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RESEARCH ON THE PROCESSING PARAMETERS OF MICRO-CONNECTOR BASED ON MICRO-INJECTION MOLDING

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Abstract- Micro injection molding process of micro-connector is analyzed in this paper. The orthogonal experimental method under various processing parameters is used in the micro injection molding process to decide the influence of the parameters. The weight of the micro part is selected as the judge standard of the filling condition. According to the analysis of the weight factor, the overall influence of the processing parameters, such as mold temperature, melt temperature, injection velocity, packing pressure, packing time, cooling time, is clarified. By drawing the change of the factors and levels, and influential factors resulted from the experiment results, the optimized process parameter scheme is obtained. The analysis shows that the mold temperature is the most important factor, and the cooling time is the least important factor. The proposed analysis method is verified by the experiment.
Key words - Micro-injection molding, Orthogonal experimental method, Experiment, Parameters, Mold temperature.

Introduction

With the increasing application of precision instruments and equipment, the mass-produced of the micro-connector become important. As an efficient mass product method, the micro injection is used in the industry widely. The micro injection is a multi-parameters project; the interaction of the parameters is very complex problem. How to decide the parameters of the micro injection is very important.

In this paper, an orthogonal experimental design method is proposed to decide the parameters of the micro injection process. Using the orthogonal experimental method can reduce the number of experiments and the waste of the experimental materials, save time and money, get enough accuracy simultaneously, produce optimal micro-injection products [4]. Then, the typical electronic element, micro-connector is selected to verify the proposed method. The weight is selected as the standard of the quality. The design of the micro-connector, the mold design, the mass product of the micro-connect are given in this paper.

Orthogonal Experimental Method

For a multi parameter process, how to decide the value of the parameter is a very complex problem. This problem exists in controller design, decision system and industrial process. In order to find the optimal value of the each parameter, the experiment cost so many time and money. For example, a process has five parameters and every parameter has three possible values. The number of the possible experiment is 3^5=243. And for some system, for example, the parameter is a continuous value, and the possible number of the experiment is infinity. The decision of the parameters is difficulty for those systems. Micro-injection molding process is a representative multi parameter process.

The orthogonal experimental is a statistics method for multi parameters project. The method arranges the experiment based on the orthogonal array. The orthogonal array balanced the parameters, and the optimized or sub-optimized values of the parameters are gotten by a few times of experiment. The parameter is sub-optimized values only, and is enough for industrial production.

Micro-injection molding process is a representative multi parameter process. The process includes many influential processing parameters of plastic micro-connectors. The parameters include mold temperature, melt temperature and injection velocity etc.al. For micro injection process, the parameters change continuously, it is impossible to do all the experiment to find an optimized parameter combination.

In this paper, the orthogonal experimental method is used for micro-injection molding process. The validity of the orthogonal experimental method is verified and the practical applicability of the orthogonal experimental method in micro-injection molding is proved.

The design of micro-connector

The micro-connector is used in this paper as an example. The design and experiment of the injection parameters is given in this paper and is used to prove the proposed orthogonal experimental method. The size of the micro-connector is 7*mm*×4*mm*×1.2*mm*. The sketch of the micro-connector is shown in Fig.1.

