

# Hot Runner Mold Design of Fan Diverter Parts

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**Abstract.** In this study, we discuss the case of plastic parts for the production of fan steering gear shaft parts injection molding, and use POM plastic steel to produce plastic parts from traditional cold runners. Because of the parts have a hole, which need side slide. The runner produce more waste after plastic parts injection make the runner waste account for the cost is relatively high, the cost of stock preparation is relatively increased when the product quantity demanded is great. After the crushing treatment of the waste, the backfill will affect the quality, and in the crushing process, the volume generated will make the operator to withstand up to 130 dB of noise. The actual test results show that the production cycle reduce 6.25%, while the production yield increase by about 5% and material costs reduced by 2% . It can be recovered within a year, not to mention the increase of the quality and reduction the noise on the staff of the benefit is impossible to estimate.

## 1. Introduction

Traditional cold runner plastic injection molding, need more longer runner cooling time, the plastic loss of the runner and waste treatment, virtually reduce the efficiency and yield of molding, increase production costs. Use hot runner to conduct plastic injection production of mold, generally widely use the mode of large-scale components or multi-component molding [1], mostly still only used in 3C electronic products and high-priced parts [2], while the use environment of traditional mold is used for thin parts and multicavity molds(for example one mold eight cavity molds) such as a beverage cup. For the product of the large ratio of thickness and depth, its cooling speed shall be quick, or the front end has solidified, the latter section has not filled yet, so the plastic injection cycle shall be quick, and using hot runner can solve this problem.

If the length of general plastic pass the runner and the injection parts is relatively long, the temperature is more difficult to control, the product has the problem that the precision is difficult to control, is the opportunity to use hot runner, and the hot runner can shorten the cooling time and (multiple difference) can improve the yield. In the production process, the plastic kept at a constant temperature molten state for a long time [3], compared to the cold runner, the hot runner will not remain the waste in the cooled runner. Although the waste can

be reused after backfilling, however, there is a certain proportion of limitation of backfilling waste, cannot more than 20-25% of the part material, so as not to affect the quality is too large, and need to increase facility cost of waste treatment. The noise generated in the crushing treatment process of waste is up to 130dB, and it is an occupational injury to the health of the staff, and the heating electric energy that the hot runner need to increase itself is equal to the electric energy that the runner cooling



and waste treatment need, not increase the waste of the additional energy. So the production of hot runner compared to the traditional cold runner injection molding process can reduce about 20 to 25% of the waste, while no waste generated, so do not have to deal with waste, and will not produce noise due to dispose the waste.

But even if the hot runner is used that the production would not always be perfectly conducted, it cannot be produce for the inapplicable plastic fiber reinforced material, because contain-fiber may accumulate at injection port, and make the hot runner cannot inject. However the production cost of the mould of hot runner at early stage is more than 2~4 times of the cold runner, and its structure is relatively complicated and accurate, the maintenance of mold is relative difficult [4]. But at the beginning, although the cost of hot runner is much higher than that of the cold runner, but with respect to the sophisticated parts and costly components, such as the connecting plastic components using on the car, using hot runner is the economical choice.

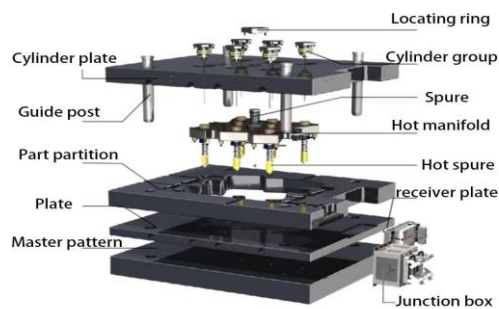
Currently, hot runner applications has more than 10 years , though already getting mature, but because of the substantial increase in mold production costs, the traditional industrial application of hot runner production is still small. In this paper ,we used the rotation shaft parts of traditional fan steering gear as the example as shown in Fig. 1, to investigate the niche of hot runner process production, because of its shape is similar to long shaft parts, the runner waste caused by mold arrangement account for the components material is up to 20%, in order to solve the related problem due to the waste disposal arising in the process of traditional cold runner, although the cost of hot runner mold is several times more than the traditional mold, general practitioner cannot accept, but if we have an in-depth understanding that we can know that using hot runner mold process assessment could save material fees, reduce costs of waste disposal, and avoid the damage to the staff of noise caused by crushing treatment of waste backfill and the deterioration of quality, it can also reduce the stress changes in hot and cold mold and extend the operation time. On the whole, the long run will be able to significantly reduce manufacturing costs and get better product quality, so that the degree of use of hot runner can easily accepted and promotion, which is the research motive of this article.

