Applied Mathematics & Information Sciences
An International Journal

Experimental Study on The Influence of Parameters on The Plastic Parts Quality of External Gas-Assisted Injection Molding

Shaofei Jiang, Wei Zheng, Jiabo Zhang and Jiquan Li

Key Laboratory of Special Purpose Equipment and Advanced Processing Technology, Zhejiang University of Technology, Ministry of Education, Hangzhou, China, 310014

Received: Jul 8, 2011; Revised Oct. 4, 2011; Accepted Oct. 6, 2011
Published online: 1 August 2012

Abstract: External Gas-Assisted Injection Molding (EGAIM) is a kind of advanced plastic molding technology, which can reduce shrinkage defects of plastic products effectively. In this paper, the mold temperature, melt temperature, gas delay time, gas holding pressure, gas holding time and other parameters were studied respectively on the effects of plastic parts for quality in the molding process of EGAIM. Experimental studies by a single factor experiment on the interactions between parameters and plastic parts quality are as follows: mold temperature, melt temperature, gas delay time, gas holding pressure and gas holding time are the main factors in the parts' shrinkage.

Keywords: EGAIM, parameters, single factor experiment, shrinkage.

1. Introduction

External Gas-Assisted Injection Molding (EGAIM) is a kind of advanced plastic molding technology, which makes use of an inert gas to exert the appropriate pressure to the back of plastic parts. In contrast to the internal gas-assisted process, gas is not introduced into the interior of the injected melt. After the mold is completely filled with plastic melt, gas is injected between the mold wall and the molten melt. The gas pressure builds up over a predetermined surface area and acts as the holding pressure. During the cooling process, the gas pressure compensates for the volume shrinkage, minimizing potential sink marks on the side opposite the ribs and thick-walled sections. The external gas-assisted injection molding technique offers several distinct advantages on producing sink-free surfaces over ribs and bosses in products for a wide variety of industries [1–3]. They are also important in thin-wall applications and in large, flat parts. The pressure will push the melt into the mold wall, making it close to the cavity wall to offset the shrinkage of injection molded parts generated in the molding process. The shrinkage of injection molded parts will be reduced to the maximum extent [4].

External gas-assisted injection molding technology is mainly aiming at reinforcing the rib structure of plastic parts or lug boss products. Also it is suitable for thin-walled and large partial plate of plastic[5]. And the plastic injection molding plastic parts quality evaluation is the depth of shrinkage. The mold temperature, melt temperature, gas delay time, gas holding pressure, gas holding time and other parameters have an effect on the parts. As a result, the parameters have gradually become a focus point in EGAIM in recent years. A single process parameter on the gas penetration depth and thickness of skin melt was studied in traditional ways. Chen S C and others studied the holding pressure and holding time on the effect of shrinkage [6–8].

In this paper, the mold temperature, melt temperature, gas delay time, gas holding pressure, gas holding time and other parameters were studied respectively on the effects of plastic parts for quality in the molding process of EGAIM. This paper intends to change one of the parameters while keeping the other parameters constant, comparative study of different section shape reinforcing ribs in the gas-assisted injection molding conditions, and study the single parameter on forming quality of the impact trend.

* Corresponding author: e-mail: zjujsf@163.com

2. Experimental design

2.1. Experimental equipment

The EGAIM injection system (shown in Figure 1) is normally same as the IGAIM injection system, but some attachments.

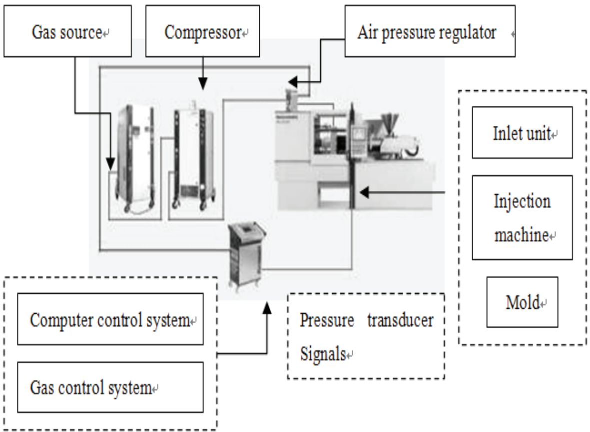

Figure 1 EGAIM injection system.

