

◆ 특집 ◆ 최신 정밀 설계재료 기술 III

사출성형 시 성형제품차수에 미치는 패킹변수의 영향

Effects of Packing Parameter on Plastic Article Dimensions in the Plastic Injection Molding

김범준^{1,*}, 신주경¹, 이정구¹, 손일선²
Bum Joon Kim^{1,*}, Ju Kyung Shin¹, Jeong Goo Lee¹, and Il Seon Sohn²

1 오산대학교 기계공학과 (Department of Mechanical Engineering, Osan Univ.)

2 오산대학교 자동차공학과 (Department of Automotive Engineering, Osan Univ.)

* Corresponding author: kultra@osan.ac.kr, Tel: +82-31-370-2662, Fax: +82-31-370-2669

Manuscript received: 2013.12.4 / Revised: 2013.12.9 / Accepted: 2013.12.27

The molding process can be divided into five separate steps: plastification, injection, holding, cooling, and finally ejection. In the plastic injection molding, the effect factor such as mold temperature, injection speed, packing pressure and inhomogeneous cooling under packing process affects both the article dimension and physical characteristics. Especially, the packing pressure is the most critical factor to affect molded articles quality among the packing parameters. In this paper, the CAE simulation considering the molding condition is performed to predict the faulty cause which appears in the packing process between cavities of injection molding machine. From the results of CAE simulation, the packing phenomena according to the product form and the gate position was investigated to improve the article quality and minimize the various molding defects. The effect of packing pressure and gate number on the injection molding was discussed.

Key Words: Injection molding (사출금형), Packing pressure (패킹압력), Warpage (굽), Shrinkage (수축), Gate (게이트)

NOMENCLATURE

ϕ : tunnel size

1. Introduction

Generally, the molding process can be divided into five separate steps: plastification, injection, holding, cooling, and finally ejection. In the plastic injection molding, the effect factors such as mold temperature, injection speed, packing pressure and inhomogeneous cooling under packing process affects both the article

dimension and physical characteristics. To decrease the molding defects, the field of optimal injection molding control is an important area for the research of precision mold design. For this reason, the CAE simulation such as mold flow has been an important tool to predict the molding defects, for example when minimizing surface defects like shrinkage, sink mark, flash, diesel effect, etc.¹ Thus, to predict the faulty cause which occurs in packing process between cavities of injection molding machines, the information such as the physical and chemical condition of plastics, the molding condition and mold structure are needed for the reliability of CAE

results. About this, Malloy et al. reported that it is possible to utilize a multi-live feed injection molding process to drive post-filling phase fluid flow during the packing and solidification of the cavity. Bushko and Stokes presented that the warpage and shrinkage of article resulted from inhomogeneous cooling and packing pressure.^{2,3} Also, Polinski et al. presented the effect of mold temperature and pressure variation for the dimensional stability and shrinkage of plastic article.⁴⁻⁶ In the manufacture of precision mold, the flow analysis tools such as C-MOLD, SolidWorks Plastics, Simpoem-Mold and MPI(Mold flow) were used to select the type of gate and runner and to obtain the reduction of time and cost, effectively. In this paper, the packing phenomena according to the product form and the gate position was investigated to improve the article quality and to minimize the various molding defect and it was compared with actual case. Also, the effect of packing pressure and gate number on the injection molding was discussed.

2. Experimental Procedure

To obtain the optimized design data of plastic injection molding, the CAE simulation was performed by MPI(Mold flow) of Autodesk Co. Ltd. First, the preprocessor was carried out using 3D cad data, and then the injection molding CAE simulation was performed in order of the flow, the cooling, the packing, and lastly, the deformation analysis was performed. A 3D FEA model was constructed using four-node tetrahedral elements.

Fig. 1 shows the runner gate system, the gate number and position of cellular phone case used for the injection molding CAE simulation. The thickness of article is 0.8mm to 1.0mm and the polycarbonate and ABS(Glass fiber 10%) was used as raw material. Table 1 shows the proposed gate information for optimal flow analysis. As shown in Table 1, the gateway, the gate position and the gate number of each case were proposed. Tables 2 and 3 shows the material properties and the boundary conditions used in CAE simulation, respectively.

