Archives of Materials Science and Engineering

Volume 28
Issue 7
July 2007
Pages 429-432

International Scientific Journal published monthly as the organ of the Committee of Materials Science of the Polish Academy of Sciences

Structure of polypropylene parts from multicavity injection mould

T. Jaruga*, E. Bociąga
Institute of Polymer Processing and Production Management, Czestochowa Univesity of Technology, Al. Armii Krajowej 19c, 42-200 Częstochowa, Poland
* Corresponding author: E-mail address: jaruga@kpts.pcz.czest.pl

Received 04.04.2007; published in revised form 01.07.2007

ABSTRACT

Purpose: The examination of structure of injection moulded parts, coming form different cavities of injection mould with geometrically balanced runners, was the purpose of this research. The parts were manufactured from polypropylene.

Design/methodology/approach: The method of optical microscopy was used. The samples were prepared from microtomed slices from parts and next they were observed in polarized light. The skin-core morphology was analyzed and spherulitic structure was described by spherulites size measuring.

Findings: The differences in morphology and spherulite size for parts from particular mould cavities were found. They are caused by different thermal conditions in each cavity.

Research limitations/implications: An injection mould with geometrically balanced runners was used for investigation. The differences in parts' structure occur for each injection mould, but they are dependent on the cavities layout and runners configuration.

Practical implications: Knowledge about the differences in structure of parts from different cavities is the reason to look to the solution by minimizing the temperature inequality in the injection mould.

Originality/value: Despite using geometrically balanced runners the cavities are not filled equally and the parts have different structure. In some recent works the issue of flow imbalance in multicavity injection moulds was analyzed and even some solutions of this problem were proposed. All investigation was focused on simultaneous plastic flow into all cavities, but there were no investigation of parts' structure and properties.

Keywords: Plastic forming; Injection moulding, polymer structure

MATERIALS MANUFACTURING AND PROCESSING

1. Introduction

The feed system in multicavity injection mould should be designed so that all cavities are filled simultaneously. If this is achieved the flow into the cavities is balanced and the runners are called "balanced". There are many runners' configurations in injection moulds. There are two main sorts of balanced runner systems [1]:

- naturally (geometrically) balanced runners,
- artificially balanced runners.

In the past the geometrically balanced runners were supposed to be a good solution. However, in the last decade some research works were done which proved that there are some problems to obtain flow balance even in the traditional geometrically balanced runners [2]-[7]. The research was focused on flow imbalance and its counteraction rather than on the differences in parts properties. Thus there is a need to investigate how the filling imbalance influences injection moulded parts' properties.

Polypropylene injection moulded parts are of well developed skin-core morphology. The skin is formed by mould wall and the spherulitic core inside is divided into oriented layer of high birefringence and non-oriented layer in the middle. The morphology is highly influenced by processing conditions, especially by holding pressure. At higher holding pressure the thickness of oriented layer is bigger. This affects part's shrinkage and its other properties [8]-[9].

The injection moulded parts' structure and other properties, like crystallinity degree, are influenced by injection moulding conditions [10]-[12]. Spherulite size in moulded parts also depends on processing conditions. Čermák et al. investigated polypropylene parts and showed that at higher mould temperature the spherulites are bigger [13].

2. Experimental

A multicavity injection mould was used for this investigation. Polypropylene was injected to the mould and the flow balance was checked using the short shots method. The morphology of parts from different cavities was investigated and spherulite size was measured.

2.1. Material

Polypropylene (PP) was used for investigation. The grade MALEN P F-401 with MFR = 3.00 g/10 min. (2.16 kg, 230ºC) was produced by PKN Orlen, Poland (now: Basell Orlen Polyolefins).

2.2. Machine

KRAUSS MAFFEI KM 65/160/C1 injection moulding machine was used for injection process. The maximum clamping force is 650 kN. The screw of a plasticizing unit is of 30 mm diameter.

2.3. Injection mould

The moulded parts come from an experimental 16-cavity injection mould, described in earlier papers [14]-[16]. The parts are small plates of the shape and dimensions shown in Figure 1.