2.1.1. Injection molding machine

Injection machine is the important part of the EGAIM injection system. The experiments use Guangzhou Borch Machinery Limited Company production of the type BT200V-1 injection molding machine, its shape was shown in Figure 2.

Figure 2 The Borch Type BT200V-1 injection molding machine.

The technical parameters of the Borch Type BT200V-1injection molding machine are shown in Table 1.

Table 1.Technological parameters of the Borch machine.

Injection section		Clamping section	
Screw diameter mm	35/40/45	Clam force KN	1200
Screw l/d ratio	23:1/20.5:11	Mould-opening stroke mm	340
Theoretical injection volume cm^3	182/238/301	Maximum plate s-pacing mm	790
Actual injection volume g	171/225/283	Plate size mm x mm	590x590
Injection speed cm^3/s	130/161/232	Distances mm x mm	410x410
Maximum injection pressure MPa	218/176/123	Mold volume mm	145-450
Screw stroke mm	190	Stroke of ram mm	100
Screw rotation speed r/min	187	Mandrel force KN	34.3
Maximum stroke mm	280	Ejector pins number	4+1

2.1.2. Nitrogen Generator

The experiments use the RIDE RDN nitrogen generator (Figure 3). The nitrogen will be separated from the air, and stored in a low pressure nitrogen cylinder.

Figure 3 RIDE RDN nitrogen generator.

2.1.3. Nitrogen Turbocharger

The experiments use a Bolaite BLT15A fixed type gas compressor (Figure 4), the working pressure for general is 30MPa, its main function is to increase the low-pressure storage nitrogen to the working pressure, then store them in a high pressure nitrogen cylinder.

Figure 4 Bolaite BLT15A gas compressor.

2.1.4. Gas Controller

The gas controller(Figure 5)has a dual-gas path air inlet, the time of injection and the pressure of injection can be controlled separately.

Figure 5 Gas Controller.

2.2. Experimental Mold

On the basis of traditional injection mold, the mold structure was modified and optimized on the summary of the external gas-assisted injection mold design principles. On one hand, it can verify the reliability of the external gas-assisted injection mold design principles. The structure of intake units, the optimization of intake channel and the location of intake points were done according to the structure of products. And the mould can ensure better sealing performance than traditional mould. On the other hand, it can provide the experimental mold equipment for the follow-up external gas-assisted injection experiment.

The experiments use the improved external gas-assisted injection molding (Figure 6). According to the patent of external gas-assisted injection molding mold design [9–11], transforming the traditional mould and designing a set of external gas-assisted injection mold. By testing mold, achieving the desired results.

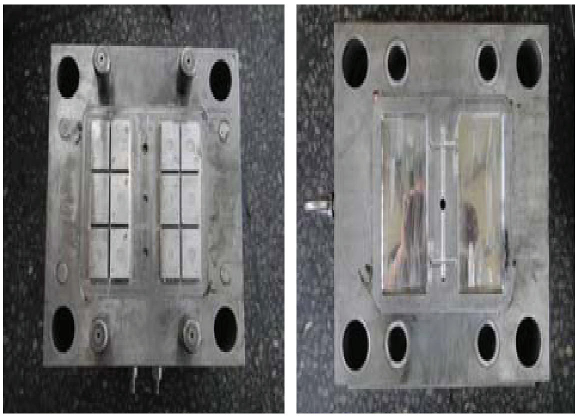

Figure 6 Experimental mold picture.

2.3. Experimental materials

In order to investigate the influence rules that the the effect of process parameters of external gas-assisted injection molding on the shrinkage, the surface of the plastic products.The larger shrinkage rate of ABS and the relatively smaller shrinkage rate of PP material were selected to the experiments.