Generally, the gate position was set a place where does not interfere with final shape of plastic article and simultaneously trace the gate mark. As mentioned above, the proposed gate position also was applied from same viewpoint and the gate number was decided with

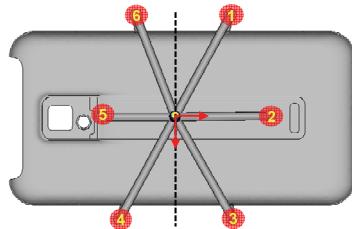


Fig. 1 Schematic diagram of gate system for CAE
(Tunnel: 1, 3, 4, 6 and Pin point: 2, 5)

Table 1 Gate information of CAE analysis

Factor	Case 1	Case 2	Case 3	Case 4
No.	6	4	4 + 2	4
Type	tunnel	tunnel	tunnel + pin point	tunnel
Size	φ 0.8 mm	φ 0.8 mm	φ 0.8 mm	φ 0.8 mm
Runner length	long	short	short	long

Table 2 Properties of plastic material

Factor	Value
Shrinkage, 3.2 mm	0.2 - 0.4 %
Dry temperature	100 - 120°C
Dry time	3 - 5 hrs
Density	1.25
Melt index	10g/10min
Melt temperature	295 - 310°C

Table 3 Boundary condition of CAE analysis

Factor	Value
Cavity temperature	110 °C
Injection pressure	160 MPa
Packing pressure	110 MPa
Injection time	0.8 sec
Packing time	1.4 sec
Cooling time	9 sec
Cycle time	20 sec

symmetric type to achieve homogeneous filling. In this study, from the viewpoint of above mentioned, the gate number was set with 4ea and 6ea for optimal flow analysis.

3. Results and Discussion

3.1 CAE results for injection condition

From the CAE results of four cases shown in Table 1, especially, the Case 1 shows relatively small deformation

Table 4 Deformation results by CAE analysis

No	Deformation(mm)		
	X axis	Y axis	Z axis
Case 1	0.11/0.10	0.16/0.13	0.12/0.12
Case 2	0.09/0.09	0.17/0.12	0.21/0.18
Case 3	0.08/0.08	0.19/0.13	0.38/0.24
Case 4	0.13/0.12	0.16/0.12	0.10/0.11

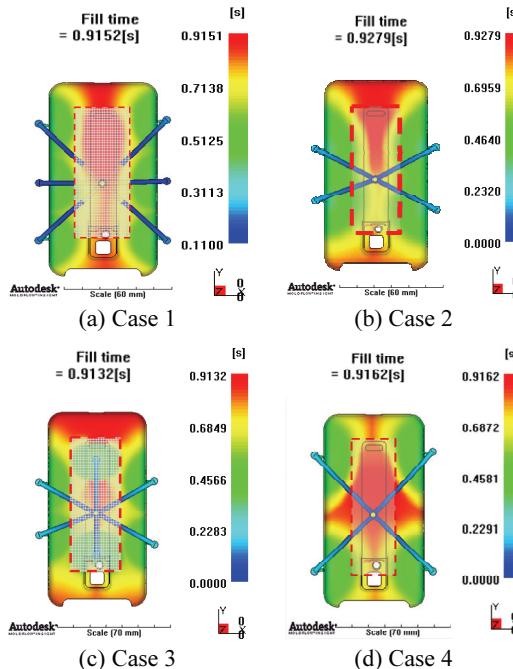


Fig. 2 Comparison of mold flow pattern with gate system

in total deformation of X, Y and Z axes by the packing pressure control of 70% at primary maximum injection pressure of 160MPa. Here, because that the deformation of X axis is directly related to the assembly tolerance, therefore the deformation of Case 1 was reasonable when considering the warpage of Z axis. Generally, from the CAE results, considering the deformation directly related to assembly, the final dimension of article was good when the dimension was smaller than the warpage.

It was good for real injection mold manufacturing indicated in Table 4(Case1). The left/right value of each axis shows that of shrinkage or the warpage.

Figs. 2 and 3 shows the results of mold flow pattern and injection pressure with the proposed gate information indicated in Table 1.

