# Polymer Fluidity Influenced by the Percentage of Filler

M. Stanek, D. Manas, M. Manas, K. Kyas, V. Senkerik, A. Skrobak and J. Navratil

***Abstract*—** Delivery of polymer melts into the mold cavity is the most important stage of the injection molding process. This paper shows the influence of cavity surface roughness and technological parameters on the flow length of polymers into mold cavity. Application of the measurement results may have significant influence on the production of shaping parts of the injection molds especially in changing the so far used processes and substituting them by less costly production processes which might increase the competitiveness of the tool producers and shorten the time between product plan and its implementation.

***Keywords*—** Fluidity, injection molding, mold, polymer, roughness, surface.

## I. Introduction

INJECTION molding is one of the most extended polymer processing technologies. It enables the manufacture of final products, which do not require any further operations. The tools used for their production – the injection molds – are very complicated assemblies that are made using several technologies and materials. Working of shaping cavities is the major problem involving not only the cavity of the mold itself, giving the shape and dimensions of the future product, but also the flow pathway (runners) leading the polymer melt to the separate cavities. The runner may be very complex and in most cases takes up to 40% volume of the product itself (cavity). In practice, high quality of runner surface is still very often required. Hence surface polishing for perfect conditions for melt flow is demanded. The stated finishing operations are very time and money consuming leading to high costs of the tool production.

The fluidity of all polymers during injection molding cycle is affected by many parameters (mold design, melt temperature, mold temperature, injection rate, pressures, etc.) and by the flow properties of polymers. Results of the experiments carried out with polypropylene contained different amount of filler proved a minimal influence of surface roughness of the runners on the polymer melt flow. This considers excluding (if the conditions allow it) the very complex and expensive finishing operations from the technological process as the influence of the surface roughness on the flow characteristics does not seem to play as important role as was previously thought. A plastic nucleus is formed by this way of laminar flow, which enables the compression of the melt in the mold and consecutive creeping. A constant flowing rate given by the axial movement of the screw is chosen for most of the flows. During filling the mold cavity the plastic material does not slide along the mold surface but it is rolled over. This type of laminar flow is usually described as a "fountain flow" (Fig.1).

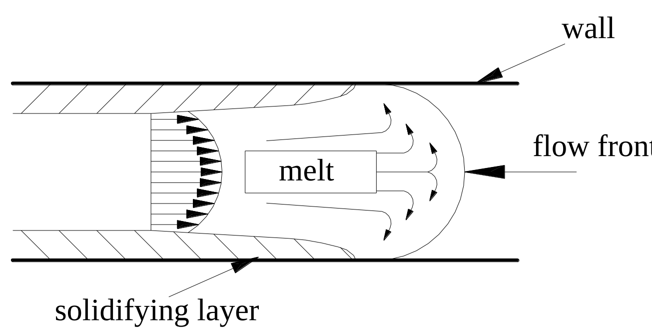


Fig. 1 Fountain flow

## II. Injection Molding

The injection mold for was designed for the easiest possible manipulation both with the mold itself and during injection molding while changing the testing plates, size of the mold gate, pressure and temperature sensors etc. The injection mold is inserted into a universal frame (Fig. 2) which was designed for use with many different injection molds that fit the size of the frame. This makes the change of the separate injection molds easier, because the frame remains clamped to the injection molding machine and only the shaping and ejection parts of the molds are changed. Attaching right and left sides of the frame to fixed and moving plates of the injection molding machine is done using four adjustable clamps on each side. [16, 17]

