

Research on Sequentially Controlled Hot Runner Injection Molding for Led Tv Rear Panel

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Abstract: The traditional injection molding method for large-scale thin-shell plastic parts is realized by multi-gate hot runner technology. Due to the simultaneous injection of multiple points, defects such as bubbles, shrink marks, and more weld marks on the product are likely to affect the appearance of the plastic part. Quality, strength and effect of subsequent painting. This article takes LED TV rear panel products as an example, and uses CAE mold flow analysis technology and hot runner sequence control technology to optimize the injection molding process and mold through the three steps of process condition presetting, molding scheme analysis and estimation, and test mold verification. Design, the purpose of obtaining good plastic parts. It provides an efficient and stable injection molding process method for the development of such large-sized, thin-shelled, and high-demand product products to solve and improve their molding defects.

1. Introduction

For large-scale thin-shell injection-molded products, due to their large size and thin wall thickness, the problems of injection molding filling and narrow process range are caused. The mold structure often adopts a multi-gate design, which makes it difficult to balance the filling of the mold cavity, and the number of weld marks increases, which seriously affects the appearance quality and mechanical properties of the product.

At present, the use of full hydraulic secondary compression injection molding technology [1] can solve the problem of difficult filling of such injection molded products, and at the same time solve the problem of light refraction of high-gloss products or transparent materials. The use of electric heating injection molding technology and high-gloss injection molding (RHCM) technology [2] can control the temperature field balance during molding, and reduce the effects of surface welding and other defects. However, these methods can achieve the molding process only through special process equipment or molds, and the process control is difficult, the waste rate is high, the energy loss is large, and the production cost is high.

Hot runner sequential control (Sequential Valve Gating, SVG for short) pouring technology [3], which uses gas / hydraulic devices and time control devices to control the movement and stop of the valve needle at a predetermined position and time, and cooperates with the nozzle valve to achieve sequential opening and closing. The melt flow achieves an orderly “relay” flow, and achieves “dynamic” control of the material flow [4]. Provides new ideas for solving the above problems.

This article will take the LED TV rear panel as the research object, based on the CAE mold flow analysis technology and sequential control hot runner technology, explore the product hot runner valve gate opening and closing control law, and study the optimization of the product injection process scheme under different process conditions. Inferior, and through the test experiment, verify the CAE mold flow analysis results to optimize the injection molding process.

2. Sequence Control Principle and Characteristics of Hot Runner Structure

The sequential control of the hot runner is the opening and closing of the nozzle gate by the valve needle driven by the gas / hydraulic device. However, the control of the gas / hydraulic device is no longer only mechanical, but a time sequence control device is introduced. The time setting sequence opens and closes the valve, so that the material flow flows sequentially and sequentially, and the filling process is balanced and controllable.

As shown in Figure 1, the interior of the SVG hot runner mold structure is mainly composed of ① positioning ring, ② nozzle, ③ heating wire, ④ hydraulic cylinder, ⑤ plunger, ⑥ heating rod, ⑦ manifold, ⑧ valve needle, ⑨ thermocouple, ⑩ Nozzle and other components, there are temperature control device, pneumatic / hydraulic drive device, needle valve time control device and so on.

