3D-Simulation and Experiment of Gas Penetration Length in Gas-Assisted Injection Molding

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Abstract

Gas-assisted injection molding process is much complicated，the process parameters have multiplied. In this paper, a product with typical character of gas-assisted injection molded part is employed as the object of study. With the mould of gas-assisted injection molding and MPI/3D GAS in Moldflow software，the influence rule of the 6 important process parameters on gas penetration length in gas-assisted injection molding (GAIM) were studied by the methods of physical experiment and 3D numerical simulation.

Keywords: *GAIM; process parameters; gas penetration; numerical simulation; experiment.*

1. Introduction

Gas-assisted Injection Molding (GAIM) is one of important and innovative molding process. In the developed countries, the technology are widely used to manufacture large ultra-thin or over thick plastic parts, it has become a developing trend of transforming conventional injection molding process. The technology has the advantages of conventional injection molding, at the same time, dramatically avoid the defects. It is considered a revolution of the injection molding technology[1,2]. The technology has commercialized more than ten years, due to the introduction of gas, GAIM process becomes much more complicated, at present the research on GAIM processing property is not mature， different researchers have different results, even some are contradictory. For example, the gas penetration length becomes longer with the increase of gas pressure in reference [3], but the conclusion is opposite in reference [4] and [5]. So, the influence rule of the 6 important process parameters on GAIM were studied by the methods of physical experiment and 3D numerical simulation in this paper. The results have good use for reference to the setting of process parameters.

In recent years, certain progress has been made in numerical simulation of CAE about GAIM. The geometry object of Midplane mode is thin wall parts without 3D features, the midplane mode has its limits and can't coincide with experimental results[6]. The most research model is Midplane model but not 3D model. However, The MPI/3D GAS of Autodesk Moldflow 2010 software can predict experimental results of GAIM well, it can coincide with experimental results and previous numerical simulation results. The MPI/3D GAS plays an very important leading role on GAIM, at the same time, it provides an effective technology for the precise control of gas penetration in the actual production[2]. Gas penetration length and fingering width range are simulated in different technological conditions in this paper, and compared with the experimental data. The influence rule of the 6 process parameters on gas penetration were studied.

2. Experimental Program

2.1 Experimental Product

The object of the study is 200 mm long, The cross-section shape and dimensions of the product are presented in Figure 1.

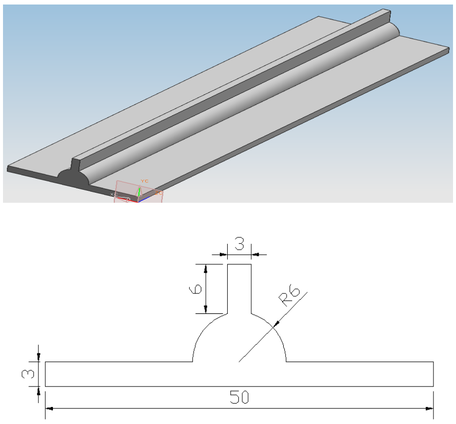


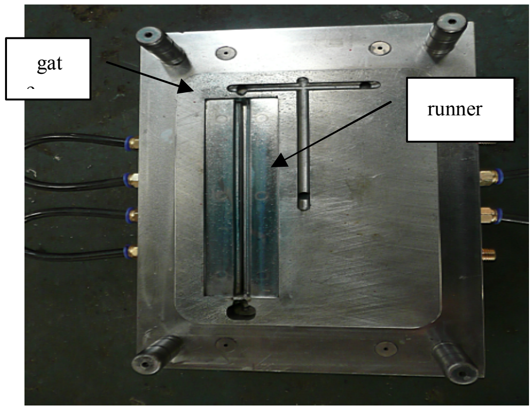
Fig.1 shape and dimensions of product

2.2 Experimental Material

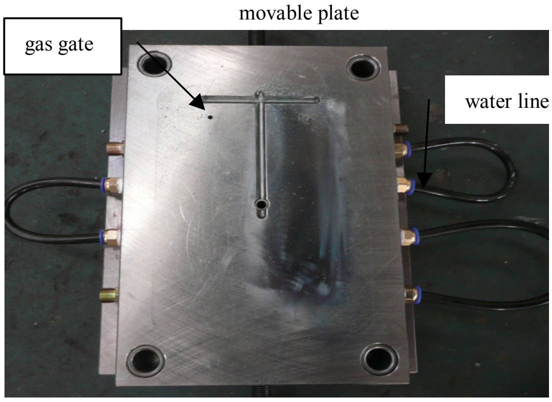
PP is selected as the simulative and experimental material, the material properties are shown as in table 1. PP is a commom and representative material of GAIM [7].