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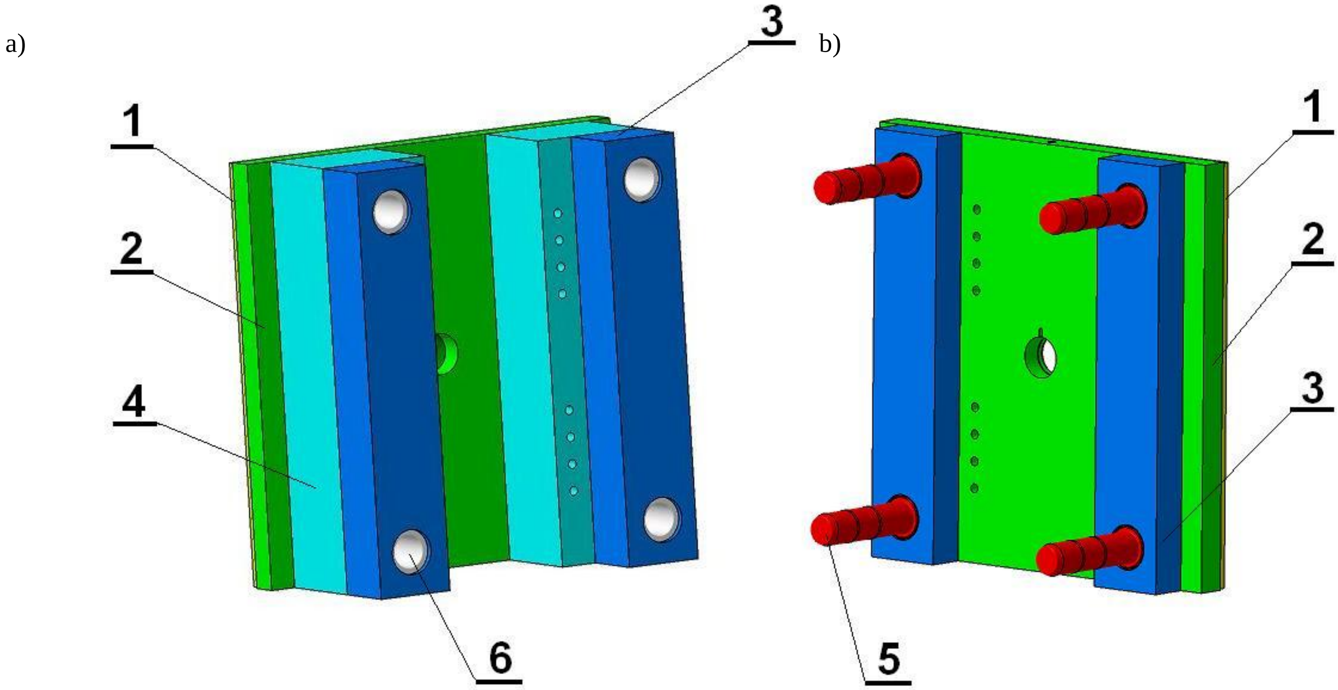



Fig. 2 Universal frame
a) left side, b) right side
1 – insulating plate, 2 – clamping plate, 3, 4 –spacers, 5 – guide pillar, 6 – guide bush

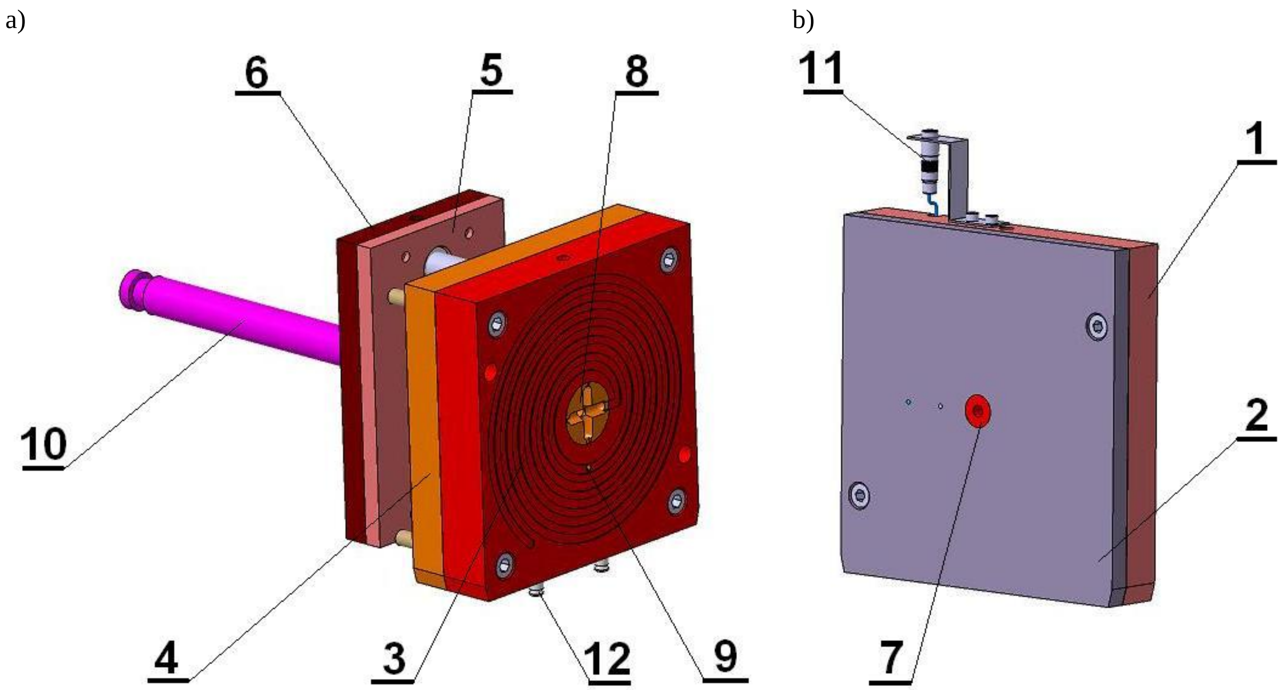



Fig. 3 Shaping part of the injection mold
a) left side, b) right side

1 – clamping plate, 2 – testing plate, 3 – shaping plate, 4 – plate, 5 – anchor plate, 6 – ejector plate, 7 – sprue puller insert, 8 – special sprue puller, 9 – ejector, 10 – ejector rod, 11 – pressure sensor, 12 – cooling end

The shaping part of the injection mold is composed of right and left side. The most important parts of the injection mold concerning the measurements are: testing plate, cavity plate and a special sprue puller insert. There is possible to use pressure and temperature sensors in the mold cavity for the values progress evaluation.

