Research on Changed Design of Gate Position of Window Frame of Automobile Front Door

Haorui Zhai¹,Xin Xing¹,ZhuAn Zheng¹,Conggui Sun²,Chen Teng¹

¹School of Automobile Engineering, Yancheng Institute of Technology, Jiangsu Yancheng China
²Jiangsu Yuyan Mould Technology Co., Ltd. Jiangsu Yancheng China

18251423907@163.com, Yancheng institute of technology, 1 middle road, hope avenue, tinghu district, yancheng city, jiangsu province, China

Abstract. The front door sash of the car is selected as the research object, and the design of the original gate position causes the warpage displacement of the front door sash to be large. Based on the CAE principle, using Moldex3D mold flow software analysis, it was found that the cause of the large amount of warpage deformation was flow imbalance. Then, according to the principle of flow balance, the design of the gate position was changed. The results of the mold flow analysis showed that the warpage displacement decreased from 18.5 mm to 14.1 mm, and the overall optimization was 24%. And the comparison found that the molding pressure was reduced from 224 MPa to 171 MPa (single cavity), and the clamping force was reduced from 2003 Ton to 1474 Ton (single cavity).

1. Introduction
The window frame of automobile front door is a kind of window frame installed on the front door. It is a kind of exterior ornament with beauty and practicability. Besides making automobile beautiful, it also has good ability of shock absorption and noise elimination[1]. The example product in this paper is an injection moulding part of window frame of front door for luxury car made by Jiangsu Yuyan Mould Technology Co., Ltd. As shown in Fig.1 (a), the product is shaped as "U" and made of PA6 + GF15. It is a product of polyamide including 15% glass fiber, adopting a mode of two points to produce. Its single cavity volume is 302 cc, and the meat thickness of the product is evenly distributed with an average thickness of 1.5 mm. Just like the Fig.1 (b):
Reducing vehicle weight by using lighter materials is a popular approach for improving fuel efficiency. Due to their ability to enhance mechanical performance as well as satisfy safety and durability requirements, fiber-reinforced-thermoplastic compounds are now commercially available as candidate materials. In general, the shell-core structure, as the orientation structure of the flow-induced orientation of fibers, is found in injection molded parts[2].

The gate of injection mold is the narrow part between the runner and the cavity. It accelerates the movement of the plastic conveyed by the runner, so that the plastic can enter the cavity faster and better.[2] The size and position of gate have a great influence on the quality of plastic parts. The shape of this model is "U". The inappropriate location of gate will lead to unbalanced flow in filling process, which will easily lead to large warpage displacement. The size of gate can be changed according to the factors after opening, but the position of gate is difficult to change after opening, so the position of gate should be analyzed in advance. Based on the finite element model flow analysis technology, product problems can be pre-judged before they arise. Moldex3D Mould Flow Analysis Software developed by Taiwan Kesheng Company is a very useful analysis tool. Its BLM solid grid and hot runner module provide reliable guarantee for the accuracy of Mould Flow Analysis. The simulation results are for four stages of a typical injection moulding: Filling, Packing, Cooling and Warpage[3-5].

2. Analysis of original scheme design

2.1. Design of original gate location

The design of the two points is adopted. The number of grids is too large, and the analysis time is longer. Based on the symmetric cavity, the analysis of single module hole is carried out in order to save the analysis time. The appearance of the product is strictly required, the edge line should be clear and there should be no runner trace, the warpage displacement should not be too large, and the forming period should be controlled within 20 seconds. In view of the above situation, the hot runner technologies adopted, and the gate position is gummed in the way shown in Fig.2 (1)The method of "hot runner + cold runner" is adopted. As shown in Fig.2 (a), the red arrow in the figure represents the hot runner, and the cold runner is used between the hot runner and the plastic part[6]. This design avoids the problems of single hot runner feeding resulting in tiger skin pattern on plastic parts and long product cycle caused by cold runner; (2)The size of gate is 10mm *5mm by side feeding as shown in Fig.2 (b).
2.2. Model flow analysis results

The process parameters are set as follows: (1) Filling stage: the filling time is 4 sec, and the upper limit of pressure is 200 MPa. (2) Pressure holding stage: Pressure holding time is 6 sec, divided into three stages: 4 sec/124 MPa, 1 sec/93 MPa, 1 sec/46 MPa. (3) Cooling stage: cooling time is 10 sec. (4) Temperature setting: Nozzle temperature is 265 ℃, cooling water temperature is 75 ℃. The above scheme is simulated and analyzed by Moldex3D. The results are as follows Fig.3.

**Figure 2. Glue feeding mode**

![Glue feeding mode](image)

**Figure 3. Filling Results**

Fig.3 (a) shows that there is no difference when filling 2.12 sec and plastic filling 50%. Fig.3 (b) shows that when filling 3.18 sec and plastic filling 75%, the plastic entering the cavity through different gates reaches the flow end at the position indicated by the red arrow on Fig.3 (b). By filling 85% of Fig.3 (c), it can be seen that the flow end at the upper right corner is larger than that at other flow ends, which indicates that the time of the flow end at the upper right corner of the plastic part is longer than that at other parts. Comparing Fig.3 (b) with Fig.3 (c), it is obvious that the position indicated by the red arrow on the upper right side of the plastic part (c) is longer than the filling time at other parts of the plastic part, which results in unbalanced flow. Fig.3 (d) In filling 4.03 sec, 95% of...
filling can be seen. The red arrow points to the filling end of the whole plastic part. The filling time here is obviously longer than other parts of the plastic part. It is the last filling and the latest entry into the holding stage, resulting in the phenomenon of flow imbalance.