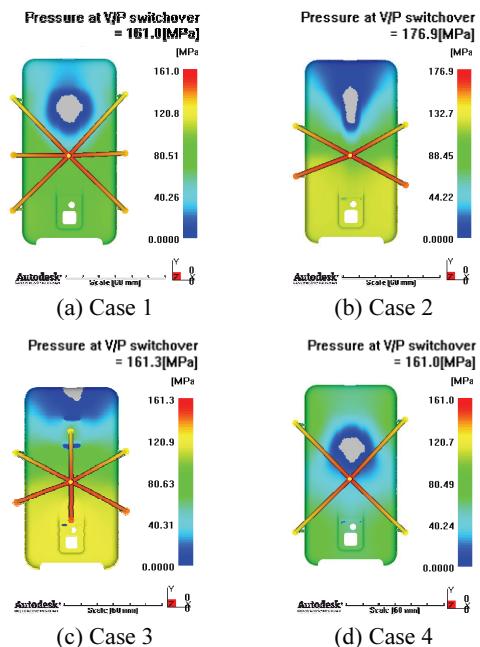


Fig. 3 Comparison of injection pressure with gate system

As shown in Fig. 3, the Case 1 which consists of 6 tunnel type gates only shows the injection pressure of 161MPa and relatively homogeneous pressure condition than other cases. In case of the Case 2 with the gate of 4 tunnels, the injection pressure was 176MPa and it was highest among 4cases.

Figs. 4 and 5 show the comparison results of shrinkage deformation along the X axis and Y axis on the packing pressure obtained by CAE simulation of each case, respectively.

Fig. 6 shows the comparison results of warpage deformation along the Z axis resulting from shrinkage of X and Y axis. The warpage is affected by many different parameters in the injection molding process.

Especially, when using conventional design of the cooling system, the most important parameters has been identified as packing pressure, mold and melt temperature, packing time, and to some extent, cooling time.⁷⁻¹⁰

The warpage of Case 1 shows the reverse direction of Z axis. The warpage direction of Case 2 was normal.

The warpage of Case 3 which consists of 4 tunnels and 2 pin points showed the normal direction of Z axis, and the warpage value was highest among all cases in spite of the same injection pressure of Case 1.

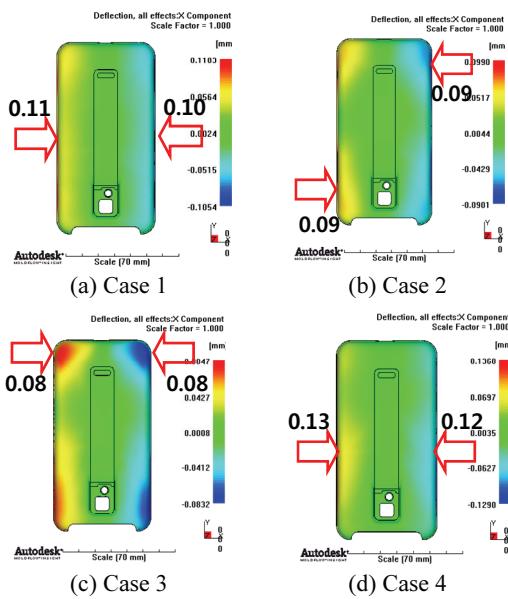


Fig. 4 Comparison results of shrinkage for X axis

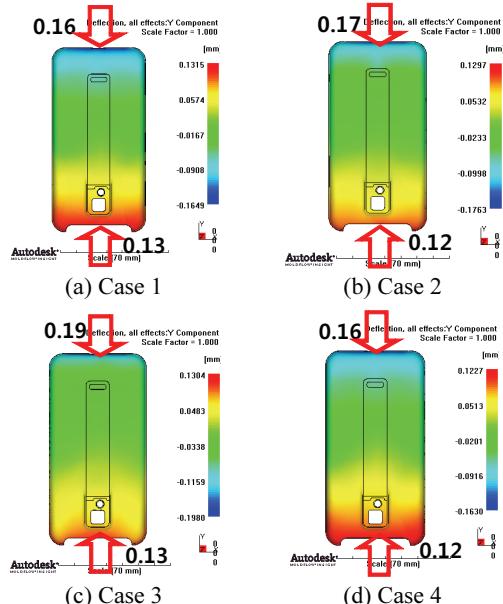


Fig. 5 Comparison results of shrinkage for Y axis

The CAE result of Case 4 with four gate number shows the injection pressure of 161MPa and that the direction of warpage was normal.

As mentioned above, from the CAE results of Case 1, 2, 3 and 4, it shows a marked difference in the shrinkage and warpage deformation.