2.3 Experimental Mould

The mould used in this experimental are made by JiaRen mould company of Zhejiang province of China, shown as in Figure 2.



movable plate



stationary plate

Fig. 2 experiment moulds

2.4 Process Parameters

The influence rule of the 6 important process parameters on GAIM were studied by the methods of numerical simulation and physical experiment. Single factor is used in the study, process parameters setting are as shown in table 2.

Table 1 Experimental material

Name	Manufacturer	Trademark	Melt index（g/10min）	Melt density (g/cm3)	Solid density (g/cm3)
PP	SK Corporation	Yuplene R370Y	18	0.73764	0.89925

The benchmark is marked with overstriking underline.

Table 2: Experimental material

order number	Short-shot size /%	Melt temperature /℃	Mold temperature /℃	Gas delay time/s	Gas pressure /MPa	Gas injection time /S
1	75	220	20	0	3	5
2	80	230	30	1	10	10
3	85	250	40	2	15	15
4	90	260	50	3	20	20
5	95		60	4	25	
6	100				30	

3. Results and Discussions

3.1 Effect of Short-shot Size

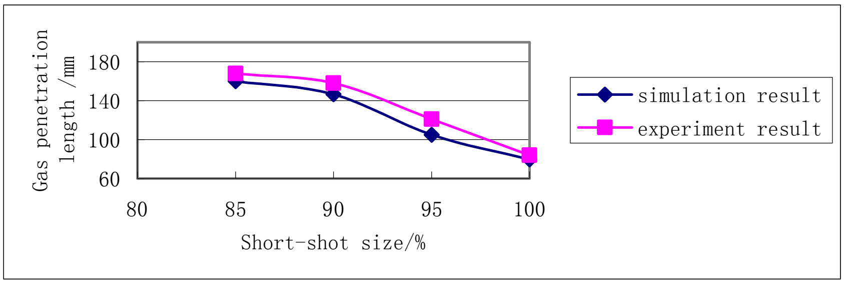
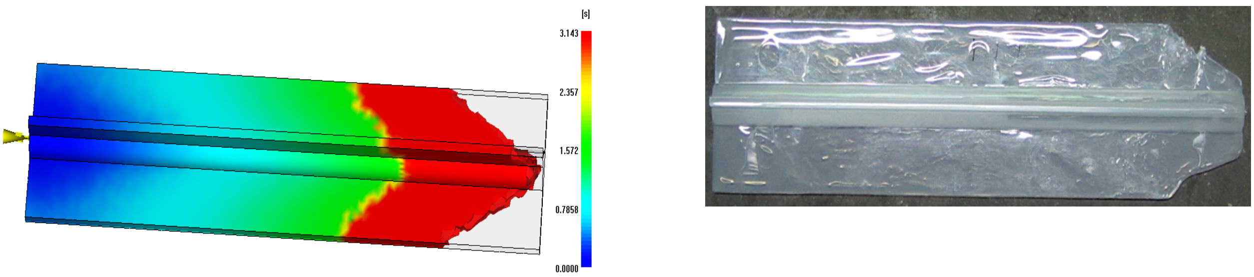
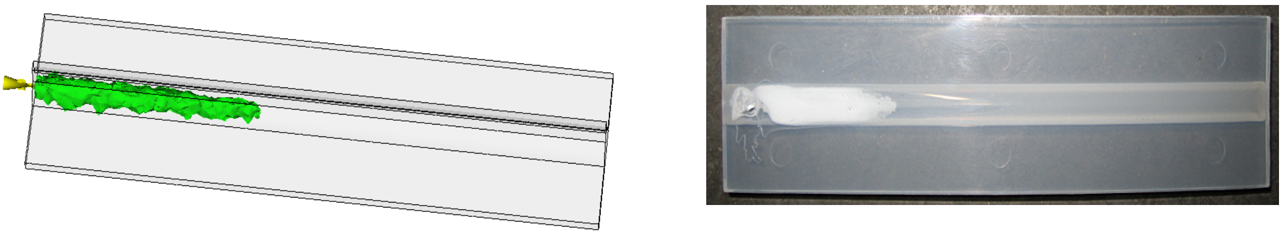