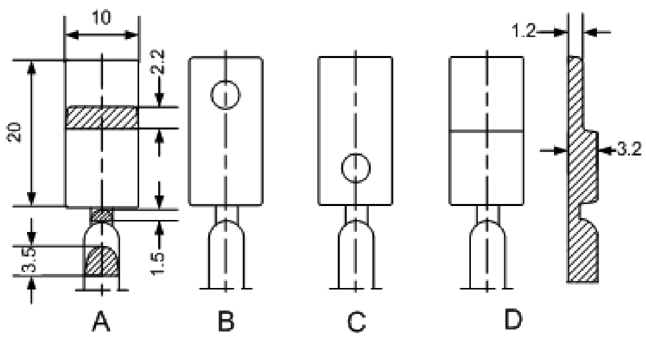

Fig. 1. Injection moulded parts with gates and runners

Parts A, B and C are of thickness 2.2 mm. Part D is stepped with two thickness values: 1.2 and 3.2 mm. Parts B and C have holes to form weld and meld lines. The layout of parts in the mould with the runner system is shown in Fig. 2.

2.4. Processing conditions

The parts were injection moulded at the following processing conditions:

- melt temperature: $T_i = 240$ ºC
- mould temperature: $T_m = 30$ ºC
- injection velocity: $v = 95$ mm/s
- holding pressure: p_H=40 MPa

Short shots method war used to check how the cavities are filled. In this investigation the holding stage was skipped and injection time was adjusted short enough to obtain cavities not filled totally.

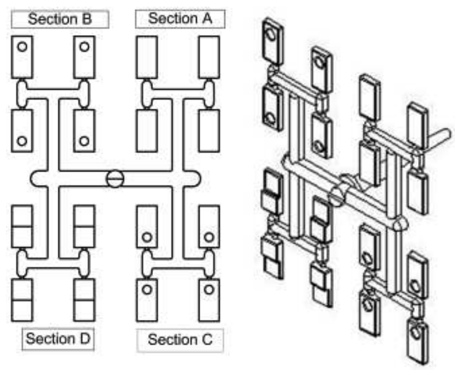

Fig. 2. Layout of parts in the experimental mould

2.5. Microscopic investigation

The parts' morphology was investigated using optical microscopy. The samples of 15 μm thickness were microtomed by Anglia Scientific microtome and prepared for observations at Olympus BH-2 microscope in polarized light. The samples were cut longitudinally from the parts, as it is shown in Fig. 3. The structure was observed in the half-thickness of the samples in the middle of parts' length.

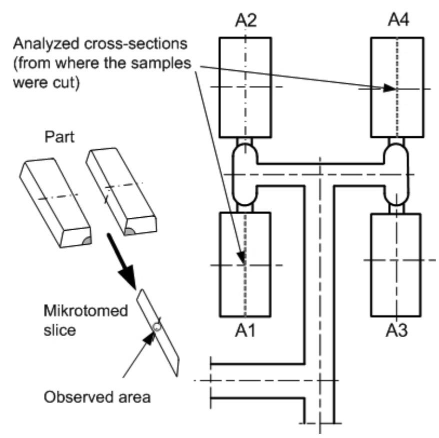

Fig. 3. Samples taken from parts obtained from mould section A

Spherulites were measured manually using optical microscope graphical software. At first calibration was made and then two diagonals of a spherulite were measured. For each part 100 spherulites were measured in the center area of sample.

3. Results and discussion

3.1. Short shots

The injection moulding process parameters were changed to obtain short shots. The injection time t_i was short enough that flow front did not reach the cavity end wall and the holding stage was skipped. The cavities were not filled totally and the flow front advance showed the sequence of cavities' filling.

Despite the geometrically balanced runners the cavities are not filled at the same time, but in a particular sequence. The cavities placed in the mould centre (numbered "1"), which is more heated by the sprue, are filled as the first.

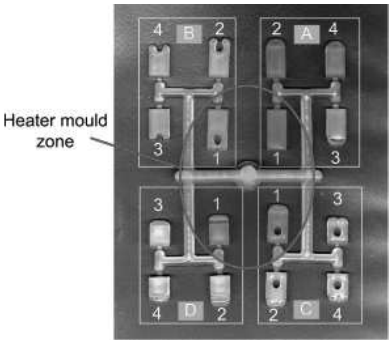

Fig. 4. Short shots made at injection time t_i=0,55 s

In further investigation of properties (morphology, DMTA) the parts from section A were compared.