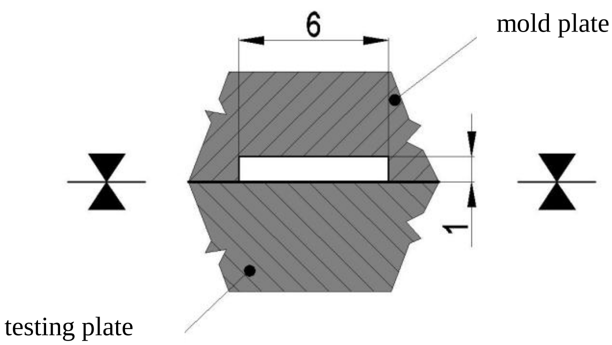



Fig. 4 Cross section of mold cavity

The cavity (Fig. 5) of testing injection mold for is in a shape of a spiral (Fig. 6) with the maximum possible length of 2000 mm and dimensions of channel cross-section: 6x1 mm. The cavity is created when the injection mold is closed, i.e. when shaping plate seals the testing plate in the parting plane of the mold. [2]

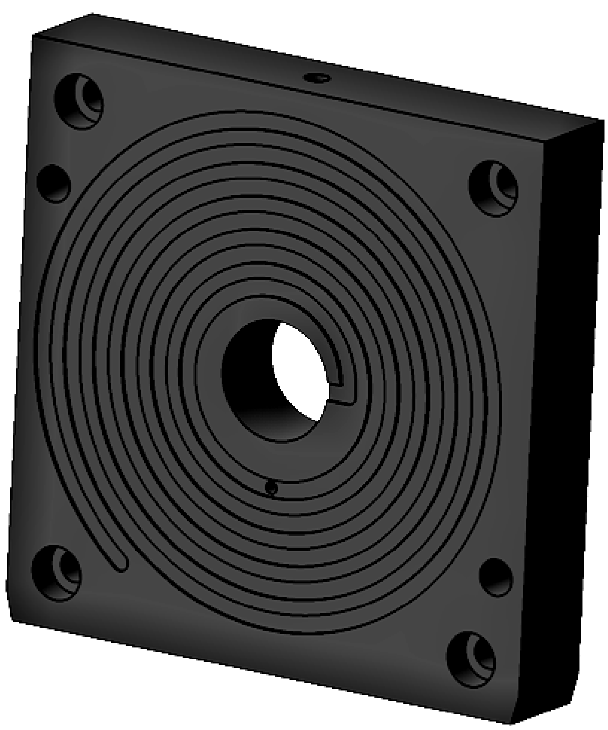


Fig. 5 Cavity plate – shaping plate

Fig. 6 Testing sample – spiral

Testing Injection mold can operate with 5 easy exchangeable testing plates (Fig. 7) with different surface roughness.

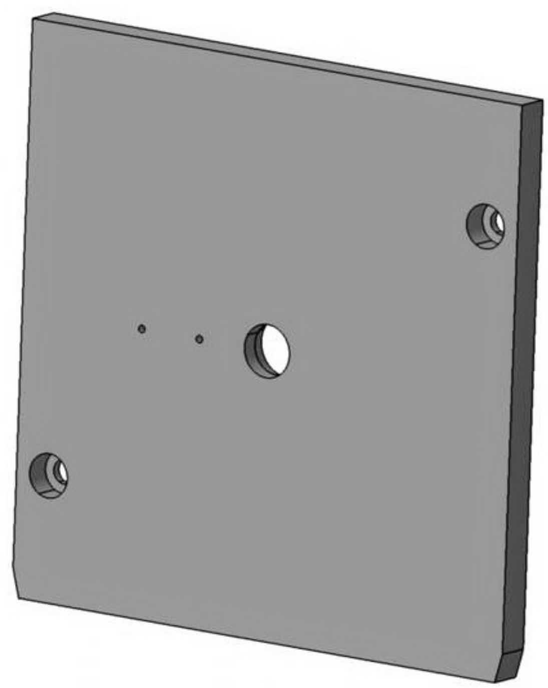
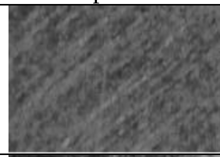
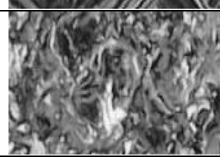


Fig. 7 Cavity plate – testing plate

The surface of the plates was machined by four different technologies, which are most commonly used to work down the cavities of molds and runners in industrial production. These technologies are polishing, grinding, milling and two types of electro-spark erosion – fine and rough design (Table 1).