Fig. 3 The relation curve of short-shot size and gas penetration length



Simulation result Experiment result

Fig. 4 Gas penetration result of 75% short-shot size



Simulation result Experiment result

Fig. 5 Gas penetration result of 100% short-shot size

Short-shot size is the ratio of the volume of the injection mold cavity melt to the volume of full shot. It is usually between 70%～97%, and the specific digit is defined according to the plastic parts structure, process conditions .

The effect of short-shot size on gas penetration were studied by the methods of numerical simulation and physical experiment, as shown in Figure3. We could see that gas penetration length is falling with the increase of short-shot size, the simulation and experimental result coincide with the law. It shows that the increase in short-shot size will decrease gas space, reduce gas penetration length and increase the difficulty of the gas penetration.

The mold cavity has not been fully filled when short-shot size is 75% because of the short-shot size is too little, as shown in Figure 4. Only a small minority of gas enters the product and the part of no gas appears shrinkage defect mark when short-shot size is 100%, as shown in Figure 5, the simulation and experiment results clearly reflect this. So, the product will be unqualified if the melt is too little or too much, therefore, the quality of the parts will be good only when short-shot size is appropriate.

3.2 Effect of Melt Temperature

Melt temperature is an important process parameter affecting the GAIM. The effect of melt temperature on gas penetration were studied as shown in Figure 6. From Figure 6 we can come to the conclusion that gas penetration length decrease with melt temperature increasing. This is because with increasing melt temperature, viscosity and flow resistance decrease, liquidity improve, gas channel radius increase, finally the gas penetration length decrease.

In selecting, under the precondition to satisfy the production requirements, melt temperature shoud be chosen higher. But increasing melt temperature will increase the cooling time, extend the production cycle and reduce the production efficiency. So, Balance Analysis is needed.

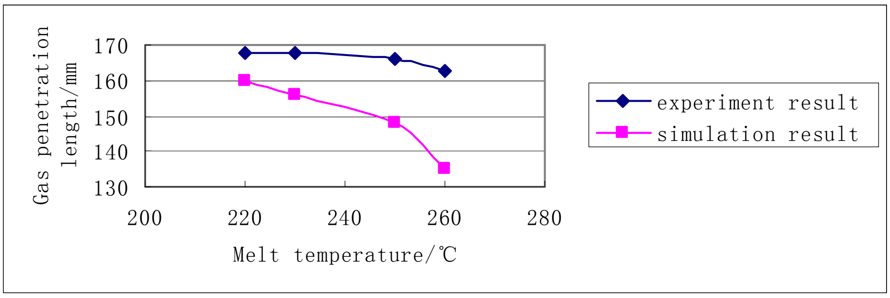


Fig. 6 The relation curve of melt temperature and gas penetration length

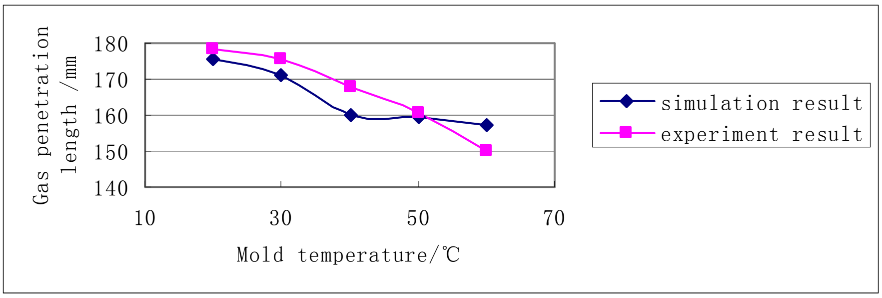


Fig. 7 The relation curve of mold temperature and gas penetration length

3.3 Effect of Mold Temperature

The effect of mold temperature on gas penetration were studied as shown in Figure 7. We can see that gas penetration length decrease with mold temperature increasing. Higher temperature reduce solidification velocity, make more melt flow foword, so, gas penetration length decrease.

