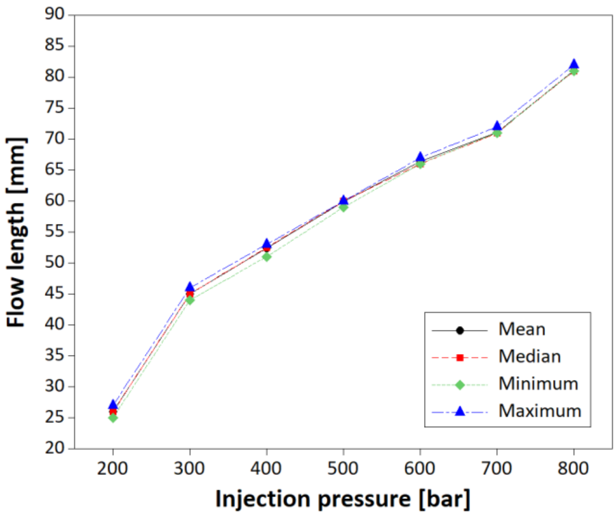


Figure 7: Flow length vs. injection pressure- selected statistical values (testing plate Ra 0.8)

Fig. 6 and Fig. 7 depict the relationship between flow length and injection pressure. Both these graphs represent values for the cavity plate with surface roughness of Ra 0.8. As can be seen from these figures, flow length gradually grew with increasing injection pressure. Likewise, the trend was the same for all testing cavity plates. Another notable result is the range of the data. The range was small and no outliers were measured.

These results correspond with the predicted trend. As expected, flow length enchanced with increasing injection pressure.

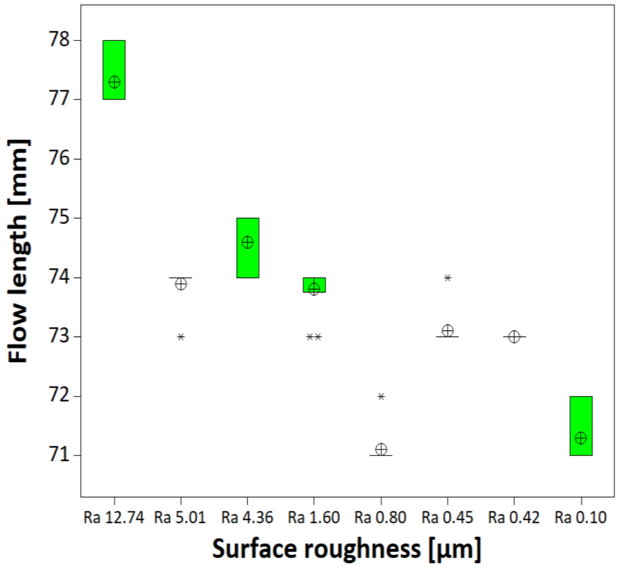


Figure 8: Flow length vs. surface roughness (injection pressure 700 bar)

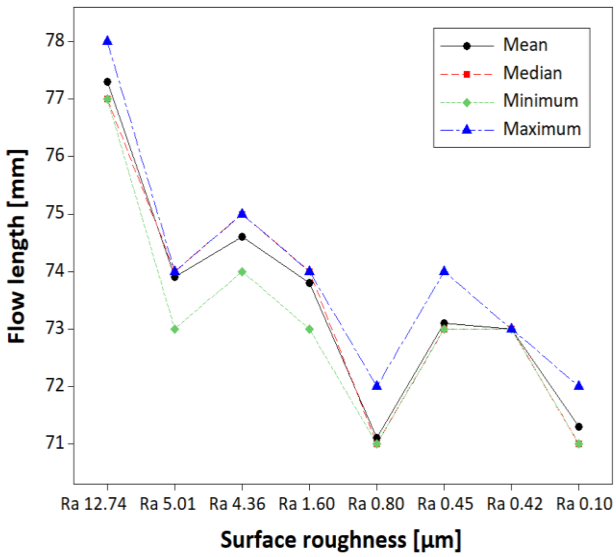


Figure 9: Flow length vs. surface roughness - selected statistical values (injection pressure 700 bar)

Fig. 8 and Fig. 9 present the influence of surface roughness on flow length. Injection pressure was set to 700 bar for values in these graphs. As illustrated in these graphs, the maximum flow length was achieved using the plate with the highest surface roughness. On the contrary, testing cavity plates with lower surface roughness have resulted in lower flow length values.

It is known, that polymer melt flow is affected by the quality of the mould cavity surface. General expectation is that using finishing operations, such as grinding or polishing, may improve the polymer flow. Instead, as results shown, it is possible to claim that flow length of testing samples decreased with declining surface roughness of the mould cavity. As a result, this important finding can have significant impact on the injection mould manufacturing costs. Costly finishing technologies can be excluded from the mould cavity machining process. In addition, this can shorten the time needed for the injection mould production.