Table 1 Surfaces of testing plates

| Plate surface | Surface photo |
|---|---|
| Polished plate ($R_a$ = 0,102μm) |  |
| Grinded plate ($R_a$ = 0,172μm) |  |
| Electro – spark machined plate with a fine design ($R_a$ = 4,055μm) |  |
| Milled plate ($R_a$ = 4,499μm) |  |
| Electro – spark machined plate with a rough design ($R_a$ = 9,566μm) |  |

The testing plates are made from tool steel (DIN 1.2325) whose are used for simple and fast changing the surface of the mold cavity. [7]

## III. Tested polymers

Natural polypropylene (Moplen) and polypropylene (Hostacom) with different amount of filler – glass fibers (5%, 10%, 15%, 20%, 25%, 30%, 35%, 40% of short glass fibers) has been used for the experiment.

Injection molding machine ARBURG Allrounder 420C with oil tempering unit Regloplas 150 smart were used for testing samples production.


Fig. 8 Injection molding machine ARBURG Allrounder 420C

## IV. Injection molding process simulation

a)

b)

c)

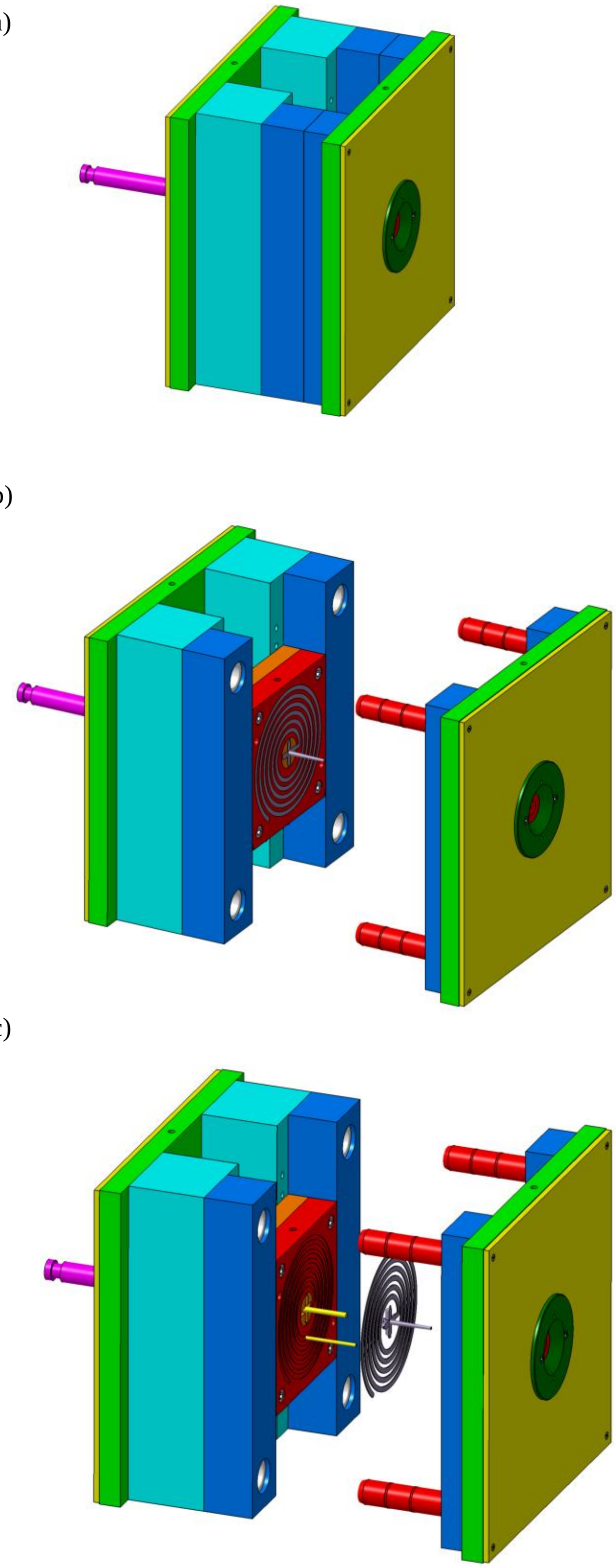


Fig. 9 Injection molding cycle
a) closing the mold, injection of the melt, packing, cooling,
b) opening the mold, c) ejection of the testing sample

A simulation of the injection molding process in SW Autodesk Moldflow Insight 2011 was carried out for comparison with the reality.