3.4 Effect of Gas Delay Time

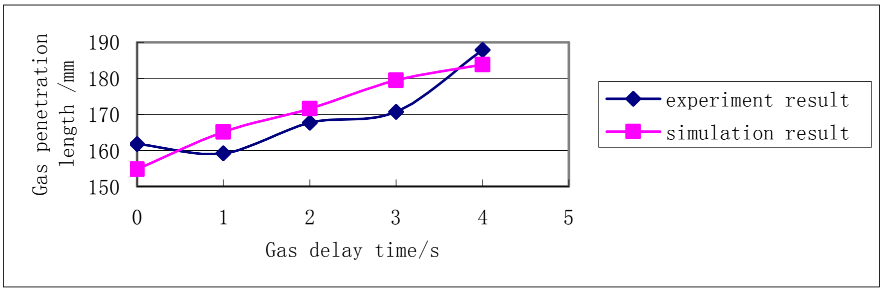
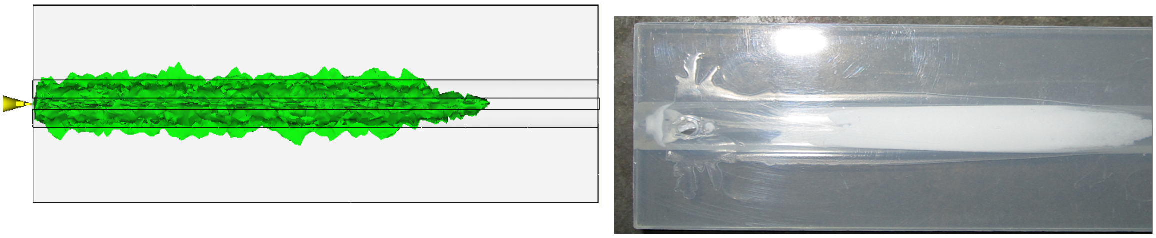


Fig. 8 The relation curve of gas delay time and gas penetration



Simulation result Experiment result

Fig. 9 Gas penetration result of 0s gas delay time

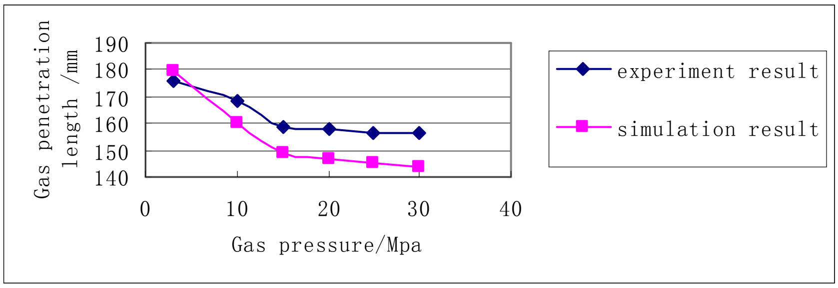


Fig. 10 The relation curve of gas pressure and gas penetration length

The effect of gas delay time on gas penetration were studied as shown in Figure 8. Fingering width range decrease with mold temperature increasing. The experiment and simulation results have the same trend. The study suggests that more gas delay time is better to the gas channel quality.

Too little gas delay time may aggravate gas fingering defect,as shown in Figure 9. Long delay time can reduce the degree of gas fingering, but too much delay time may give rise to no gas penetration or an absence of gas penetration.

3.5 Effect of Gas Pressure

Gas pressure that is characteristic of GAIM. Unsuitable choice of gas pressure may cause multiple defects. Therefore, study on gas pressure is particularly important. The results of simulation and experiment are as shown in Figure 10.

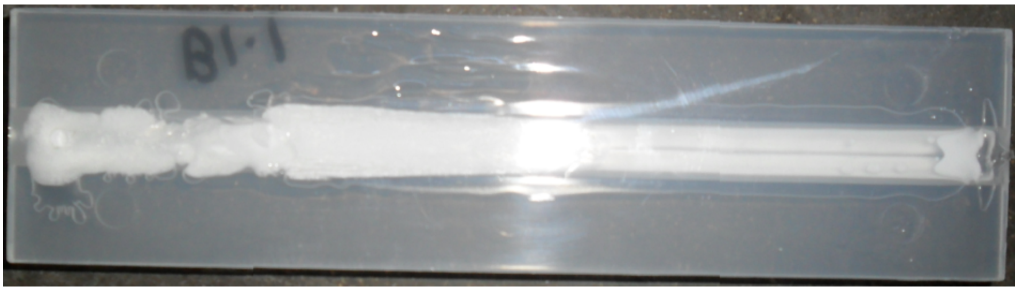


Fig. 11 gas bubble inside gas channel(gas pressure 25Mpa)