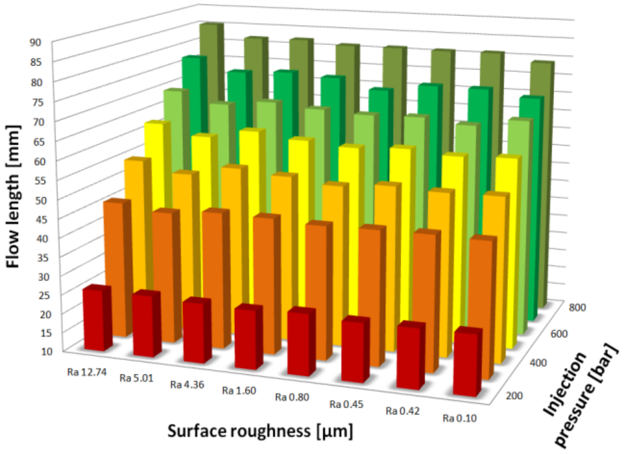


Figure 10: Influence of injection pressure and surface roughness on the flow length

Fig. 10 summarizes the influence of injection pressure and surface roughness on the flow length. As shown in the figure, flow length gradually climbed with increasing injection pressure and moderately went down with decreasing surface roughness of the cavity testing plate.

4 CONCLUSIONS

This research investigates the influence of injection pressure and surface roughness of the mould cavity on the flow length of POM melt. These results present the nearly linear trend in relationship between injection pressure and flow length of POM.

These results also show that flow length slowly went down with decreasing surface roughness of the mould cavity. Furthermore, the trend was evident while the surface roughness of the testing cavity plate contributed to the final surface roughness by only about 43%.

In conclusion, flow length of POM melt was positively affected using the mould cavity with high surface roughness. This finding is important and can save time and resources during injection mould production. This could be achieved in practice by excluding costly finishing methods (grinding or polishing) within some parts of the injection mould. These parts can be the cold runner system (excluding the sprue to provide a smooth ejection of the part) or parts of the mould cavity resulting in non-visual and non-functional surfaces of the final product.

ACKNOWLEDGMENTS

This work was supported by the European Regional Development Fund under the project CEBIA-Tech Instrumentation No. CZ.1.05/2.1.00/19.0376 and by the Ministry of Education, Youth and Sports of the Czech Republic within the National Sustainability Program project no. LO1303 (MSMT-7778/2014). Moreover, it was supported by the Internal Grant Agency of TBU in Zlin: no. IGA/FT/2020/003.

REFERENCES

[Aguado 1999] Aguado, J., David, P. (1999) Feedstock Recycling of Plastic Wastes, p. 206. Cambridge, UK: Royal Society of Chemistry, p. ISBN 978-085-4045-310.

[Arburg 2018] Arburg. Arburg Allrounder 470 C Golden edition [online]. 2018 [19-02-2019]. Available from: https://www.arburg.com/.

[Bernasconi 2007] Bernasconi, A., Davoli, P., Rossin, D., Armanni, C. Effect of reprocessing on the fatigue strength of a fibreglass reinforced polyamide (2007), 38 (3), pp. 710-718. doi: 10.1016/j.compositesa.2006.09.012.

[Bobek 2017] Bobek, J. Injection molds for thermoplastic processing [online]. 2017 [18-02-2019]. ISBN 978-80-7454-674-7. Available from https://publi.cz/books/179/Cover.html, [in Czech].

[Dolinay 2011] Dolinay, J., Dostalek, P., Vasek, V., Vrba, P. Teaching platform for lessons of embedded systems programming (2011), pp. 158-160. ISBN: 978-161804004-6.

[Gordon 2010] Gordon, M.J. Total quality process control for injection molding. 2nd ed. Hoboken, N.J.: 2010. Wiley series on plastics engineering and technology ISBN 978-0-470-22963-7.

[Halevi 2003] Halevi, G. Process and operation planning. Boston: Kluwer Academic Publishers, 2003. ISBN 14-020-1653-0.

[Janostik 2016] Janostik, V., et al. The Influence of runner system on production of injection molds. MATEC Web of Conferences, 2016, Vol. 76. ISSN 2261-236X.

[Kasgoz 2016] Kasgoz, A., Akın, D., Durmus, A. Quantifying Structural and Solid-State Viscoelastic Properties of Poly(propylene) (PP)/Poly(oxymethylene) (POM) Blend Films (2016), 301 (11), pp. 1402-1414. doi: 10.1002/mame.201600109.

[Stanek 2017] Stanek, M. Influence of technological parameters on polymer flowability: Tomas Bata University in Zlin, 2017. ISBN 978-80-7454-674-7, [in Czech].

[Zeman 2018] Zeman, L. Plastic injection: theory and practice. Prague: Grada Publishing, 2018. ISBN 978-802-7106-141, [in Czech].

[Zenkiewicz 2009] Zenkiewicz, M., Rytlewski, P., Moraczewski, K., Stepczyńska, M., Karasiewicz, T., Richert, J., Ostrowicki, W. Effect of multiple injection moulding on some properties of polycarbonate (2009), 37 (2), pp. 94-101.

CONTACTS

Ing. Petr Fluxa
Tomas Bata University in Zlin,
TGM 5555, 760 01 Zlin, Czech Republic
fluxa@utb.cz

doc. Ing. Michal Stanek, Ph.D.
Tomas Bata University in Zlin,
TGM 5555, 760 01 Zlin, Czech Republic
stanek@utb.cz

Ing. Martin Ovsik, Ph.D.
Tomas Bata University in Zlin,
TGM 5555, 760 01 Zlin, Czech Republic
ovsik@utb.cz

Ing. Adam Dockal
Tomas Bata University in Zlin,
TGM 5555, 760 01 Zlin, Czech Republic
a_dockal@utb.cz