The greater shrinkage of PP material and smaller shrinkage of ABS material were selected in this experiment. Material parameters refer to table 2.

Table 2. Technological Parameters.

	PP	ABS
Manufacturer	Schulman GMBH	Chi Mei Corporation
Type	Polyflam RPP1058-295	Polylac PA-757
Recommended range of mold temperature	20°C˜80°C	20°C˜70°C
Recommended range of melt temperature	200°C˜280°C	180°C˜240°C
Maximum allowable melt temperature	320°C	260°C
Ejection temperature	93°C	84°C

2.4. Experimental model

The experimental model is the product injecteded from the experimental mold by the injection molding machine.

The experimental model was shown in Figure 7, the model had six cavities surrounded by stiffener.

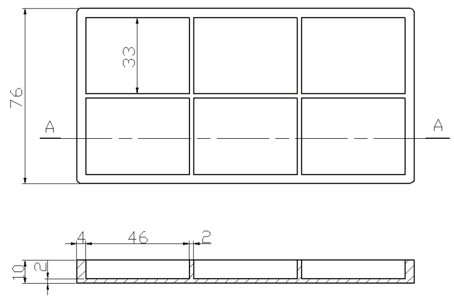

Figure 7 Experimental model.

2.5. Experimental method

The effects of process parameters on the quality of products were researched In the paper. Influencing factors includs mold temperature, melt temperature, gas delay time, gas holding pressure, gas holding time and other parameters. A single factor experiment was used to study the interactions between parameters and plastic parts quality.

3. Analysis of influence of a single process parameter on forming a result trend

3.1. Experimental method

Single process parameter changes by changing a process parameter, keeping other parameters constant, then study the trend of single process parameters on the forming results. The parameters are set as follows: Mold temperature: 50°C, 55°C, 60°C, 65°C, 70°C; Melttemperature: 200°C, 2 10°C, 220°C, 230 °C, 240°C; Gas delay time: 0s,0.5s, 1 s,1.5 s,2s; Gas holding pressure: 2MPa, 4MPa, 6MPa, 8MPa,10 MPa; Gas holding time: 5s,10s,15 s,20s,25s; Gas delay time is calculated by the end of melt filling stage. With changing of a parameter, the remaining parameters should be maintained its intermediate value, for the observation of the effect of parameters on surface quality of the product trend. The parameters of the control group are: Mold temperature: 60°C; Melt temperature: 220°C; Gas delay time: 1s; Gas holding pressure: 6MPa; Gas holding time: 15s.

3.2. Experimental data and data analysis

Table 3.EGAIM parameters influencing trends table.

Test number	Mold temp °C	Melt temp °C	Gas delay time s	Gas holding pressure MPa	Gas holding time s	Depth of shrinkage um
1	50					36
2	55					34
3	60	220	1	6	15	30
4	65					28
5	70					27
6		200				30
7		210				31
8	60	220	1	6	15	32
9		230				33
10		240				35
11			0			29
12			0.5			30
13		220	1	6	15	30
14			1.5			31
15			2			32
16				2		33
17				4		31
18	60	220	1	6	15	29
19				8		28
20				10		28
21					5	34
22					10	31
23		230	0.5	6	15	28
24					20	27
25					25	27

The experimental results of samples and the depth of the surface shrink are shown in Figure8. Specific parameters are shown in Table 3.

Based on the above experimental results, obtaining the impact of various process parameters on the external gas-assisted injection molding.

3.2.1. The effect of mold temperature on external gas-assisted injection molding

In this Figure, the horizontal coordinates represent for mold temperature, and vertical coordinates represent for the depth of shrinkage.The relationship between them could be seen in the graphics. The black spots in the graph represented the depth of shrinkage at different temperature. As is shown in Figure 9, with the rise of mold temperature, the depth of the product's surface shrink have an apparent downtrend. Because the melt begins to cool after launching into the cavity at the stage of filling.