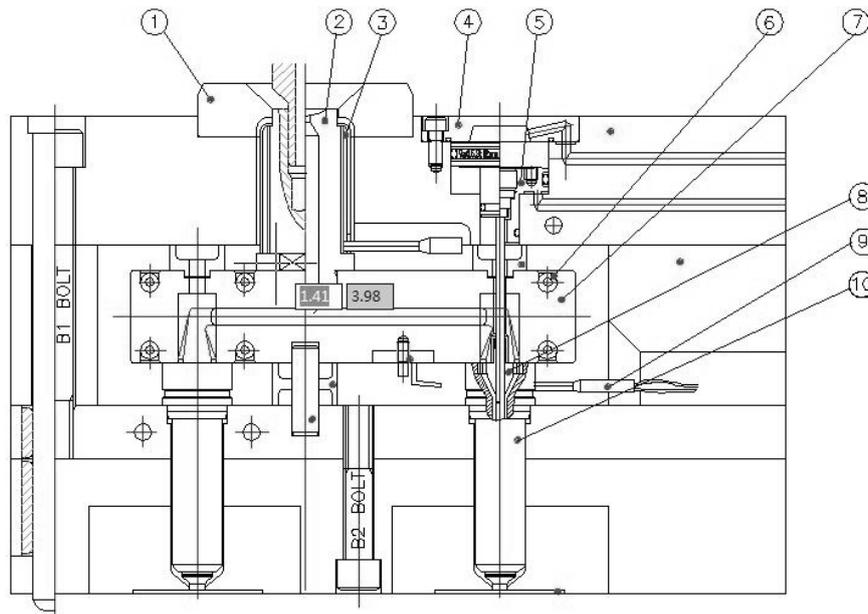


Fig.1 Svg Hot Runner System Structure

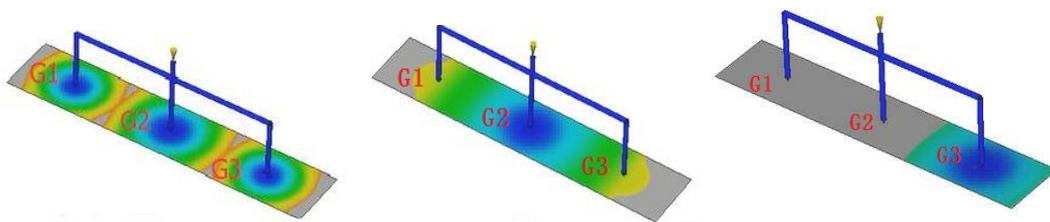
3. Sequential Valve Hot Runner Features

Compared with other types of hot runners, SVG has the following advantages in engineering applications: during the injection molding process, the materials in the runners will not always melt, the runners will not form, and there is no need to design the device to discharge materials. Compared with other systems, it has a larger nozzle gate channel, which can effectively reduce the filling time, reduce the molding cycle, and obtain higher production efficiency. The valve-controlled gate and the design of the return groove ensure the gate. When closed, no resin will remain on the surface, ensuring no casting marks on the surface of the product; it can effectively improve defects such as welding marks and shrink marks on the surface of large thin-walled plastic parts, and improve the surface quality of the product; it can also effectively reduce the clamping force and maintain the mold Filling balance, reducing process characteristics such as warpage of the product.

Of course, SVG hot runner also has some shortcomings that are not easy to solve: the implementation of technology requires precise regulation, such as the time sequence of gas / hydraulic devices, motion control; the effective control of the temperature of each section of the hot runner, and the cooperation between the gate valve needles Accuracy and other factors are the key factors that affect the molding. Therefore, there are very high requirements for operation and maintenance personnel; the pressure loss along the hot runner is relatively large, and a large injection pressure is required as a support, which places higher requirements on the injection molding equipment.

The molding CAE numerical simulation technology, through computer simulation of the plastic product molding process, provides a good basis for the subsequent design of high-quality molds and molding process parameters. CAE software is used to perform finite element modeling of the product, build product models, mold casting, and cooling structure models. Through flow simulation in the cavity, it can analyze and predict surface defects after injection molding of the product; through cooling simulation, it can analyze Predict the shrinkage and warpage of the product. These analysis results will guide the design and optimization of the product and mold structure. After the optimization, the improvement of the predicted defects will be further analyzed until the expected good product is obtained [5].

Take a long plastic piece as an example, as shown in Figure 2, using three-point hot nozzle injection, mold flow numerical simulation and simulation experiments using Moldflow software, first finite element modeling, hot runner process parameter settings and other operations Through the simulation of filling, understand the principle of sequential control of valve needle opening and closing in the hot runner.



