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, polymer material (with different flow properties) 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. Because the finishing operations of machining are very time and money consuming leading to high costs of the tool production.

Keywords — injection molding, mold, polymer, roughness, surface, fluidity.

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 selected types of polymer materials 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.

II. INJECTION MOLDING

The testing samples were prepared by injection molding technology (injection molding cycle is shown on Fig. 2). The injection mold for was designed for the easiest possible manipulation both with the mold itself and during injection molding process while changing the testing plates, size of the mold gate, pressure and temperature sensors inside the cavity, etc. The cavity space of the mold is generated by the female mold part, called cavity, and a male mold part, called the core. It is necessary to fill the mold cavity fully during the injection molding process. The ability of cavity filling could be affected by the polymer properties and the properties of cavity walls.

Fig. 1 Fountain flow

During filling the mold cavity the plastic material does not slide along the steel mold surface but it is rolled over. This type of laminar flow is usually described as a “fountain flow” (Fig.1).
A. Testing plates

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.

The cavity (Fig. 4) of testing injection mold for is in a shape of a spiral (Fig. 5) 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. The mold cavity is cooling by flowing oil from tempering unit. [2]

Testing Injection mold can operate with 5 easy exchangeable testing plates (Fig. 6) with different surface roughness.
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]

Injection molding machine ARBURG Allrounder 420C 1000 – 350 with oil tempering unit Regloplas 150 smart were used for testing samples production.

**B. Sprue puller insert**

Special sprue puller insert enables the exchange of differently sized gates. Size of the gate could be 1, 2, 4 or 6 mm.

**C. Testing injection mold**

The testing injection mold is inserted into a universal frame 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]

### III. Tested Polymers

Six types of thermoplastic polymers with different flow properties (MFI - Melt Flow Index) were tested:

- polypropylene (PP) Mosten GB 003, MFI = 3,3
- polyethylene (LDPE) Bralen VA 20-60, MFI = 20
- thermoplastic polyurethane (TPU) Ellastolan C 78 A, MFI = 6,1
- acrylonitril-butadien-styren (ABS) Polylac PA 757, MFI = 2,4
- polypropylene filled by 20% of chalk Taboren PH 89 T20, MFI = 14.4
- polypropylene filled by 10% of chalk Keltan TP 7603, MFI = 16.9

IV. RESULTS

The filling of mold cavity depends on material properties, technological conditions and surface quality. The lower is the viscosity of polymer (measured by Melt Flow Index) the better cavity filling has been achieved (Fig. 8 and Fig. 9).

Rising injection rate and filling pressure have a result in better in mold cavity filling (Fig. 11) Above mentioned results of polymer melt behaviour during mold filling were expected. New and very important result rises from experiments which analyzed the influence of surface quality on injection mold filling. It could be generally said that the surface quality of flow pathway significantly affect flow of polymer melt. It was found that better quality of wall surface worsened the flow condition the length of injected sample spiral was shorter. This finding could have very important effect for tools producers. There is not necessary to use high precision cutting operation and it would be possible to exclude some very costly final operation as for example grinding or polishing.

Fig. 8 Influence of flow length on surface quality and type of polymer (injection pressure 8 MPa)

Fig. 9 Influence flow length on surface quality and type of polymer (injection pressure 6 MPa)

Fig. 10 Influence of flow length on surface quality and injection rate (Taboren, gate 6 mm, injection pressure 6 MPa)

Fig. 11 Influence of flow length on surface quality and injection pressure (Keltan, gate 6 mm, injection rate 30 mm.s⁻¹)
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. 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.

V. CONCLUSION

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