The cooling rate slows down due to high mold temperature, forming a thin layer of gas condensation. Thus, the gas can be more effective to push the melt into the mold wall in packing stage. It can compensate for the product

Figure 8 The parameter trend of experimental results.

surface without shrinkage, in order to obtain a higher quality of products.

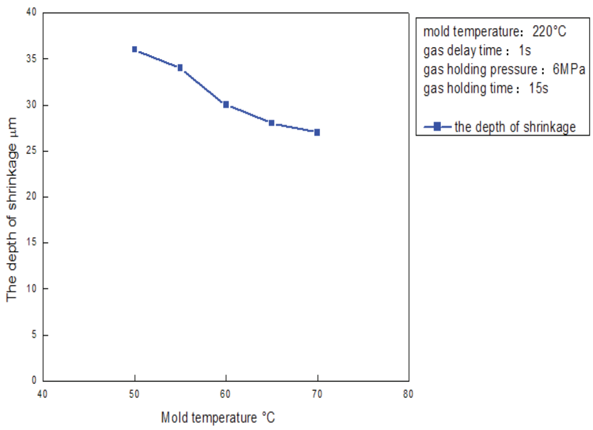

Figure 9 The mold temperature on the effect of external gas-assisted injection molding.

3.2.2. The effect of melt temperature on external gas-assisted injection molding

In this Figure, the horizontal coordinates represent for melt temperature, and vertical coordinates represent for the depth of shrinkage. The relationship between them could be seen in the graphics. The black spots in the graph represented the depth of shrinkage at different temperature. As is shown in Figure 10, the depth of shrink increases in melt temperature, but the degree of change is not obvious.

Mainly because of the different temperatures of the high-temperature melt launched into the cavity of the same temperature, the melt has few differences in cooling rate at the instant of having a certain thickness of the condensate layer, so that the effect of gas pressure is limited. So the melt will not be able to be pushed into the mold surface completely that appearing the shrinkage.

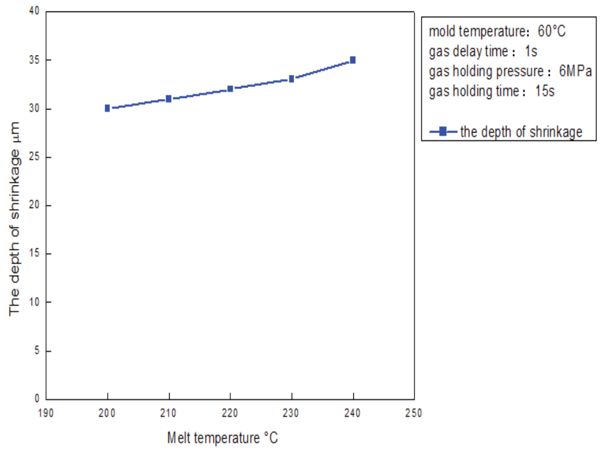

Figure 10 Melt temperature on the effect of external gas-assisted injection molding.

3.2.3. The effect of gas delay time on external gas-assisted injection molding

In this Figure, the horizontal coordinates represent for gas delay time, and vertical coordinates represent for the depth of shrinkage. The relationship between them could be seen in the graphics. The black spots in the graph represented the depth of shrinkage at different temperature. As is shown in Figure 11, the product's surface shrink increases with the increase of gas delay time in the filling stage. The gas delay time is defined by the end of the melt filling at the beginning of injection, and it is based on the melt rigidity. The gas will blow through plastic and reach the mold cavity on the other side under the condition of lacking rigidity.

On the contrary, the air pressure will be very difficult to reach the mold wall on the other side. Because the melt has completely solidified, the pressure is not enough to compensate for the shrinkage. So the gas delay time cannot be too short nor too long.