3.2. Morphology of injection moulded parts

The classical skin-core morphology was observed. The comparison of morphology for part A1 (cavity filled first in mould section A) and part A4 (cavity filled as the last one) is presented in Fig. 5.

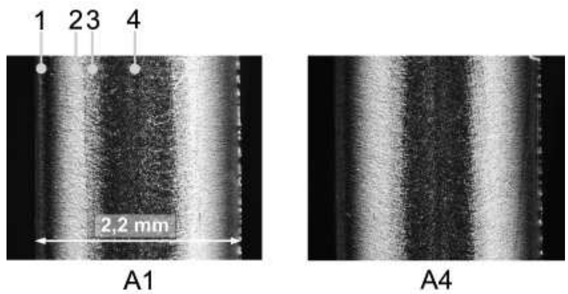

Fig. 5. Morphology of parts from cavities: A1 (left) and A4 (right); 1-skin layer, 2–oriented core zone, 3- transient zone, 4-non-oriented core zone

In parts A1 wider transient zone was observed. Cavities A1 are placed in hotter mould zone and there are better conditions for polymer relaxation in core oriented zone. Since the parts from different cavities differ in morphology, they are also supposed to differ in properties.

3.3. Spherulite size

The structure in the core layer of parts is spherulitic (Fig 6). In parts A1 the observed spherulites are bigger.

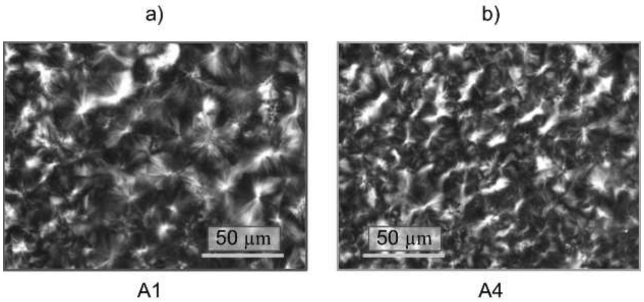

Fig. 6. Spherulitic structure (in core layer) of parts from cavities 1 and 4 in mould section A

The histograms show the distribution of spherulite size in parts A1 and A4 (Fig. 7). The average size of spherulite is bigger for parts A1 (30,00µm) than for parts A4 (26,49µm), so the shift of the distribution curve is noticeable. The distribution meets the requirements for normal distribution.

Cavities A1 are filled first, and are placed in hotter mould zone. The higher mould wall temperature makes better conditions for spherulites growth.

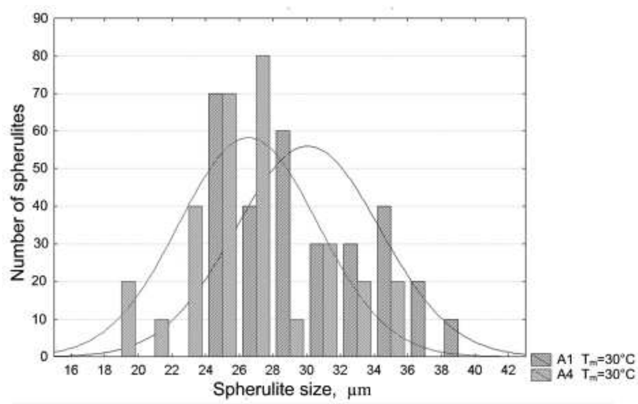

Fig. 7. Spherulite size in the core layer of parts from cavities 1 and 4 in mould section A

4. Conclusions

Polypropylene parts from a multicavity injection mould with geometrically balanced runner differ in structure.

The part's morphology and structure is dependent on the location of the cavity in which the part was manufactured. The structure differences of parts are the result of different thermal conditions in particular cavities (mould wall temperature) that also influence the flow in the cavities during the filling stage of injection moulding.

Since structure affects properties, the parts from multicavity injection mould should have different properties. When the requirements of moulded parts' quality are high, it is very important to assure the equal mould wall temperature in all the cavities of injection mould.