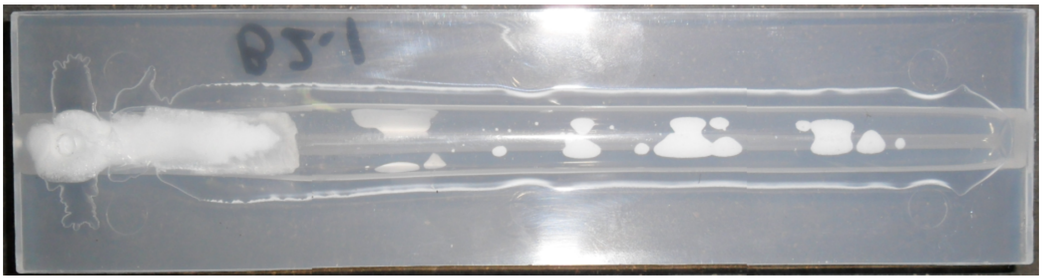


Fig. 12 Expansion phenomenon(gas pressure 30Mpa)

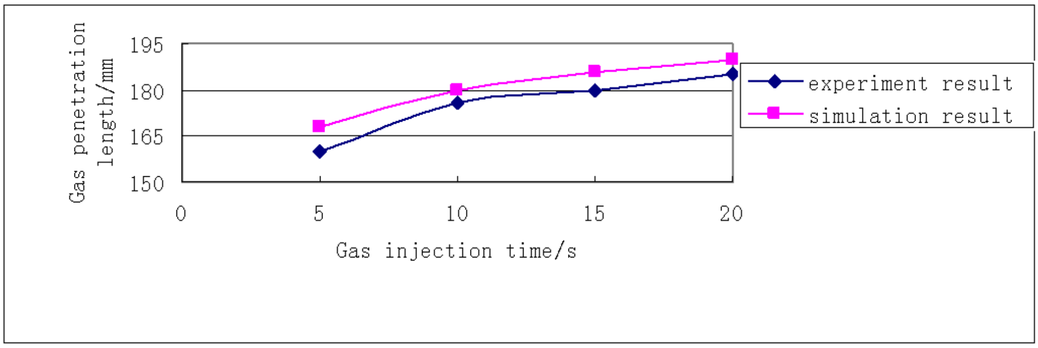


Fig. 13 The relation curve of gas injection time and gas penetration length

With gas pressure increasing, the ability of gas penetration increase, and more melt flow to the end of mold cavity, making gas channel diameter lager, so gas penetration length decrease, as shown in Figure 10. The results indicate that high gas pressure is bad to GAIM processing, we usually choose low gas injection pressure.

In the experiment, we found that high gas pressure is liable to cause gas bubble inside gas channel, as shown in Figure 11. The gas bubble has an effect upon the density and shrinkage of the product, finally, the quality of the product will fall off. The solution is to increase gas injection time and gradually remove gas pressure after the melt solidifying completely.

In the experiment, we also found the expansion phenomenon of the product, as shown in Figure 12. This is due to the high gas pressure, which is not expelled before demould. The solution is to expel high gas pressure from gas channel and make the gas pressure in the gas channel equal to the circumstance.

3.6 Effect of Gas Injection Time

The effect of gas injection time on gas penetration were studied by the methods of numerical simulation and physical experiment, as shown in Figure 13. It shows that the longer gas injection time, the longer gas penetration length.

The effect of gas injection time on gas penetration is significant. The suitable coefficient is the fundamental condition that assures product quality. The principle of gas injection time is possiblely short on the premise of the product quality.

4. Conclusions

GAIM is a new technology based on traditional injection molding technology which is widely used because it has been overcome many disadvantages of traditional injection molding technology. Due to the introduction of gas, method of gas injection and process parameters becoming more complex. Therefore, it is necessary to do a thorough study on GAIM. In this paper, the influence rule of 6 different process parameters were studied by the methods of numerical simulation and physical experiment to guide production.

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