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Plastic flow investigation in multicavity injection mold

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The aim of this article is to show the difference in cavity filling in a multicavity injection mold with geometry-balanced runners. This is an important issue for mold designers who take effort to assure simultaneous filling of each cavity. In experiments the 16-cavity injection mold was used. The mold has 4 sections, each with one geometry type cavities. Short shots were made to show inequality of cavity filling. It was found that the difference occurs for all considered shapes of cavities and regardless of process parameters used for investigation as well as for the different kind of plastics (LDPE, PP and POM were tested)

1. INTRODUCTION

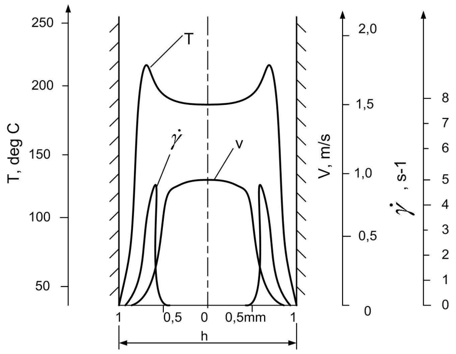

Figure 1. Flow velocity, plastic temperature and shear rate distribution in cavity / runner cross section; T – temperature, v – flow velocity, $\dot{\gamma}$- shear rate, h – cavity / runner thickness [5,6]

The quality of injection molded parts is very important. Requirements for plastic parts are still increasing, especially in an automotive industry. The biggest automotive companies specified their requirements to their deliverers within PPAP (Production Part Approval Process). Deliverer is a manufacturer of a particular kind of injection molded part(s) or an assembly in which plastic parts are mounted. It is required to mark each injection molded part with codes. The code should include the number of cavity in which this part was formed. It can be obtained when special inserts are placed inside an injection mold. This helps to find out whether a defect in production is a result of not properly designed or manufactured mold.

For multicavity molds it is necessary to design a balanced runner system so that filling conditions were the same or very similar for each cavity. Geometrically (naturally) balanced runners, where the distance from injection point to each cavity as well as runners' cross sections are the same, are usually considered as a design which gives the same conditions of cavity filling. However, in such molds the filling inequality is often observed [1]. It is connected with phenomena occurring during plastic flow

in runners [1,2,3,4]. During plastic flow inside the runner or cavity a shear rate peak near the mold wall is observed (Figure 1).
It is connected with a frozen layer creation. High shear rate in this area is the reason of an increase in temperature and a decrease in viscosity of a liquid plastic. Flow velocity has the highest values in the middle of the channel.

The temperature and velocity conditions inside runners affects cavities' filling. Each runner bend is an area where plastic from a high temperature region is moved to the inner side in the next runner (Figure 2). So cavities which are fed through the runners in which plastic from the high temperature region flows are supposed to be filled first. It can be named "spiral effect" [7,8].

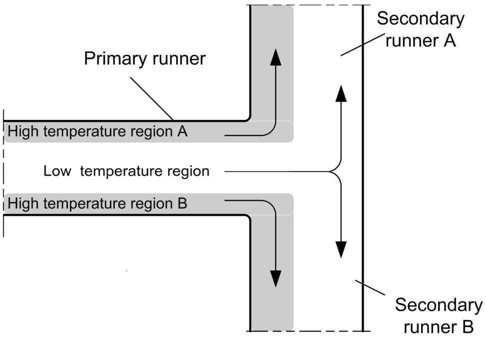

Figure 2. Distribution of the shear induced laminates into secondary runner system [2]

2. EXPERIMENTAL

The aim of this article is to show the inequality in cavities' filling and that it is not sufficient to balance runners, by designing the same cross-section and the same length of the flow path to all cavities, to have cavities filled simultaneously.

The 16-cavity injection mold was used. The mold is divided into 4 sections, each with 4 cavities of an equal geometrical shape (Fig. 3). In secions A, B, C rectangular plates of dimensions 10x20 mm and a thickness 2,25mm were molded in the cavities. Cavities in section D are divided into two areas – of thickness 3,25 and 1,25 mm. The runner cross section area decreases when approaching gates – three channels of different cross-section can be distinguished. Gates are half-circular with a radius of 1,5 mm.

The mold was mounted in the KRAUSS-MAFFEI KM 65/160/C1 injection molding machine.

In Figure 3. the layout of cavities and runners in the mold is shown. Cavities are marked by numbers from 1 to 4 according to the supposed order of their filling. Cavities number 1 should be filled first and then cavities number 2. The difference should also be observed for cavities number 3 and 4. Cavities 3 are placed nearer to a local high temperature region and it can be predicted that they will be filled earlier than cavities 4.

Three plastics were used for investigation. They are specified in Table 1.

