Application of Sequence Control Injection in Modified Design of Car Front Bumper

WANG Feng, ChenGuodong, BU Jiling, ZHOU Bin

Zhuzhou Times New Material Technology Co., Ltd. Hunan,412007,China

Email: wangfeng4@teg.cn, wangfeng4@csrzic.com

Abstract: In view of lightweight and cost reduction, a bumper has been redesigned, which results in weld lines during the manufacture. For that, a new method of sequence control technology is introduced. The simulation results with the new method and the traditional method were compared. The results showed that the weld lines were removed, and at the same time, the injection balance was better and the injection pressure was decreased by using the sequence control technology. The sequence control technology is of great practical significance to bumper manufacturing.

Key words: Front bumper; Weld line; Sequence control technology; Numerical simulation

1. Introduction

With the development of the automobile industry, bumper, as one of the main components of car body, has increasingly higher requirements, not only pursuing its harmony with the car’s style, but also meeting the requirements of lightweight and cost reduction [1]. In this study, a bumper was investigated. The up grille, the down grille and the main body were made together. Meanwhile, the thickness of the bumper was reduced from 3.5mm to 3mm; it not only reduces the weight of the product, but also reduces the number of molds from three sets to one set, which means the molds’ cost is reduced at the same time. By using Moldflow software, the modified product was simulated. It was found that the product had good shape molding performance, but the weld line was obvious. In order to fix the weld line defect, the sequence valve control injection system was introduced [2-5]. By contrasting the simulation results with the results using traditional injection system, it was proved that the sequence valve control technique can not only effectively improve the weld line quality, so the surface quality and mechanical properties are improved, but also reduce the mold loss and increase the economic benefits.

2. Structure optimization

In order to reduce the product’s weight and the mold’s cost, a bumper was optimized, of which the dimensions were length × width × height = 320 × 1595 × 627 mm. The original thickness was 3.5mm. The main body, the up grille and down grille were made independently, thus three sets of molds were needed. After modification, the main body, the up grille and down grille were made
together, so that the molds were reduced from three sets to one set, and the mold cost was significantly reduced. In consideration of lightweight, the thickness was reduced from 3.5mm to 3.0mm, but the thickness of matching surfaces and bolt connections were not changed. The 3D model of the bumper is shown in Fig.1. The original section is shown by the red lines, and the optimized section is shown by the blue lines in Fig. 1(a).

![Fig.1 original and optimized designs](image)

After optimization, the number of molds was reduced from three sets to one set, and the weight was reduced from 4.86Kg to 3.64Kg, which means that the weight was reduced by about 17.6%. Thus, the effectiveness of the optimization is obvious. It greatly reduces the product's cost, and improves the business competitiveness, which meets the strategy of fuel economy and sustainable development. Meanwhile, the new design may cause some injection molding problems.

3. Traditional injection system scheme

3.1 Traditional injection system

Because the up grille, down grille and the main body are made together, the runner cannot be placed in the grille, and can only be arranged at the position of the upper and lower edges. For another reason, the bumper has a large dimension; there are always some injection problems. In order to solve these problems, in traditional injection system, the combination of cold and hot runners and more gates is used [1]. In this paper, the combination of cold and hot runners and five gates is adopted, as illustrated in Fig.2.
3.2 The setting of initial parameters

Modified polypropylene material is used in traditional design. This material has many advantages, such as low cost, impact resistance, weather aging resistance, good high and low temperature performance, high heat-distortion temperature, stiffness and hardness suitability, etc., which are beneficial to the car’s lightweight, less energy consumption, and beautiful decoration. Modified polypropylene is an ideal material for manufacturing automobile bumpers [4]. During this simulation, the PF 236 X115 in the Moldflow material database was chosen, and its main physical properties are shown in Table 1.

| Melt density/g.cm$^3$ | 0.78113  |
|-----------------------|----------|
| Solid density/g.cm$^3$| 0.95023  |
| Ejection temperature/°C| 100      |
| Max shear stress/MPa  | 0.25     |
| Max shear rate/s$^{-1}$ | 10000     |
| Recommended melt temperature/°C | 240 |
| Recommended mold temperature/°C | 50 |
| Failure temperature/°C | 320      |

The main molding parameters are shown in table1: mold temperature 50 °C; melt temperature 240 °C; injection time 5S, velocity/pressure control (V/P) conversion 99%, holding pressure 80MPa, and holding time 20s.

3.3 Preliminary analysis

The results of preliminary analysis are shown in Fig.3. Because the five gates inject at the same time, there is a long, deep weld line (marked by red line) that seriously affects the appearance of the products.
4. Optimization of injection system

4.1 Theory of sequence Control Injection System

In order to fix the weld lines defect, the sequence control injection system is introduced. By using the precisely controlled needle-gate injection system, each gate’s opening and closing time depend on the plastic melt filling process, and can be controlled individually. Needle-gate injection nozzle adopts the cascade injection control technique. The melt from the firstly opened nozzle is used as the front melt flow. The melt from the subsequently opened nozzle directly flow into the inside of the previous melt, and promote the melt to keep filling, so there is only one flow front in the filling direction, meanwhile the flow front temperature increases. By using needle-gate injection system, the weld line can be eliminated effectively or be limited at less important places of the products, so high-grade products can be made.