(a) Simultaneous hot runner injection (b) SVG central diffusion sequential injection (c) SVG linear progressive injection

Fig.2 Moldflow Simulation Principle of Sequential Control Hot Runner

As shown in Figure 2 (a), in the conventional hot runner structure, three nozzle gates G1, G2, and G3 are injected at the same time. According to the filling simulation, the plastic flow front between gates G1 and G2 and G3 and G2 form a large Welding angle is expected to form welding mark defects. As shown in Figure 2 (b), the SVG structure is center-diffusion sequential injection. First open the G2 gate valve pin. When the plastic melt front passes through the G1 and G3 gates, open the G1 and G3 valve pins, and the G2 melt is integrated into the G1 and G3 interiors and pushed forward together until it fills the cavity. During the entire pouring process, no cold stream fusion will be formed, and no fusion mark defects are expected, which is suitable for forming large plastic products.

As shown in Figure 2 (c), the SVG linear progressive type, first open the G3 gate valve pin, when the melt front flows through G2, open the G2 valve pin instantly, G2, G3 melt flow to G1. When the leading edge of the melt flows through G1, the G1 valve pin is opened momentarily until the cavity is filled. The whole process, such as a relay race, sequentially opens the needle valve, and the material flow is transferred to complete the filling. No weld marks are produced. Suitable for forming long plastic parts.

4. Optimization of Injection Molding Process Based on Cae Numerical Simulation of Hot Runner Sequence Control

The appearance of the rear panel of this LED TV is a thin and shallow box structure with a thickness of 1.6 ~ 3.5mm, and its outer dimensions are: 920mm * 430mm * 73.8mm. It is selected from Taiwan Chi Mei's universal grade ABS, POLYLAC (ABS + PC). Model PA757 is a commonly used material for electrical enclosures. The main processing performance is shown in Table 1. The injection molding machine of China Haitian Company is selected, model: HTF3300X-B.

Table 1 Pa757 Material Performance Parameters

PROPORTIONg/c m3	SOLUTION TEMPERATU RE °C	MOLD TEMPERATU RE °C	DEMOLDING TEMPERATU RE °C	SHEAR RATE [1/s]	MAXIMUM SHEAR STRESSMPa	MOLDING SHRINKAG E %
1.05	180~240	30~70	84	100000	0.5	0.4~0.7

Table 2 Working Parameters Of Haitian Htf3300x-B Injection Molding Machine

SCREW DIAMETER (mm)	MAXIMUM INJECTION VOLUME (g)	INJECTION SPEED (g/S)	INJECTION PRESSURE (MPa)	CLAMPING FORCE (KN)	MOLD HEIGHT (mm)	EJECTION STROKE (mm)
215	39612	2121	135	33000	900~1900	500

According to product structure and process requirements, Moldflow geometry tools are used to create valve nozzles and runner structures. By determining the optimal gate and quantity, the initial plan determined to use 6-point glue. In order to ensure the pouring balance, the distance from the 6 gates to the entrance of the mainstream channel is consistent and arranged in parallel. As shown in Figure 2, the nozzles Structural modeling should be different from ordinary hot runners, because the valve nozzle has a valve needle in the middle, and the vertical runner section is a “ring” structure. First set the nozzle valve gate as the hot gate attribute. According to the actual hot runner selection, the shape is circular $D1 = 5\text{mm}$, named in order: G1 ~ G6. Set the vertical hot runner attribute and set the inner and outer diameter of the annular runner. It is: $D = 16\text{mm}$, $d = 5\text{mm}$; set the properties of the hot runner, with a diameter of 16mm; set the properties of the hot runner, the dimensions of the two ends of the cone are $d = 8$, $D = 16$; the length of each section is set according to the selected hot runner structure set.