Table 1. Plastic used in experiments

Plastic	Trade name	Manufacturer	MFR [g/10 min.]	Melt temperature [ºC]
LDPE	Politen	Chemical Company Blachownia, Poland	0,36 (190ºC, 2,16 kg)	220
PP	Malen-P F401	PKN Orlen, Poland	3,00 (230ºC, 2,16 kg)	230
POM	Sniatal M8	Nyltech, Italy	48,00 (190ºC, 2,16 kg)	190

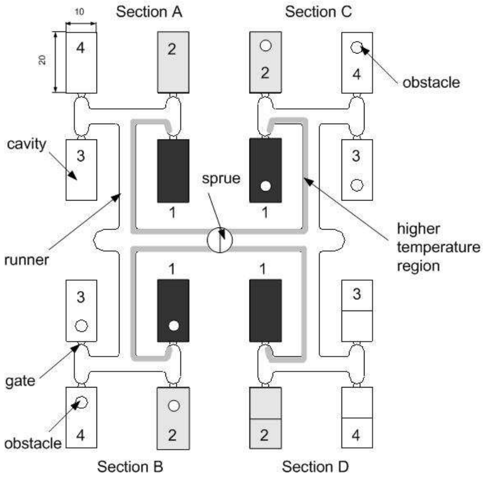

Figure 3. Layout of cavities in the multicavity mold - geometrically balanced runners

Injection molding conditions were chosen so that short shots were obtained – not completely filled cavities. An injection time was set short enough to have injection molding cycle without a packing phase. For all plastics a mold temperature was 30ºC. Flow rate values were 10, 50 and 120 ccm/s. A melt temperature is given in Table 1.

3. DISCUSSION

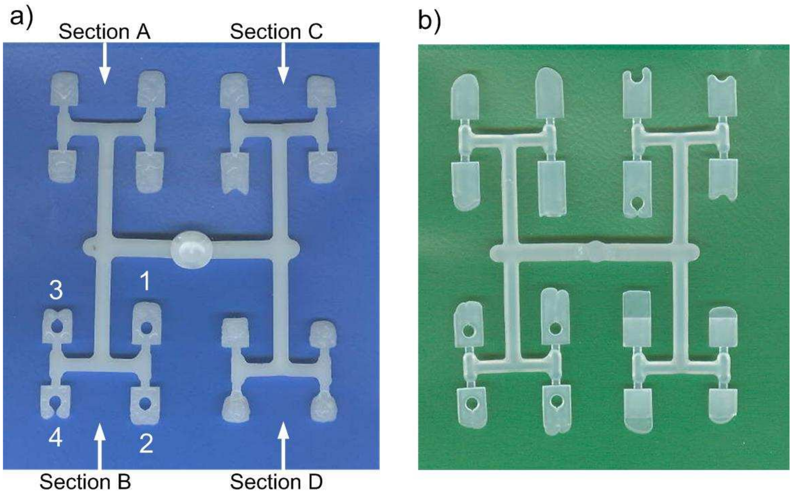

Figure 4. Short shots made for a) POM Sniatal M8, flow rate 50 ccm/s, injection time 0,35 s b) LDPE Politen, flow rate v=50 ccm/s, injection time 0,42 s

The short shots showed significant differences in cavities' filling for all plastics and for all investigated flow rates as well as for all cavity sections.

Examples of injection molded parts obtained at short shots are showed in Figure 4. Cavities number 1 are filled first and then, for most cases, the sequence of other cavities' filling was according to the above mentioned order (Fig. 3).

Cavities with obstacles, in sections B and C, allowed to observe weld and meld lines creation. Weld lines are created just behind the obstacle, where melt fronts flowing from oposite directions collide. Meld lines occure if the melt streams flow parallel to each other

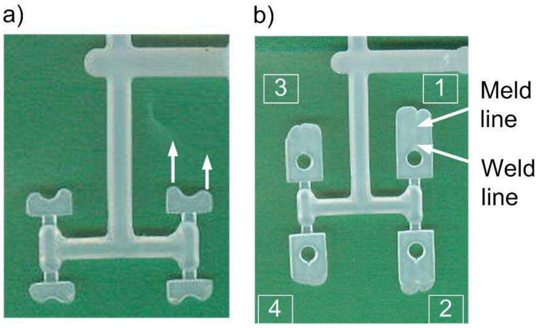

Figure 5. Weld and meld lines displacement in cavities from section B – short shots made for LDPE; a) flow front position before obstacles – injection time 0,34 s, b) weld and meld lines formed behind obstacles – injection time 0,42 s

and create a bond between them. In Figure 5 the way of cavities with obstacle near the gate filling is shown for LDPE. The weld and meld lines tend to be formed not in the straight line behind obstacle but they are moved towards one cavity corner. It is caused by faster flow of plastic at a one side of the cavity. This side is adequate to the high temperature side inside the runner. It shoud be noticed that the gate's cross-section in this mold is quite big and it probably allows plastic to save its trend of flowing in the runner.

4. CONCLUSIONS

Even geometrically balanced runners cannot assure the simultaneous filling of mold cavities. High shear rate near the mold wall causes the increase in temperature and decrease in viscosity of plastic. This leads to a faster plastic flow in this hotter area. The difference grows up after each change in a plastic flow direction inside runners. As a result some cavities are filled earlier, with a hotter and faster flowing plastic. Different flow velocity profiles in the cross-section of particular runners can also affect the cavity filling and weld and meld line position in cavities with obstacles.

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