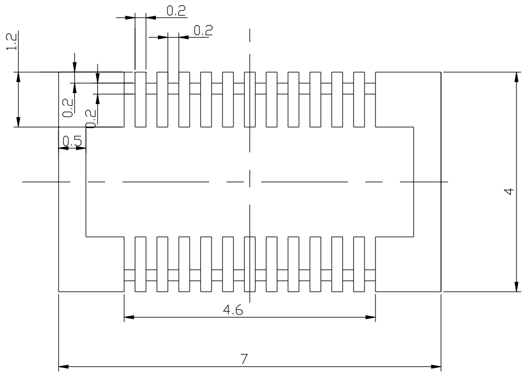

Fig.1 Schematic of micro connector structure

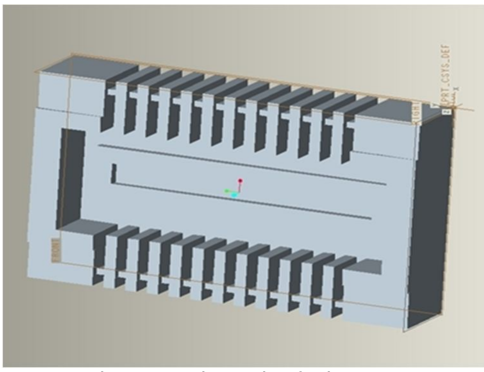

Fig.2 3D Schematic of micro-connector

Experimental design

There are many factors that affect the micro-connector. Six factors which affect the micro-injection molding process is selected, they are mold temperature(^{o}C), melt temperature(^{o}C), injection velocity(*mm*/*s*), packing pressure(*MPa*), packing time(*s*) and cooling time(*s*). Orthogonal table L25(56) is used, each factor has five levels with a total of twenty-five group of experiments.

Experimental levels are shown in Table.1. The experimental index is the weight of the micro-connector, with which to measure the process parameters whether reasonable. Because the weight of individual micro-part is very small, the weight of a single micro-part is not accurate. Here, five mold of each group of the micro-connector is measured, and each mold has four cavities, it is to say that each group has twenty micro-connectors. The weight of the twenty micro-connectors is measured and the average value is used in the evaluation.

Mold design and fabrication

The melt is injected into the cavity with a very high injection pressure and velocity, high mold temperature of the micro-injection molding is also important [1]. However, the higher mold temperature causes the longer cooling time, and also longer cycle time. The ideal situation is that wall temperature of the injection mold is higher than the glass transition temperature [2]. This will cause a shorter cooling time. Here,the oil cooling method is used to control the mold temperature.

Micro-connector mold which have four cavities in one mold is two-plate structure. Mold cavity processing take the micro-grinding combine with the micro-milling. The photo of the mold is shown in Fig.3.

Table.1 Factors and levels

Exp. No.	Mold temperature(A)	Melt temperature(B)	Injection velocity(C)	Packing pressure(D)	Packing time (E)	Cooling time (F)
1	1(70)	1(315)	1(85)	1(10)	1(1.0)	1(1.0)
2	1(70)	2(320)	2(90)	2(15)	2(1.5)	2(1.5)
3	1(70)	3(325)	3(95)	3(20)	3(2.0)	3(2.0)
4	1(70)	4(330)	4(100)	4(25)	4(2.5)	4(2.5)
5	1(70)	5(335)	5(105)	5(30)	5(3.0)	5(3.0)

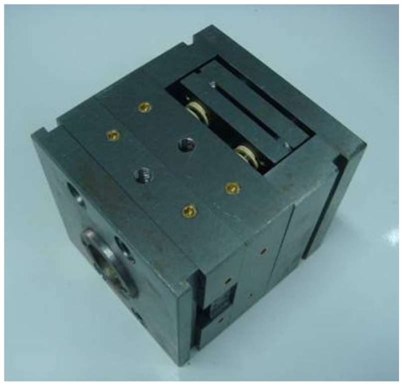

Fig.3 The photo of micro-connector mold

Materials and Equipment's

The experimental material is liquid crystal polymers (LCP) with the model of Zenitem 6130L. The model of the experimental micro-injection is TRO52EH, its screw diameter is 15mm and manufacturer is Japanese Sodick Corporation. The model of the Precision electronic balance which is used to measure the micro-part's weight is AR1140/C, its accuracy is 0.0001*g* and the manufacturer is OHAUS Company.

Experiment

The orthogonal experimental method is chosen to arrange the experiment, the concrete processes are:

(1) Determine the experiment target;
(2) Determine the influential factors and levels;
(3) Select the proper orthogonal table;
(4) Do the experiment based on the orthogonal table;
(5) Analyze the data of the experiment;
(6) Optimize the parameters;
(7) Determine the influential extent of each factor;
(8) Get a set of optimal parameters combination;
(9) Do the experiment to verify the optimal parameters combination.

Results of Experiment

Fig.4 is the photo, and Fig.5 is the SEM photo of the micro connector.