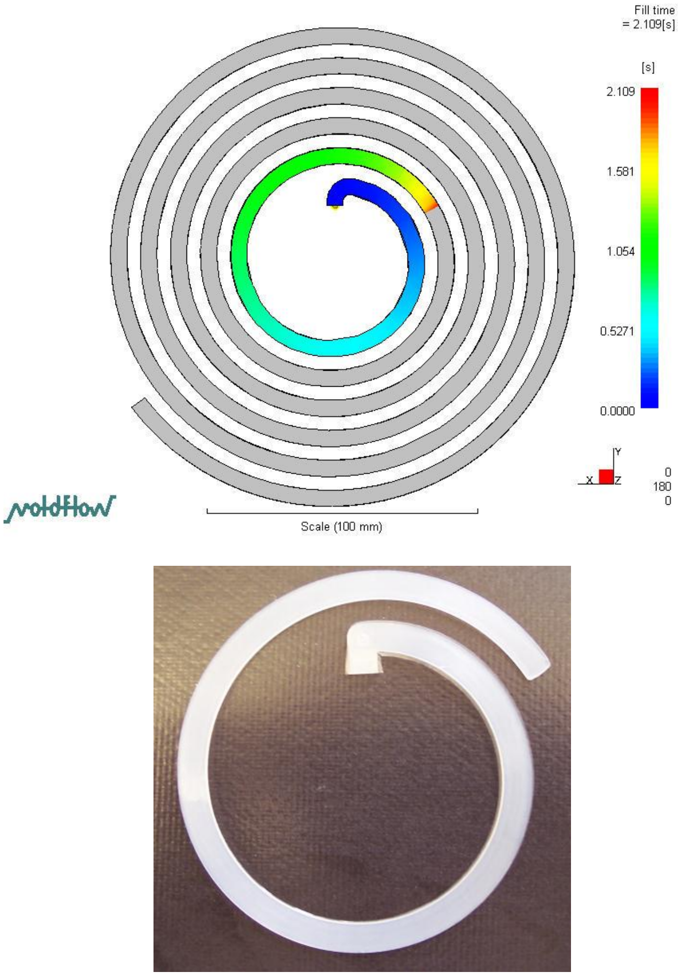



Fig. 10 Flow length

The same conditions were set as during the actual injection molding process. The flow length in the mold cavity of the polymeric material was observed. The comparison was done using only the polished plate, because the SW Autodesk Moldflow Insight does not enable to alter the quality of the surface cavity. The results from both real injection molding process and simulation prove congruent, see Fig. 10.

## V. Results

The aim of the measurements was to find out the influence of separate parameters, especially the quality of the injection mold cavity surface and filler amount, on the flow length. The main results of the measurement and testing are given on the following pictures.

### *A. Influence of material fluidity on surface roughness*

Influence of the flow length on surface quality is shown on the next pictures. The surface quality was changed by the testing plates with different surface roughness (Table 1).

The amount of glass fibers filler has significant influence on flow properties. With raising percentage of glass fibers there can be seen shorter length of spirals.

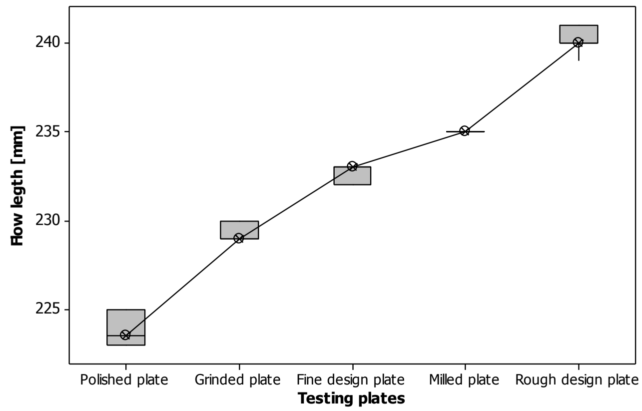



Fig. 11 Influence of the flow length on surface quality (0% glass fibers)

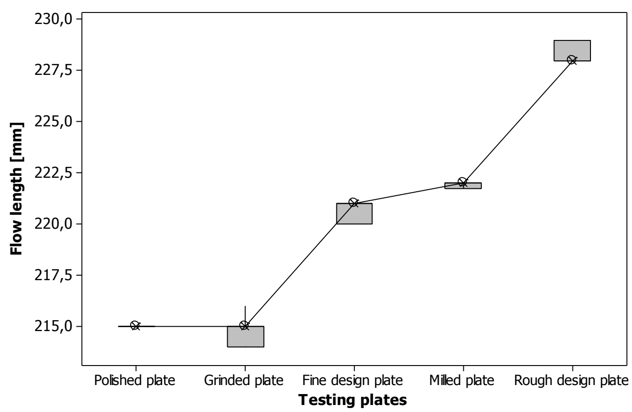



Fig. 12 Influence of the flow length on surface quality (5% glass fibers)