Figure 4. Pressure distribution at the end of filling

Figure 5. Total warpage displacement

The pressure distribution at the end of filling shown in Fig. 4 shows that the pressure rises rapidly in the area where the filling is completed earlier. When the filling is completed, the pressure distribution is not uniform. The red arrow on the graph is the filling end, so the pressure is the lowest. In summary, the color bar in Fig.3 and Fig.4 shows that the time to reach the end of the flow is quite different, and the pressure in the area where the filling was completed earlier rises faster, resulting in uneven distribution of the overall pressure, showing the phenomenon of flow imbalance, which buries a hidden danger for the large warpage displacement.

Fig.5 shows that the maximum warpage displacement of demoulding product is 18.5mm. After enlarging 5 times on the right side, we can see that the shape of the plastic part warps in the direction indicated by the red arrow, and the displacement is large. By comparing the warpage displacement caused by various factors, Fig.6 (a) is the total warpage displacement of 18.5 mm, Fig.6 (b) is the total area shrinkage effect of the displacement of 14 mm, Fig.6 (c) is the fiber alignment effect of the displacement of 9.4 mm, and Fig.6 (d) is the temperature difference effect of the displacement of 0.3 mm. The warpage of plastic parts is mainly due to the uneven shrinkage caused by unbalanced flow in the filling process and the alignment effect of fibers caused by 15% glass fiber in the material, while the warpage caused by temperature difference can be neglected.
3. Analysis of Optimized Scheme Design

3.1. Gate Position Change Design
Regional shrinkage and fiber matching lead to warpage deformation of 18.5mm of final product, improve flow balance, reduce the pressure imbalance of plastic parts, and effectively reduce the deformation caused by regional shrinkage. The influence of fibers on warpage is more complex. It is usually possible to change the arrangement of fibers only by changing the flow trend, so as to improve warpage. According to the analysis results of the previous mould flow, it is determined that the original gate position design caused the imbalance of flow, resulting in the problem of large warpage displacement of plastic parts, which is difficult to meet the requirements of product quality and the appearance quality of plastic parts, and then the gate position is changed. In order to improve the uneven pressure distribution caused by flow imbalance, the excessive forming pressure and clamping force, and the warping of regional contraction effect caused by subsequent non-uniform shrinkage, the four gate positions at the arrow in Fig. 7 are moved towards the flow end, i.e. the direction indicated by the red arrow, to try to adjust the flow.
3.2. Result analysis and comparison

After changing the design of gate position, the result is analyzed by Moldex3D, and the analysis result is shown in Fig.8 (left: original design; right: changed design; left and right are omitted below).

From Fig.8 (a) 75% filling time, it can be clearly seen that the filling time in the left picture is 75% filling time, the upper left flow end is mostly not full, while the upper right picture is almost full. Fig.8 (b) filling 95% at the end of the flow, through the color bar, we can see that the upper right part of the left picture is still not filled with the cavity, the difference of the flow end time is large, which leads to the phenomenon of flow imbalance; while in the right picture, the cavity has almost been filled, the distribution of the color bar is more uniform, and the flow end time is roughly the same, the difference is not big. By comparing the pressure curves of the two schemes shown in Fig.9 (a) (red curve is the original design curve, green curve is the change design curve, and omitted as red curve and green...
curve below), it can be seen that the maximum pressure of the red curve is 224 MPa (single die hole), while the maximum pressure of the green curve is 171 MPa (single die). Compared with the original design, the design changes optimize the flow balance. At the same filling speed, the filling pressure is smaller and the forming pressure is reduced by 53 MPa. Comparing the lock force curves of the two schemes shown in Fig.9 (b), it can be seen that the maximum lock force of the red curve is as high as 2003 tons (single die hole), while the maximum lock force of the green curve is only 1474 Ton (single die hole). The smaller the forming pressure, the smaller the lock force requirement, the lower the lock force by 529 Ton.

![Pressure curve of rubber inlet and Curve of clamping force](image)

(a) Pressure curve of rubber inlet and (b) Curve of clamping force

**Figure 9. Contrast curve**

By comparing the warpage displacement of the two schemes with Fig.10, the result is enlarged by 5 times. It is obvious that the warpage displacement of the modified design is smaller than that of the original scheme. In the final maximum deformation, the optimization ratio is 24% from 18.5 mm to 14.1 mm.

![Warping displacement](image)

**Figure 10. Warping displacement**

4. **Physical verification**

Based on the above CAE flow analysis results, the scheme after the change of gate position is handed over to Swift Company for the actual test model comparison. The field test model and the forming product are shown in Fig.11. From the drawing of the forming product, it can be seen that the warping displacement of the right figure is smaller than that of the left one, which is close to the result of Moldex3D analysis, and the warping displacement has been improved obviously.
5. Summary

Based on CAE technology, the optimization of gate position for warpage displacement is analyzed by Moldex3D flow analysis software. Through the comparison of the results, it is found that the warpage displacement is reduced and the forming quality of the product is improved by changing the gate position of the design compared with the original design. Through analysis and comparison, it is verified that the modified design has better analysis results than the original one. The forming pressure is reduced from 224 MPa to 171 MPa (single cavity). At the same filling speed, the filling pressure is smaller. The clamping force decreases from 2003 Ton to 1474Ton (single die hole), and the requirement of clamping force decreases with the decrease of forming pressure. The warpage displacement was reduced from 18.5 mm to 14.1 mm by adjusting the gate position through changing the design, and the overall optimization was 24%.

However, with the continuous progress of science and technology, computer CAE simulation is more and more suitable for actual production, which makes it a stable reference before the actual production of finished products, and greatly improves the quality of product shaping and reduces the waste of resources.

6. Reference

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