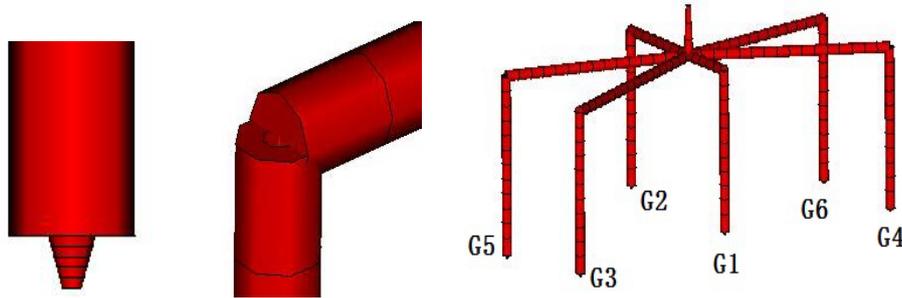


Fig.3 Svg Valve Gate Location and Runner Structure Modeling

By studying the results of the isotherm analysis of the filling, it was found that the initial design scheme was in the molding. When the gate of the G1 valve was opened, the plastic melt did not reach G5 during the injection process, and the isotherm was dense, indicating the flow resistance there Larger, the front melt stays, it is expected that when the G5 valve gate is opened, it cannot reach the position as scheduled, causing the melt to flow backwards and causing welding defects. As shown in Figure 3 (a).

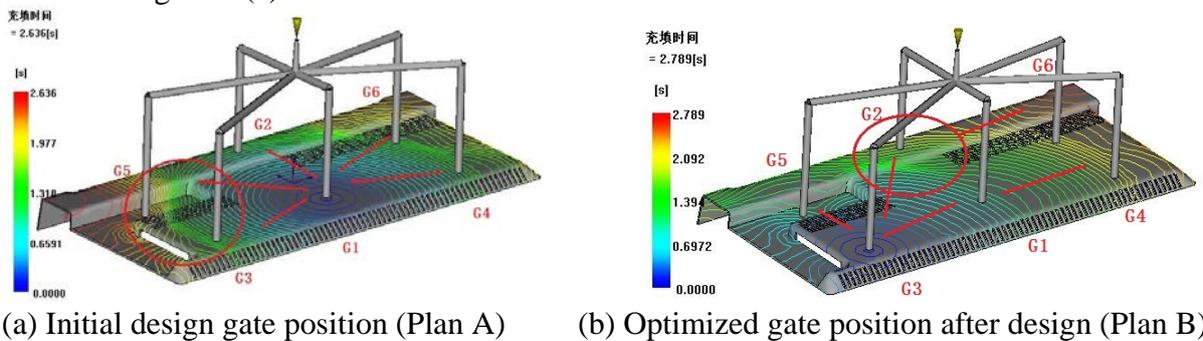


Fig.4 Analysis Results of Filling Time Isotherms

The reason is that the design concept of this runner system is the balance of the gates. When using the hot runner to sequentially control the pouring, the nozzles are opened sequentially and the relay is completed. It is necessary to maintain a close distance between the nozzles. The first

opening gate is too far away from the lower gate, which causes the material flow distance to be too long, leading to the stagnation of the front melt. In addition, the complexity of the structure of the plastic product itself will also lead to the complexity of the melt flow. The solution is to calculate the approximate melt flow distance between valve gates by calculating the melt flow rate, and then through CAE filling experiments, adjust the distance between the nozzles, and set a reasonable pouring position [6]. According to the above method, the gate position is adjusted as shown in Table 3.

Table 3 Svg Nozzle Position Adjustment Table

Gate	G1,G2	G3	G4	G5	G6
initial position (X,Y,Z)	initial position	(305,-175,0)	(290,-150,0)	(300,80,-25)	(280,30,0)
Adjust position (X,Y,Z)	No Adjust	(-200,-60,0)	(-225,-95,0)	(-200,-90,-25)	(-215,25,0)

After the gate position is optimized, the filling analysis is performed again to obtain a stable melt flow state. Based on this, the design and optimization of the structure of the SVG system and the mold runner are carried out.

Based on the hot runner valve gate 6-point injection, two valve gate opening schemes can be formed. Solution A adopts the center diffusion method, that is, the central gate G1 is opened first, and the plastic melt flows toward the other five gates at the same time. When the melt flows through a gate, the gate should be opened instantaneously, and then injected until Fill the cavity. As shown in Fig. 3 (a); Solution B: Linear progressive type, that is, the gate G3 on one side is opened first, the plastic melt flows to the gates G1, G2, G5 at the same time, and the plastic melts after the gates of G1 and G2 are opened. The body continues to flow to G3 and G4, and then the gates of G3 and G4 valves are opened until the cavity is filled.