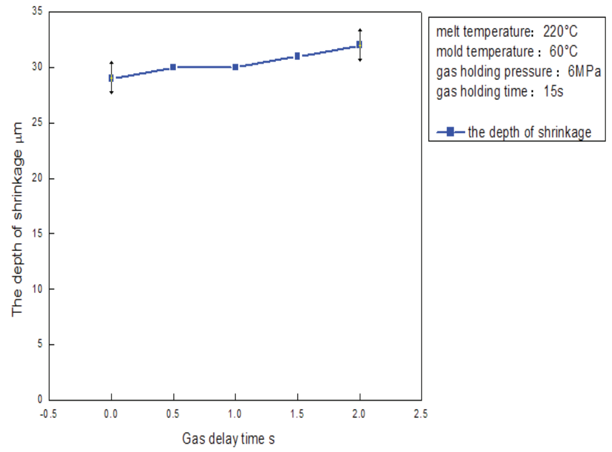

Figure 11 Gas delay time on the effect of external gas-assisted injection molding.

3.2.4. The effect of gas holding pressure on external gas-assisted injection molding

In this Figure, the horizontal coordinates represent for gas holding pressure, and vertical coordinates represent for the depth of shrinkage. The relationship between them could be seen in the graphics. The black spots in the graph represented the depth of shrinkage at different temperature. As is shown in Figure12, the gas pressure is obviously insufficient under 2 MPa, and increasing the pressure of the gas is helpful to improve the packing effect. When gas pressure increases to 10MPa, the shrinkage does not have an obvious improvement.

With the increasing of the stress, the pressure of pushing the melt to the mold wall will be higher in external gas-assisted injection molding. Generally speaking, higher injection pressure can improve the quality of parts and the demould process can be more smoothly. But the gas will make through the plastic when the pressure is too much high.

3.2.5. The effect of gas holding time on external gas-assisted injection molding

In this Figure, the horizontal coordinates represent for gas holding time, and vertical coordinates represent for the depth of shrinkage. As is shown in Figure 13, there is a

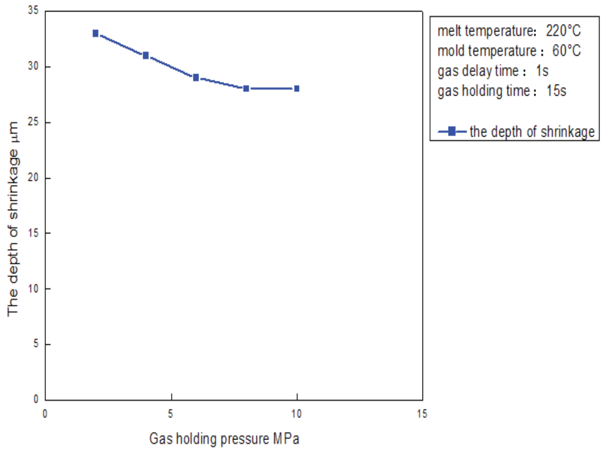

Figure 12 Gas holding pressure on the effect of external gas-assisted injection molding.

shortage of holding pressure under the holding time of 5 seconds, but the product shrinkage did not further reduce when holding pressure time increased to 15 seconds. The packing time refers to the time between injection and exhaust gas. And gas pressure just work before the plastic is not solidified. Therefore, the long blowing time will waste the amount of nitrogen, because the plastic will be solidified in the process of injection.

If the gas is released before the plastic solidification, the shrinkage is still appeared. Long gas holding time cannot reduce the contraction of the surface all along. But the appropriate gas holding time is sufficient to reduce the shrinkage of the surface. Also it can shorten the molding cycle and save the cost.

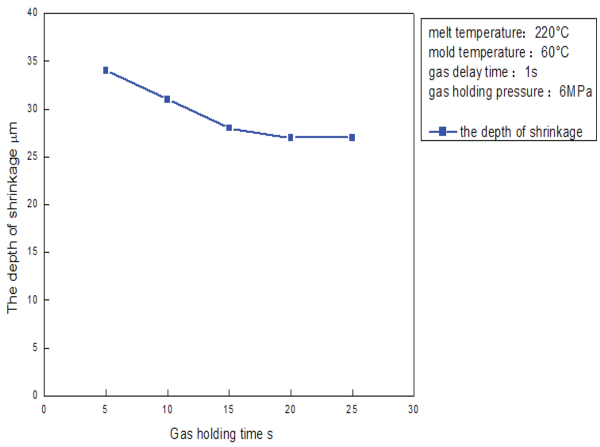

Figure 13 Gas holding time on the effect of external gas-assisted injection molding.