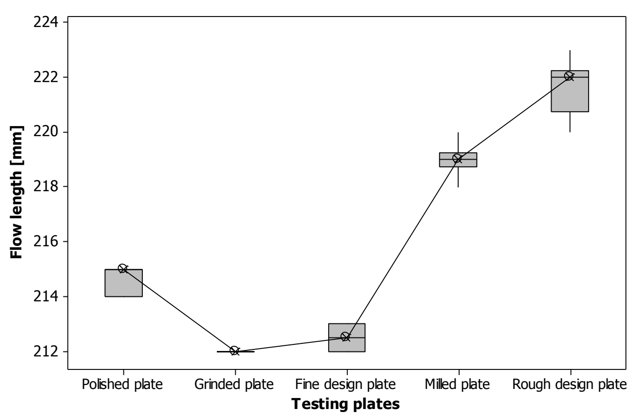



Fig. 13 Influence of the flow length on surface quality (10% glass fibers)

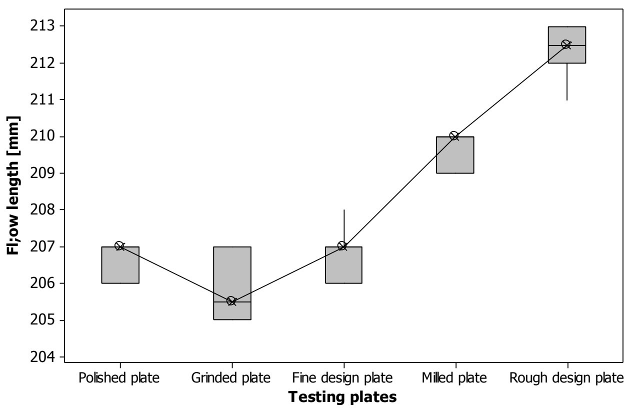



Fig. 14 Influence of the flow length on surface quality (15% glass fibers)

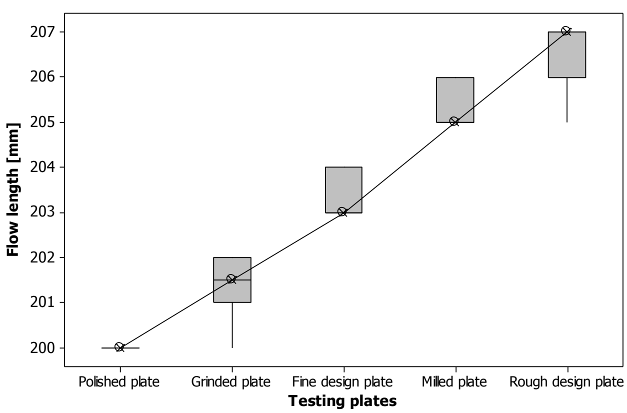



Fig. 15 Influence of the flow length on surface quality (20% glass fibers)

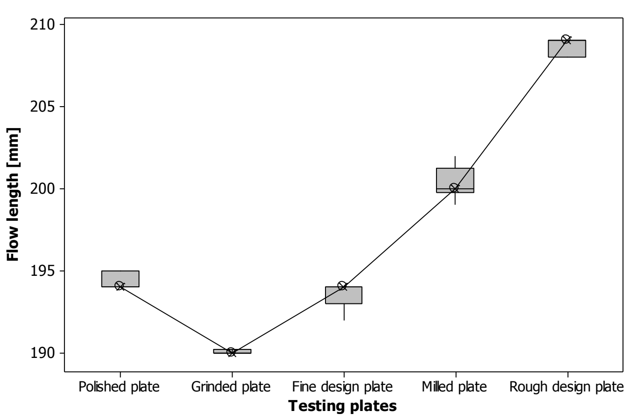



Fig. 16 Influence of the flow length on surface quality (25% glass fibers)

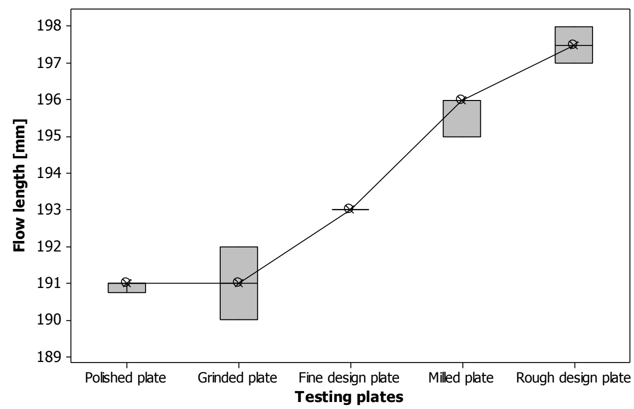



Fig. 17 Influence of the flow length on surface quality (30% glass fibers)