## **2. Hot runner system**

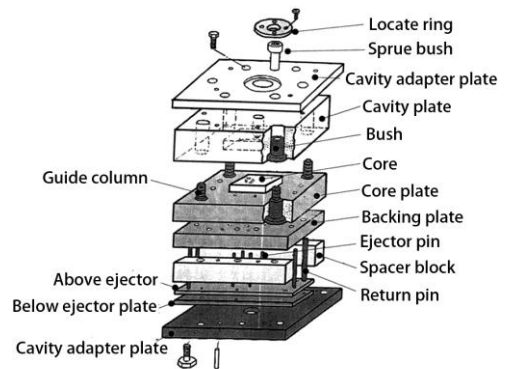
Hot runner is also called micro channel, and the overall system is shown in Figure 1 [1]. It means heating in the electric coil out of the runner tube after injection each time makes the plastic in the runner free of solidification without discharging the waste in the runner when demoulding. The plastic in the runner is not solidified, so the runner is still smooth when injecting next time [5].

As shown in Figure 2 [6], when the common mold uses the cold runner, the hot plastic encounters cold mold, which recues the plastic temperature and causes pressure drop under the friction loss so that when it is injected to the mold hole, the plastic mobility has become poor and caused poorer packing and pressure holding effect and further affects the shape, appearance, dimension precision and physical property of the finished product [7]. And the waste produced must be disposed for secondary processing by the waste machine, as shown in Figure 3 [8]. If hot runner technology is applied to the mold, the temperature of hot runner is the same as that of the nozzle of injection molding machine, so it avoids the condensation of plastic on the surface of runner. Moreover, there is no runner waste when using hot runner system, so it reduces the raw material consumption and thus reduces the product cost.

In the mold cavity, the temperature and pressure are even, the stress of plastic part is small and the density is even. Under the small injection pressure and within a short molding time, the better product is molded under such system than common injection molding system.



**Figure 1.** Hot runner explosion drawing



**Figure 2.** Traditional mold



**Figure 3.** Waste produced using traditional runner and waste treatment

### 3. Moldflow analysis of mold

Because of the parts have a hole, injection mold was limited by injection molding machine. Arrangement mode of one mold with eight holes. By using Moldex3D mold flow software, the paper analyses the packing, pressure maintaining and cooling of trial production in the mode of one mold with eight holes, predict the warping analysis of the product, observe the temperature analysis result of hot runner, optimizes the result so as to shorten the mold development and trial error process.

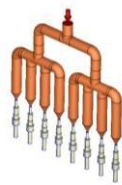
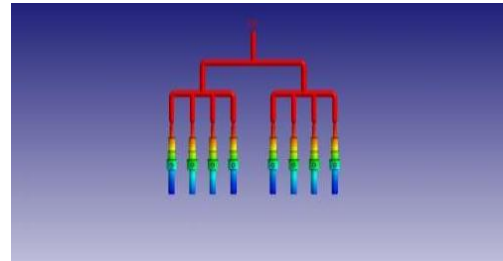
The material model is POM CELCON M90. The component is shown in Table 1 and the processing condition of the injection molding machine is shown in Table 2: the packing time is 1.54s, the injection pressure is 200MPa, the holding pressure is 200MPa and the cooling time is 22.4s. Through software analysis, the better packing time result is 1.564s, the holding pressure is 83.14MPa and the cooling temperature is 212.417 °C. The mold flow analysis results are shown in Figure 4 to Figure 8 and the design case is rational, which can provide practical production of mold.