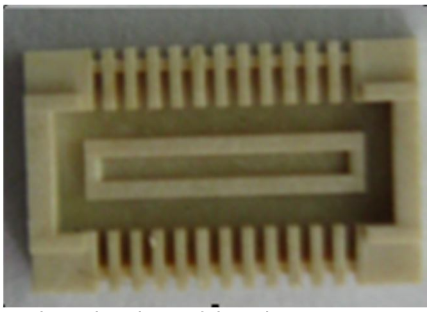

Fig.4 The photo of the micro connector

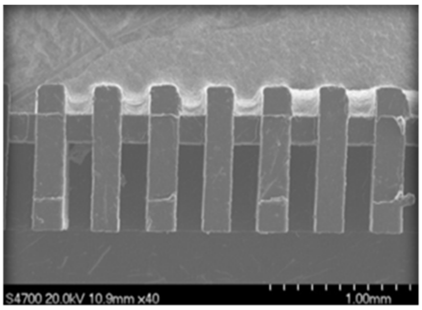

Fig.5 SEM photo of the micro connector

The Analysis of Experimental Results

The orthogonal experiment results are shown in Table.2. According to analyze the weight of the micro-connector, the optimal process parameters combination $A_2B_5C_4D_3E_2F_5$ is found. Finally, using the range method to analyze the prioritized order of the influential factors:

R_A =174.98-125.39=49.59;

R_B=175.35-145.055=30.295;

R_C =175.145-140.15=34.995;

R_D=175.15-143.645=31.505;

R_E =175.16-138.955=36.205;

R_F=175.00-145.13=29.87.

We can get $R_A > R_E > R_C > R_D > R_B > R_F$, the mold temperature has the largest range, which is the main factor, while the cooling time has the smallest range, which is the minimum factor in the six factors that affect the weight of the micro connector. The important extent of the factors is A, E, C, D, B, F. From Fig.6, A has the largest change and F has the smallest change.

From the tendency chart of factors and levels:

(1) Mold temperature select level 2, that is to say, the mold temperature is neither too low nor too high. If the mold temperature is lower, the material will be cooling without shaping, which will cause the surface of the micro-connector filling uneven. If the mold temperature is higher, the cooling time and molding cycle time will be increased, which will reduce the production efficiency.

(2) The higher the melt temperature causes smaller of the flow resistance and better of the melt flow.

(3) According to the principle of shear thinning, the greater of the injection speed cause smaller flow resistance of the fluid. However, in actual production, the larger injection speed will not benefit for the exhaust of the mold, while the larger shear force will make the degradation of the melt easily. The experimental results show that it is more reasonable to choose the level 4 for the injection velocity [9].

(4) Packing pressure chooses level 3, which indicate that the packing pressure is suitable. If the holding pressure is too small, the melt will be not completely filled and the density will be decreased. The bigger packing pressure causes bigger residual stress and longer molding cycle.

(5) Packing time choose level 2. If the packing time is too long, the strength of the micro-connectors will be reduced, which will cause the drawing of patterns difficult. At the same time, the nozzle is cool, and the next quality of the micro-part will be not guaranteed. If the packing time is too short, the micro-connector will emerge shrinkage cavities.

(6) Cooling time choose level 5, the productivity is improved by shortening the cooling time appropriately.

The micro-connector filling rate is the result of the comprehensive effect of process parameters. It isn't that the bigger of various process parameters are the better. We need through the molding process experiment to obtain the optimal level combination and then we can effectively improve the molding quality of the micro-connector.

Then calculate the variation sum of square of freedom of various factors, the index contribution rate of the experiment is obtained, as is shown in Table.3.

From table 3, the index contribution rate is as high as 32.23% through the change of the level of the mold temperature which is the most important factor affecting the experiment; the index contribution rate is 22.32% through the change of the level of the packing time which is the secondary factor; the index contribution rate is 18.72% through the change of the level of the injection velocity; the index contribution rate of the packing pressure, melt temperature and cooling time is between 9% and 10%.The order of the experimental index contribution rate is A> E>C> D> B> F.

Conclusions

The orthogonal experimental method is suitable for multi parameters project to set the parameters of the process.

According to the analysis of the range, variation and tendency charts, the influential order is obtained. The process parameters act on the experimental index, they are mold temperature, packing time, injection velocity, packing pressure, melt temperature, cooling time.