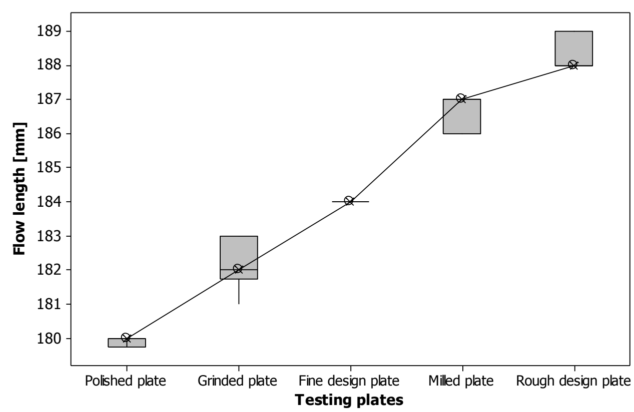



Fig. 18 Influence of the flow length on surface quality (35% glass fibers)

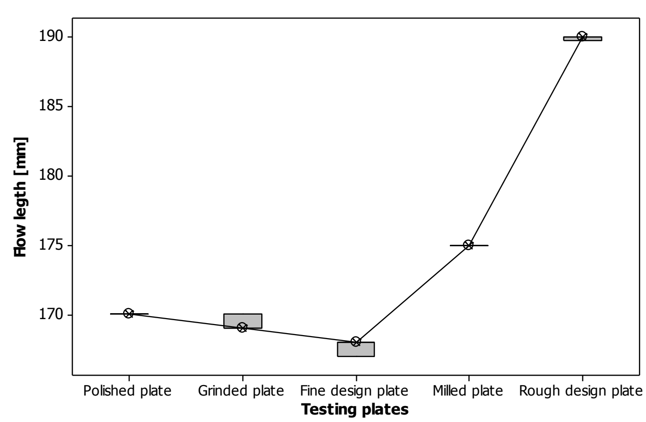



Fig. 19 Influence of the flow length on surface quality (40% glass fibers)

*B. Influence of material fluidity on filler amount*

Influence of the testing samples length on glass fibers filler amount (0, 5, 10, 15, 20, 25, 30, 40%) is shown on the next pictures. The results are displayed separately for each testing plate because of better comparison.

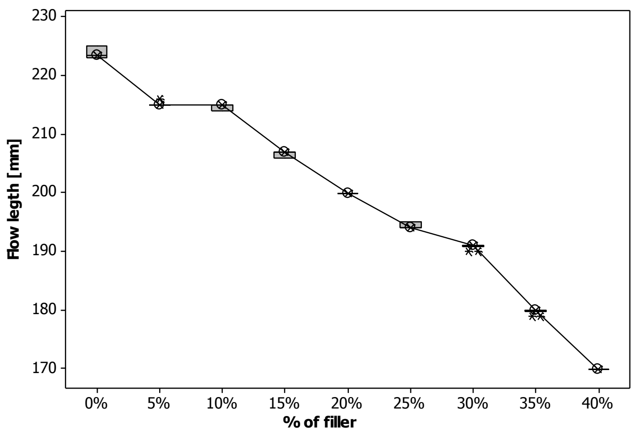



Fig. 20 Influence of the flow length on filler amount (Polished plate)

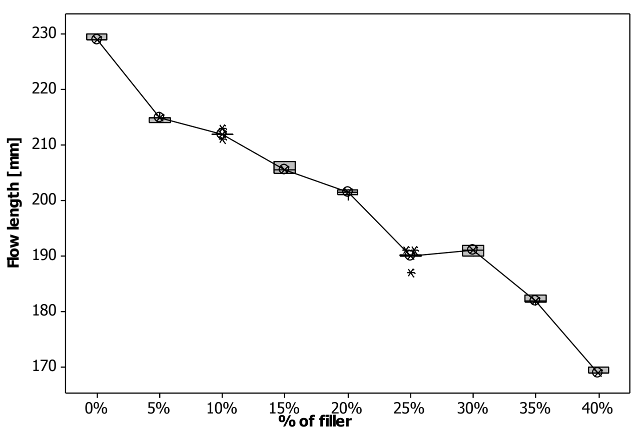



Fig. 21 Influence of the flow length on filler amount (Grinded plate)