The Moldflow valve gate controller is used to set the opening and closing time of each gate in the A and B schemes. Generally, the initial setting is that the plastic melt front reaches the valve gate, and the delay is 0.2 seconds to open. When numerical simulation is performed, the specific time of valve gate opening and closing is analyzed based on the flow state and displayed on the analysis log. Analysis of the main appearance indicators of the weld line results. It is expected that the location of the larger weld defects will be in the red line area, which will affect the surface quality and structural strength of the plastic parts. The remaining weld lines are small and distributed in the frame and the grille, without affecting the product. Surface aesthetics and strength. Compared with the common hot runner scheme, the two schemes A and B have significantly improved the weld mark defects, and the scheme B is slightly better than the scheme A, so the scheme B is preferred. As shown in Figure 4.

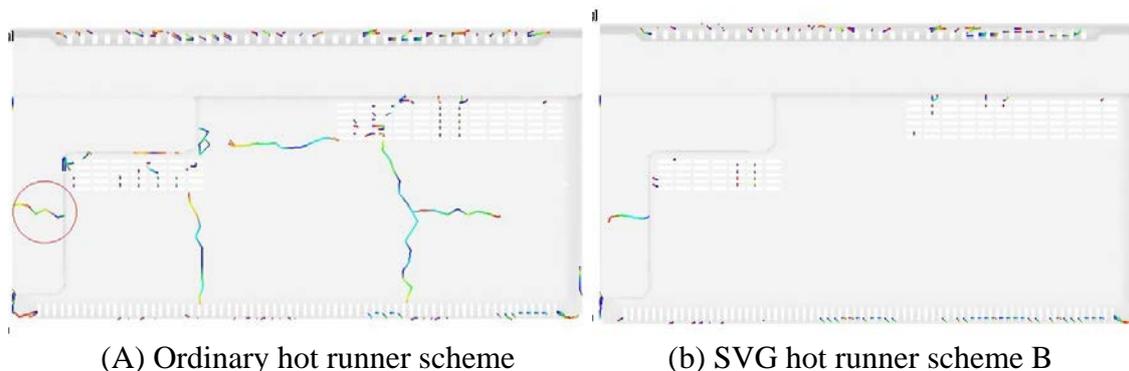


Fig.5 Comparison of Expected Fusion Lines of Various Schemes

Based on Figure 5, the melt flow trend is analyzed. The stream reaches this area and is divided into three streams, A, B, and C. As shown in Figure (a), after each flow, the branches A of A and B merge, and A2 and C fusion will form a weld line at the position shown in Figure (b). The flow diversion caused by the plastic part structure in this area is the main reason for the formation of weld lines. In scheme B, the first nozzle opened is G3 in this area, and the subsequent opening is G5,

so the welding line at 1 position is effectively eliminated, but the welding line at 2 positions cannot be avoided.

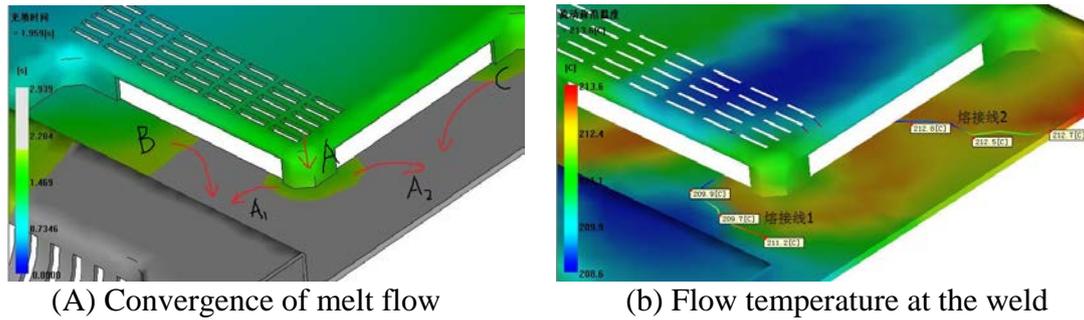


Fig.6 Analysis of Weld Line Formation

The method to solve the welding defects here is ① No treatment is performed. In the analysis, the welding line is only the appearance of the fusion of the melt angles. In the case of the high melt temperature at the front, as shown in (b), the melt temperature at the fusion is about 210°C, The melt temperature is close, which can ensure the effect of stream fusion, and theoretically no welding defects will occur. ② Locally heat the expected welding position. At present, local steam heating is often used for processing, but the mold design is difficult, and additional equipment needs to be added to increase production costs. ③ Start with the design of the cooling system, strictly control the cold water supply time in the area, and do not cool at the fusion time. This method can be used to adjust the waterway during the test.