The optimal process parameters combination scheme of the micro-connector is $A_2B_5C_4D_3E_2F_5$. The weight of the micro-connector is the result of the comprehensive effect of the various process parameters, the process parameters is analyzed to obtain the more reliable optimal scheme combination, and then guide the actual production in order to ensure the product quality and improve economic efficiency.

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Table.2 The result of experiment

Number	A	B	C	D	E	F	W
1	A1=174.93	B1=156.83	C1=156.27	D1=162.19	E1=174.99	F1=145.13	T=795.975
2	A2=174.98	B2=155.98	C2=149.27	D2=157.74	E2=175.16	F2=157.11	
3	A3=158.09	B3=145.055	C3=174.99	D3=175.15	E3=144.38	F3=156.32	
4	A4=162.59	B4=162.77	C4=175.145	D4=157.26	E4=138.96	F4=162.42	
5	A5=125.39	B5=175.35	C5=140.31	D5=143.65	E5=162.49	F5=175.00	

Table.3 The results of variance analysis

Factors	Variation sum of square	Freedom	Index contribution rate（%）
A	462.7	4	32.23
B	108.99	4	7.6
C	268.81	4	18.72
D	143.17	4	9.97
E	320.42	4	22.32
F	131.78	4	9.18
Temperature (T)	1435.72	24	100

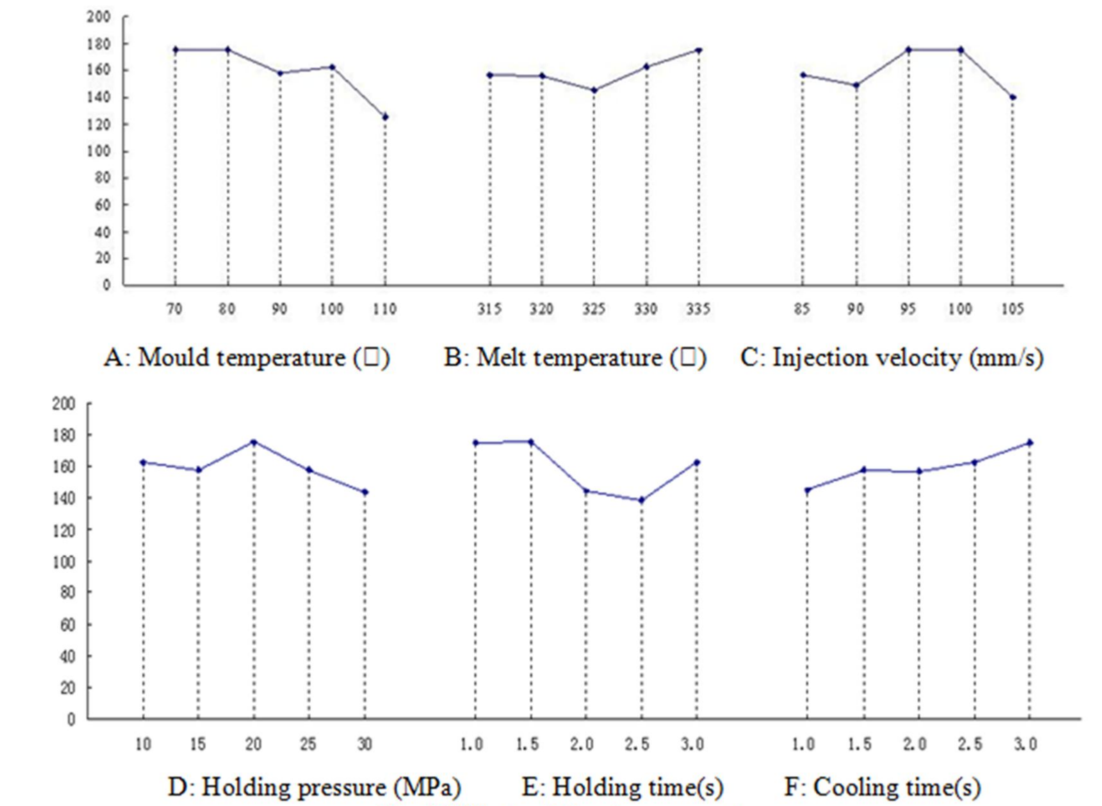

Fig 6 Effects of the six parameters