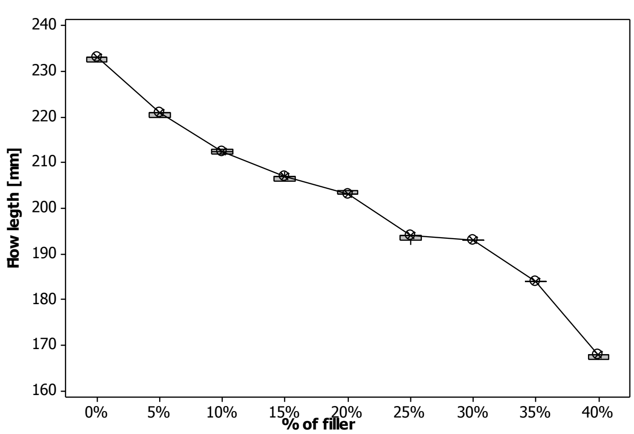



Fig. 22 Influence of the flow length on filler amount (Fine design plate)

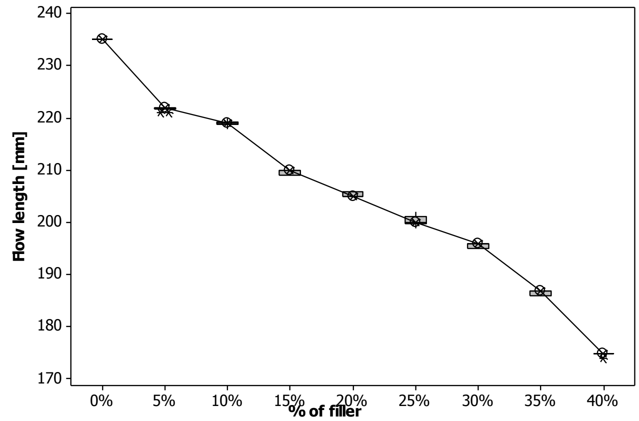



Fig. 23 Influence of the flow length on filler amount (Milled plate)

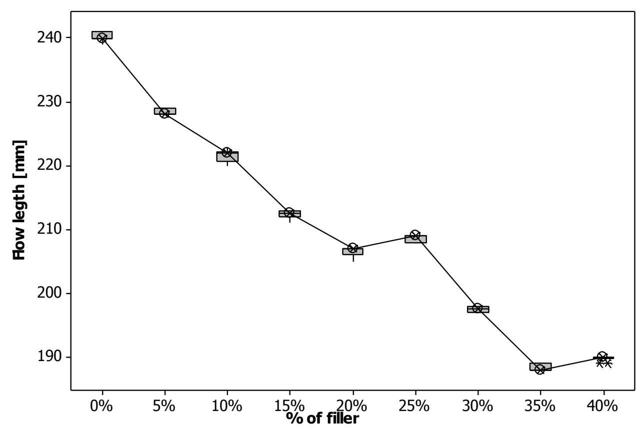



Fig. 24 Influence of the flow length on filler amount (Rough design plate)

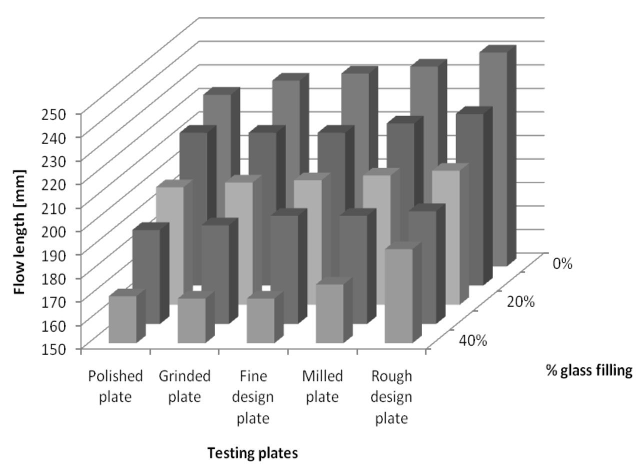



Fig. 25 Influence of the flow length on surface quality and filler amount

The fluidity was better in all ways with smaller amount of glass fibers. In case of glass fibers used as filler in polymer materials there is significant influence on worse flow material properties. On the other hand the final product form the filled material has better mechanical properties and of course lower percentage of shrinkage.

For the better imagination all results was shown in only one graph (Fig. 25). On the X axis are testing plates, on the Y axis is flow length and finally on Z axis are concentrations of glass fibers.

## VI. Conclusion

This research looked into the influence of technological parameters on filling of the injection mold cavity and the flow length respectively. The differences in flow lengths at the testing cavity plates with different surface roughness were very small, rather higher in case of rougher surfaces. But there is demonstrable difference of worse flow properties on each testing plate with increasing percentage of filler (GF – glass fibers). The measurement shows that surface roughness of the injection mold cavity or runners have no substantial influence on the length of flow. This can be directly put into practice. It also suggests that final working and machining (e.g. grinding and polishing) of some parts of the mold, especially the flowing pathways, are not necessary.

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