**Table 1.** Material component table

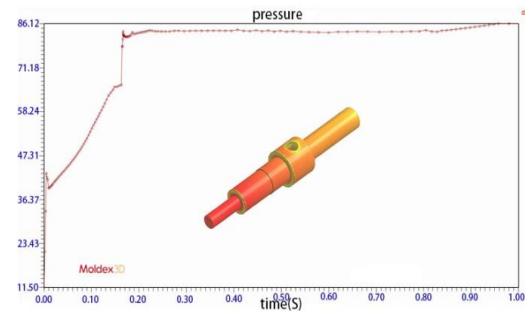
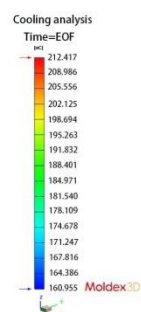
Items	Information
Material type	Thermoplastic
Material name	POM
Supplier	Celanese
Model	CELCON M90
T range	180-200(°C)
Mold T	60-100(°C)
Ejection time	135(°C)
Curing time	135(°C)

**Table 2.** Processing condition of injection molding machine

Items	Information
Filling time	1.5400(s)
Material T	190.0(°C)
Mold T	200.00(MPa)
Injection volume	58.5029(cc)
Holding time	11.0(sec)
Max holding P	200.0(Mpa)
Ejector T	134.8(°C)
Air T	25(°C)
Cooling time	22.4(sec)
Cycle time	40.0(sec)

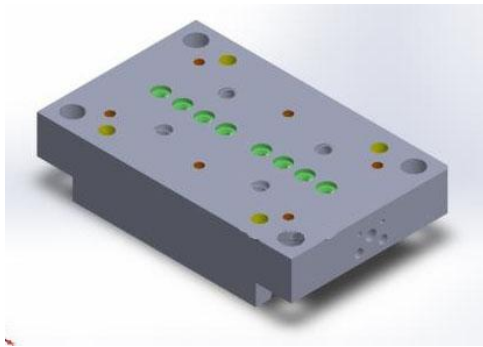
**Figure 4.** Arrangement mode of one mold with eight holes**Figure 5.** Packing analysis result

Enveloping position

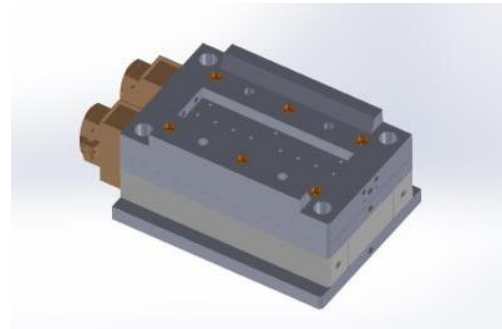
**Figure 6.** Packing analysis & enveloping position**Figure 7.** Pressure maintaining analysis0.0 20.0 mm  
10.0**Figure 8.** Cooling analysis

#### 4. Mold design and manufacturing

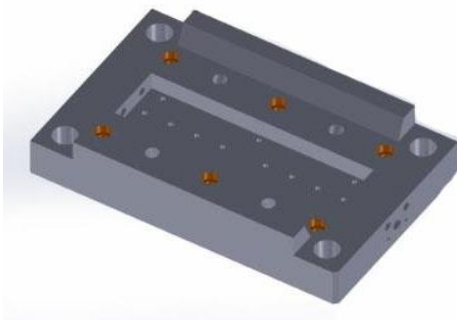
As shown in Figure 9 to Figure 12, the hot runner system diagram of one mold with eight holes, the same arrangement mode as the traditional mold is mapped by referring to the analytic result of mold flow software and using SolidWorks plotting software. After mapping, the mold flow analysis such as packing, pressure maintaining and cooling of runner should be carried out by using Moldex3D software.