3.3. *Summary of experimental results*

The effects of process parameters on the quality of products were researched by a single factor experiment. These process parameters, mold temperature, melt temperature, gas delay time, gas holding pressure, gas holding time and other parameters were studied respectively.

The horizontal coordinates represent for the studied process parameter as a variable value, and vertical coordinates represent for the depth of shrinkage. We can know from the results that mold temperature, melt temperature, gas delay time, gas holding pressure and gas holding time are the main factors in the parts shrinkage.

4. Conclusions

This paper studies the mold temperature, melt temperature, gas delay time, gas holding pressure and gas holding time on the effects of plastic parts for quality in the molding process of EGAIM, discussing the relationship between process parameters and product quality. Also, it invests the single parameter on forming quality of the impact trend by changing one of the parameters while keeping the other parameters constant, comparative study of different section shape reinforcing ribs in the gas-assisted injection molding conditions. The above study has an important guiding significance in the setting of injection molding process parameters in parts production.

Acknowledgement

The research work was supported by National Nature Science Foundation of China(51005211).

References

[1] Ogando J, Fight sinks with external gas assist, Plastics Technology 16: **37** (2006).
[2] Hansen M, Building a Beter Plastic Part, Medical Design News 44(8): **45** (1998).
[3] Chen Shia Chung, Hsu Kuo Fu, Hsu Ke Sheng, A unified simulation of the filling and postfilling stagesin injection molding. Part I: Formulation, Polymer Engineering and Science 31(2): **116** (2004).
[4] Chiang H H, Hieber C A, Wang K K, Building a Beter Plastic Part, Medical Design News 44(8): **45** (1998).
[5] Mapleston P, External gas new variant of low-pressure injection, Modern Plastics 47(20): **23** (1994).
[6] Que shuijin, Jiang shaofei, Chai guozhong, Study on gas assisted injection molding process parameters on the quality forming influential trend of products, China Engineering Science 11(4): **84** (2009).
[7] Chen S C, Tseng C Y, Su C C, Study on the rib-designed part surface quality molded by external gas-assisted injection, Society of Plastics Engineers, 4: **2116** (2008).
[8] Chen S C, Lin K C, Huang S T, Study on packing effects on the part shrinkage molded by external gas-assisted injection molding process, Society of Plastics Engineers, 5: **2941** (2008).
[9] Asahi Kasei Corp, Method for gas pressurized injection molding [P], Japan: JP2001121581, (2001).
[10] Asahi Chem Ind. Co. Ltd, Gas pressure injection molding method [P], Japan: JP11198179, (1999).
[11] Kontor Moulding Systems Limited, Method and apparatus for preventing sink marks in the injection moulding of thermoplastic polymers [P], America: WO9301039, (2000).

Shaofei Jiang , Senior member of Chinese Mechanical Engineering Society, is a professor in School of Mechanical Engineering, Zhejiang University of Technology, he received his Ph.D degree from The State Key Laboratory of CAD&CG of Zhejiang University, China, and his research interest includes injection molding technology and equipment, product design theory and method and advanced die engineering.

Wei Zheng is a graduate student in school of Mechanical Engineering, Zhejiang University of Technology, he received B.Eng degree in the department of mechanical and electrical engineering from Changsha University. His research interest focus on rapid heat cycle injection molding technology and EGAIM.

Jiquan Li, fixed researcher of Key Laboratory of Special Purpose Equipment and Advanced Processing Technology, Zhejiang University of Technology, Ministry of Education, is an associate professor in School of Mechanical Engineering, Zhejiang University of Technology, he received his Ph.D degree from Shanghai Jiao Tong University, China, and his research interest includes injection molding technology and equipment, polymer material processing and forming principle.