Based on the above analysis ideas, the relevant time and sequence are continuously fine-tuned, and then Moldflow analysis is used to verify and obtain the optimal time control scheme, as shown in Table 4.

Table 4 Moldflow Needle Valve Opening Time Optimization

	G1(s)	G2(s)	G3(s)	G4(s)	G5(s)	G6(s)
Valve opening time (s)	0.93	1.71	0	1.61	0.90	1.76
Injection time(s)	5	4	5.5	4	5	4

5. Tryout Verification

In view of the properties of the household appliance of the rear panel of the LED TV, the requirements for the appearance and dimensional accuracy of the product

High, verify the improvement of the appearance quality of the rear panel of the LED TV after using the SVG control technology, and check whether the location and number of defects such as welding defects and sink marks are as expected. Based on this, make process adjustments and retest the mold.

On the injection molding machine, debug according to the process parameters set by Moldflow analysis. First adjust the injection balance by trial injection, pressurize after the balance, and set the flow rate to 600 cm³ / s, which is stable in the range of ± 10. After the injected plastic product stabilizes, take a sample and observe. Moldflow analysis is expected to show the location of weld marks and no defects. Because the difference between the leading edge temperature of the two merged melts is only 1°C and the leading melt temperature is 209°C, they are in a state of smooth fusion, so no welding defects occur as expected. G2 valve gate area does not have obvious welding defects. Analysis shows that it is closer to the G2 needle valve gate. It may be that the G5 valve port area has a complex gradient structure and the leading edge flows slowly. During the G2 valve needle opening time, Failure to flow to the G2 position causes the G2 stream recoil to merge with the G5 forward stream and form defects. For the adjustment of G2 opening time, G2 delayed opening is in line with the process requirements, so the time is set according to a 0.2s gradient, and a total of 4 parameters are set from 1.72 to 1.78, and the test die is punched to observe the

elimination of weld marks, which is more reasonable Needle valve opening period. After the trial mode adjustment, the optimized process parameters of the needle valve opening time are shown in Table 5.

Table 5 Optimization of Needle Valve Opening Time after Mold Test Verification

	G1(s)	G2(s)	G3(s)	G4(s)	G5(s)	G6(s)
Valve opening time (s)	0.93	1.76	0	1.61	0.90	1.76
Injection time(s)	5	4	5.5	4	5	4

6. Conclusion

Based on the molding CAE numerical simulation, the SVG mold structure is expected to be verified in terms of the number of gates, pouring points, hot runner selection, reserved dimensions, cooling circuit layout, water inlet selection, and insert materials, etc., and optimized accordingly. The mold scheme enables the organic combination of the mold structure and the molding process to achieve the ideal mold test state. Effectively shorten the mold design and manufacturing cycle, improve product quality, and reduce production costs.

Virtually build an injection molding process based on the molding CAE technology. Under the theoretical framework, from the analysis of plastic material performance, the choice of injection molding machine, the estimation of the molding cycle, the setting of the filling-holding pressure-cooling-warping parameters, and then SVG valve gate opening sequence and time are accurately set, and the scheme is compared and selected, which is a process of continuous modification and optimization of the molding process. In the test mode verification of the injection molding machine, adjusting the parameters of the injection molding machine in combination with the actual production is a further process optimization process. The final verification result reflects the excellent molding effect and good product quality.

Practice has proved that the molding CAE numerical technology and hot runner sequence control technology have good application value in molding such large-size, thin-shell plastic products that require higher appearance.

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