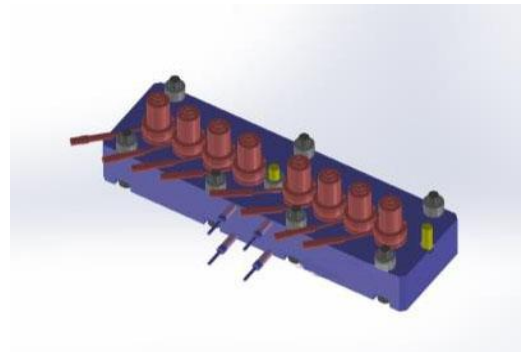
**Figure 9.** Male mold



**Figure 10.** Master pattern of mold



**Figure 11.** Prt partition

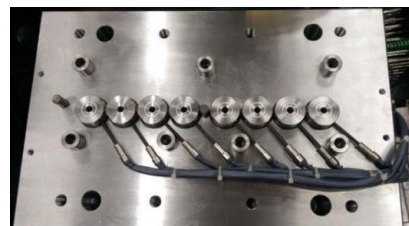


**Figure 12.** Ht runner plate

Taking the analysed parameters as reference for mold development can reduce the trial error process. The manufactured result is shown in Figure 13. to Figure 15.



**Figure 13.** Noumenon of mold



**Figure 14.** Part partition



**Figure 15.** Hot runner gate



## 5. Analysis and comparison

Using the Injection rate, holding pressure and holding time as experimental factor, each factor adopted 3 levels, used statistical analysis software minitab to conduct Taguchi statistics could obtain  $L_9$  ( $3^4$ ) orthogonal table, the combination of each experimental parameters repeated 3 times and conducted 27 experiments, and the injection and measurement results are as shown in Table 3.



**Figure 16.** injection Experiment

And then according to the injection experiment of plastic parts of experimental combination shown in Figure 16, due to the shape of the shaft is step-shaped and its number is large, it can't be detected by general projector, so chose flat head gauge at 0.01mm precision to measure the deflection on CNC, firstly using standard round bar with HSS TOOL  $\mu$ -class as the calibration benchmark of the base and the fixture, the deflection is in the  $1\mu\text{m}$ , after calibration, the measurement component of the Run Out value is shown in Figure 17 and Figure 18. And Run Out value of the shaft parts needed to measure is the smaller the better, is a smaller-the-better type characteristic.

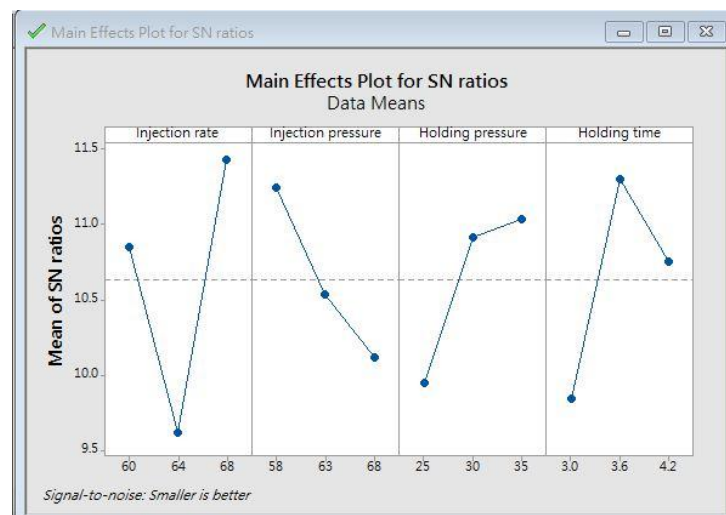


**Figure 17&18.** Instrument calibration

After experiment, get the SN ratios. And the optimal parameters of injection rate, injection pressure, holding pressure and holding time are 68mm/s, 58kg/cm<sup>2</sup>, 35% and 3.6 second respectively.

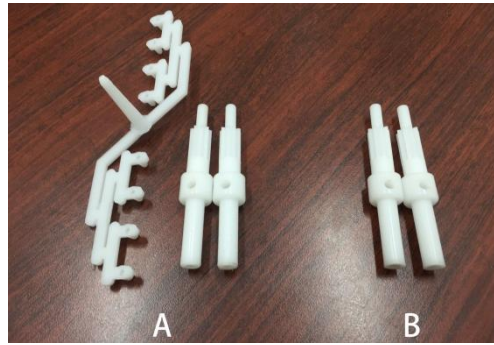
**Table 3.** Experiment parameters and SN ratios