Acknowledgements

This work was financially supported from Polish Ministry of Scientific Research and Information Technology. Budget for science in years 2005-2006; Grant number 3 T08E 032 28.

References

[1] J.P. Beaumont, R. Nagel, R. Sherman, Successful Injection Molding, Hanser Publishers, Munich, 2002.

[2] J.P. Beaumont., Runner and Gating Design Handbook. Tools for Successful Injection Moulding, Hanser, Munich, Cincinatti, 2004.

[3] Beaumont Runner Techologies Inc., http://meltflipper.com.

[4] P.S. Cook, H. Yu, V. Clinton, V. Kietzmann, F.S. Costa, Prediction of flow imbalance in geometrically balanced feed systems, Proceedings of the 63rd Annual Technical Conference & Exhibition ANTEC 2005, Boston, 2005, 526-530.

[5] H.E. Casaldi, T. Michel, Process Window as Effected by Shear Induced Flow Imbalance in Multicavity Moulds, Proceedings of the 59rd Annual Technical Conference & Exhibition ANTEC 2001, Dallas, 2001, 3112.

[6] R. Cooney, D. Neill, L. Pomorski, An Investigation of Part Variation in Multi-Cavity Injection Molds When Using Cavity Pressure Control, Proceedings of the 59rd Annual Technical Conference & Exhibition ANTEC 2001, Dallas, 2001, 3116.

[7] G.Y. Su, H. Yokoi, W.M. Yang, A Study on Filling Imbalance of Plastic Injection Moulding in Multi-cavity Mould with "H" Pattern Runner System, Proceedings of the Conference "Europe-Africa Meeting of Polymer Processing Society", Athens, 2003, (on CD), 89-O.

[8] A.J. Pontes, M.J. Oliveira, A.Z. Pouzada, Studies on the Influence of the Holding Pressure on the Orientation and Shrinkage of Injection Molded Parts, Proceedings of the 60rd Annual Technical Conference & Exhibition ANTEC 2002, San Francisco, 2001, 98.

[9] A.J. Pontes, M.J. Oliveira, A.Z. Pouzada, The Effect of Holding Pressure on the Shrinkage and Birefringence of Injection Molded Polypropylene Plates, Materials Science Forum 455-456 (2004) 814-817.

[10] J. Koszkul, P. Postawa, Temperature distribution on the molding surface during cooling stage and its influence on the molding structure, Proceedings of the 11th Scientific International Conference „Achievements in Mechanical and Materials Engineering" AMME'2002, Gliwice-Zakopane, 2002, 295-298.

[11] J. Nabiałek, J. Koszkul, The influence of the thermoplastic injection molding on the molding degree of crystallinity, Proceedings of the 11th Scientific International Conference „Achievements in Mechanical and Materials Engineering" AMME'2002, Gliwice-Zakopane, 2002, 353-356.

[12] J. Koszkul, P. Postawa, Crystallinity degree change for mouldings and its influence on quality at extreme parameters of injection, Proceedings of the 12th Scientific International Conference „Achievements in Mechanical and Materials Engineering" AMME'2003, Gliwice-Zakopane, 2003, 509-512.

[13] R. Čermák, M. Obadal, P. Ponížil, M. Polášková, K. Stoklasa, A. Lengálová, Injection-moulded α- and β-polypropylenes: I. Structure vs. processing parameters, European Polymer Journal 42 (2005) 1840-1845.

[14] E. Bociąga, T. Jaruga, J. Koszkul, Plastic Flow Investigation in Multicavity Injection Mold, Proceedings of the 12th Scientific International Conference „Achievements in Mechanical and Materials Engineering" AMME'2003, Gliwice-Zakopane, 2003, 107-110.

[15] E. Bociąga, T. Jaruga, Microscopic investigations of polymer flow in the runners of 16-cavity injection mold, Polimers 51 (2006) 843-851 (in Polish).

[16] E. Bociąga, T. Jaruga, Visualization of melt flow lines in injection moulding, Journal of Achievements in Materials and Manufacturing Engineering 18 (2006) 331-334.