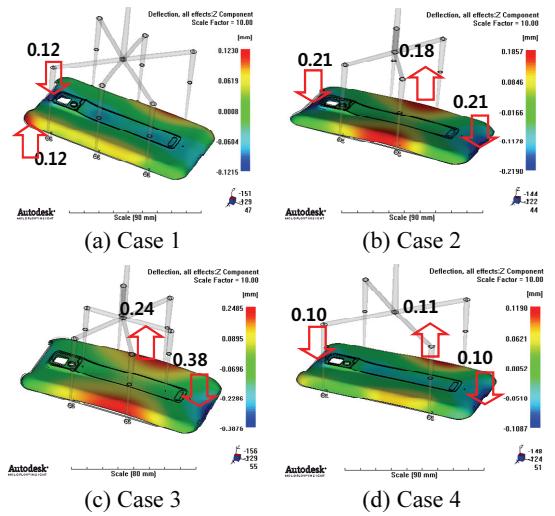


Fig. 6 Comparison results of warpage for Z axis

In Case 3, the shrinkage and warpage deformation along the X, Y and Z axes shows 0.08/0.08(mm), 0.19/0.13(mm) and 0.38/0.24(mm), respectively. Among the deformation along 3 axes, especially, the shrinkage along the X axis is very important when considering the product form in this study. As shown in Fig. 4, the deformation of Case 3 along the X axis, 0.08/0.08(mm) was excellent among all cases when considering the assembly dimension along the X axis, whereas the Case 1, 2 and 4 shows wide difference with 0.11/0.10(mm), 0.09/0.09(mm) and 0.13/0.12(mm), respectively.

On the other hand, for the analysis of deformation along the Z axis, the deformation of Case 3 increases rapidly with increase of the packing pressure shown in Fig. 6(c). This shrinkage and warpage deformation along the X, Y and Z axes resulted in the increase of Z axis warpage with increase of the packing pressure. Likewise, the incorrect packing pressure affects non-uniform packing pressure in cavity. Finally, it occurs that the quality problem such as a distortion, sink mark and a dimension degree. Therefore, the role of packing pressure maintains a constant cavity pressure and decreases the residual stress of plastic parts.

4. Conclusions

In this study, for the injection molding CAE simulation, the mean wall thickness of 1.0 mm is applied

to the plastic molded article; it can be estimate the contents of fault such as a deflection and shrinkage according to the variation of packing pressure from the results of CAE simulation.

After the analysis of cavity filling process by using the injection molding CAE program, the coordinate of 6 gate position to minimizing the fault by packing pressure was proposed with the importance of optimized gate position for actual injection molding.

ACKNOWLEDGMENT

This research was supported by Osan university Research Program in 2013.

REFERENCE

1. Tan, K. H. and Yuen, M. F., "A Fuzzy Multiobjective Approach for Minimization of injection Molding Defects," *Polym. Eng. Sci.*, Vol. 40, No. 4, pp. 956-971, 2000.
2. Malloy, R., Gardner, G., and Grossman, E., "Improving Weld Line Strengths Using a Multi-Live Feed Injection Molding Process," *ANTEC'93*, pp. 521-529, 1993.
3. Bushko, W. C. and Stokes, V. K., "Dimensional Stability of Thermoplastic Parts: Modeling Issues," *ANTEC*, pp. 482-485, 1996.
4. Polinski, A. J., Bushko, W. C., and Stokes, V. K., "Dimensional Stability of Thermoplastic Parts: Model Experiments," *ANTEC*, pp. 486-490, 1996.
5. Bushko, W. C., Stokes, V. K., and Polinski, A. J., "Dimensional Stability of Thermoplastic Parts: Comparison of Shrinkage Data With Predictions," *ANTEC*, pp. 491-495, 1996.
6. Lee, H. S. and Yoo, Y. G., "Effects of Processing Conditions on Cavity Pressure During Injection-Compression Molding," *Int. J. Precis. Eng. Manuf.*, Vol. 13, No. 4, pp. 2155-2161, 2012.
7. Huang, M. C. and Tai, C. C., "The Effective Factors in the Warpage Problem of an Injection Molded Part with a Thin Shell Feature," *JMPT*, Vol. 110, pp. 1-9, 2001.
8. Chang, T. C. and Faison, E., "Shrinkage Behavior and Optimization of Injection Molded Parts Studied by the Taguchi Method," *Polym. Eng. Sci.*, Vol. 41, No. 5, pp. 703-710, 2001.
9. Kurtaran, H., Ozcelik, B., and Erzurumlu, T., "Warpage Optimization of a Bus Ceiling Lamp Base using Neural Network Model and Genetic Algorithm," *JMPT*, Vol. 169, No. 2, pp. 314-319, 2005.
10. Ozcelik, B. and Erzurumlu, T., "Comparison of the Warpage Optimization in the Plastic Injection Molding using ANOVA, Neural Network Model and Genetic Algorithm," *JMPT*, Vol. 171, No. 3, pp. 437-445, 2006.