No.	injection rate	injection pressure	Holding pressure	Holding time	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	SN
1	60	58	25	3.0	0.12	0.23	0.67	0.22	0.43	0.26	0.19	0.57	9.99
2					0.17	0.2	0.28	0.18	0.3	0.12	0.34	0.14	
3					0.16	0.18	0.19	0.35	0.16	0.27	0.64	0.29	
4	60	63	30	3.6	0.24	0.09	0.07	0.52	0.19	0.17	0.19	0.29	11.71
5					0.36	0.28	0.29	0.45	0.02	0.28	0.04	0.26	
6					0.22	0.25	0.36	0.03	0.18	0.32	0.25	0.11	
7	60	68	35	4.2	0.35	0.16	0.37	0.34	0.33	0.25	0.21	0.08	10.85
8					0.07	0.48	0.18	0.36	0.23	0.17	0.55	0.33	
9					0.32	0.2	0.21	0.15	0.12	0.38	0.17	0.25	
10	64	58	30	4.2	0.51	0.29	0.49	0.03	0.15	0.15	0.29	0.27	10.63
11					0.57	0.54	0.2	0.14	0.17	0.31	0.24	0.4	
12					0.01	0.15	0.25	0.17	0.31	0.23	0.06	0.06	
13	64	63	35	3.0	0.25	0.2	0.53	0.51	0.39	0.46	0.57	0.24	9.13
14					0.34	0.07	0.05	0.37	0.3	0.19	0.13	0.22	
15					0.09	0.16	0.52	0.2	0.48	0.22	0.53	0.43	
16	64	68	25	3.6	0.45	0.63	0.05	0.12	0.57	0.23	0.29	0.31	9.08
17					0.56	0.64	0.47	0.18	0.25	0.34	0.3	0.08	
18					0.37	0.25	0.01	0.12	0.02	0.24	0.3	0.42	
19	68	58	35	3.6	0.06	0.02	0.01	0.05	0.28	0.07	0.15	0.28	13.12
20					0.38	0.4	0.13	0.28	0.1	0.29	0.14	0.27	
21					0.22	0.12	0.2	0.14	0.39	0.3	0.01	0.17	
22	68	63	25	4.2	0.23	0.4	0.34	0.07	0.08	0.48	0.14	0.22	10.77
23					0.45	0.25	0.05	0.08	0.28	0.14	0.16	0.36	
24					0.57	0.01	0.23	0.27	0.37	0.12	0.24	0.43	
25	68	68	30	3.0	0.02	0.22	0.46	0.52	0.03	0.3	0.1	0.44	10.41
26					0.45	0.22	0.46	0.52	0.07	0.1	0.22	0.29	
27					0.08	0.01	0.18	0.14	0.19	0.26	0.26	0.5	

**Figure 19.** SN ratios

The injection molding of product using traditional cold runner needs longer gate cooling time, plastic loss of gate and waste treatment, which reduces the productivity and increases the cost. The waste produced in the gate can be recycled and mixed with new raw material for secondary injection molding and completing the consecutive processing work, but waste backfilling also affects the product quality and the maximum waste packing ratio cannot exceed 20% to avoid affecting the quality of plastic parts. Meanwhile, the noise produced in the treatment process is as high as 130

decibel, which affects operator's hearing seriously. In addition, the waste grinding process also needs additional energy and thus forms energy waste. Therefore, compared with the injection molding with traditional cold runner, the production using hot runner can reduce the waste by 20%-25% and thus reduces the noise of disposing the waste. The different is shown in Figure 19 and Figure 20.



**Figure 20.** (a) & (b) Parts and wastes produced by using traditional cold runner

## 6. Conclusion

The application and production of hot runner mold centers on large plastic parts or electronics parts with high unit price. The mold manufacturing cost is over two or three times than that in traditional form, so it is seldom applied to traditional home appliances with meager profit.

The manufacturing with hot runner system mold can increase the annual yield. The single production cycle of parts injected by the hot runner is shortened from the original 85s to 80s, with 6.25% shortened than the original production cycle. If one day is calculated as eight working hours, one mold with eight holes can increase 170 parts, the annual increased yield reaches over 45,000, and the increased capacity can reach over US\$3,900. Moreover, there is no waste produced and no need waste recycling, which enhances the production yield rate from 99.9% to 99.95%, while the production yield increase by about 5% and material costs reduced by 2% and reduces the noise greatly that operators don't have to bear the noise as high as 130 decibel.

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