4.2 Sequence Control Injection System

The location of the injection system is the same in both programs. The dimensions of the sprue, runner and gates remain unchanged. But at the end of the hot runner there are needle-gates, which can control the gate opening time and closing time.

At the beginning of injection, gate1 opens first, and the melt starts filling. When the flow front arrives at gates2 and gate3, both of them open at the same time. The flow front keeps going and reaches a certain place (in order to control the weld line at a certain position, repeated attempts are required), and then gate4 and gate5 open together. As shown in fig. 4, the five gates’ injection time is not equal, and all of them keep open until the pressure releases. This sequence control method is very simple, and demands less pressure on the injection molding machine, so it is widely used in the actual production process.
4.3 Optimized analysis results

4.3.1 Weld line

The overlay of the weld line, temperature and pressure are shown in Fig.5 (the area of the weld line is marked by blue line). The weld line has a significant influence on the surface quality and mechanical properties of products, so the appearance of it is avoided. If it is not possible, it should be tried to reduce its length, or prevent it from showing at critical locations [6-8]. According to the evaluation standard of the weld line, the quality of weld line is mainly affected by two factors, one is the temperature and pressure when the weld line is forming, and another is the meeting angle and whether there are air traps.

As is shown in Fig.5, compared to the results of the conventional system, the weld line is obviously shorter and only appears at the connection of the up grille and the main body. According to the evaluation standard of the weld line, the temperature difference is small and almost the same with the initial injection temperature when the weld line is forming, at the same time, the pressure is high, and the meeting angle is small, when the sequence control technology is used. Through study, it is fully proved the superiority of sequence valve control injection system in control of weld line defects.

![Fig.4 gate opening pattern in sequence control technology](image)

![Fig.5 weld line distribution in sequence control technology](image)

4.3.2 Filling time

Figure 6 shows the filling time, where red color indicates the last filling site. By simulation, we can evaluate
whether the filling is balanced. If the melt reaches the end edges of the product at consistent time, it is said that the filling is balanced. If not, it is easy to cause over pressure and shrinkage mark defects. Meanwhile, it can be decided whether there is short shot. The filling time is 6.307s in traditional injection system and 6.421s in sequence valve control injection system. There are not too many significant differences between two schemes. However, the filling balance is better in valve control injection system than that in traditional injection system (color distribution uniformity is good). By analysis, it can be said that the filling time is not shorter when more gates inject at the same time. Without affecting the production efficiency, sequence valve control injection system can greatly improve the quality of the products.

4.3.3 Pressure at injection location

In traditional injection system, the cavity pressure continues increasing, and reaches the highest point 94.82 Mpa. The pressure of V/P is 80Mpa. In sequence valve control injection system, the cavity pressure continues increasing similarly, and reaches the highest point 91.50 Mpa. The pressure of V/P is 60MPa. In the sequential injection system, lower injection pressure is required, which shows that there are less resistance in the flow channel and the cavity, so that it can reduce the mold wear, extend the service life and increase economic benefits.
4.3.4 Actual maneuverability

In order to increase the maneuverability of the sequence valve control injection system in actual production process, the position control mode in simulation analysis is converted to time control mode. The detailed operation guidelines are shown in table 2.

**Table 2** optimized gates opening time

| gate | Open time/s |
|------|-------------|
|      | 0s-2.17s    | 2.17s-4.15s | 4.15s-6.421s | 6.421s- |
| 1    | open        | open        | open          | close   |
| 2    | close       | open        | open          | close   |
| 3    | close       | open        | open          | close   |
| 4    | close       | close       | open          | close   |
| 5    | close       | close       | open          | close   |

5. Conclusion

(1) Lightweight design and molds integration of the bumper can reduce the cost of products and greatly enhance the market competitiveness, and have an important guiding significance for similar automotive product design.
(2) The introduction of sequence valve control injection system in the automobile bumper production effectively solves the weld line defects, and greatly enhances the quality of the products.

(3) Simulation is a practical method in product development; it can greatly shorten the product development cycle, and improve the quality of the products.

References:

[1] Chen Wanlin. The utility of plastic injection mold design and manufacture of [M]. Beijing: Mechanical Industry Press, 2000:5-8.

[2] Zhou Jie, Lin Li li. Sequential control applications in the injection molding of car front bumper [J]. Engineering plastics application, 2008, 36 (4):37.

[3] Tan Wensheng. Study of fiber orientation in Valve-injection system of injection molding [J]. Light industry machinery, 2006, 24 (2):30-32.

[4] Luo Yi. Present simulation and prospect of China modified polypropylene particular material used for automobile [J]. Plastic technology, 1998 (10):45-50.

[5] Zhang Yanhui, Diao Hongchao. Research on numerical simulation of controlling weldline in thin wall plastics [J]. Shandong coal science and technology, 2008, (3):144.

[6] Lu Yaping. The formation mechanism and control method of weld line [J]. Mould industry, 2006, 32 (12):61–64.

[7] S. C. Malguarnera, A. I. Manisali and D. C. Riggs. Weld line structures and properties in injection molded polypropylene [J]. Polymer Engineering & Science, 2005, 45 (7):1021–1030.

[8] Cheng-Hsien Wu and Wan-Jung Liang. Effects of geometry and injection-molding parameters on weld-line strength [J]. Polymer Engineering & Science, Polymer Engineering & Science,1981,21 (17):1149 – 1155.