The Study of Injection Compression Molding of Thin-wall Light-guide Plates with Hemispherical Micro structures

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***Abstract*—Light-guide plate (LGP) is a key component of back-light modules in liquid crystal displays; warpage is one of the factors that affect the quality of LGP. Orthogonal simulation and experiment are used in this paper to study the effect of the injection compression molding (ICM) parameters, such as the melt temperature, injection speed, mold temperature, compression distance, and compression speed. Both the simulation and experiment show that the most important factor that affects the products' warpage is melt temperature. And the effect order of the parameters from the simulation analysis is melt temperature, injection speed, mold temperature, compression distance, compression speed, and the effect order from the experiment analysis is same to the simulation analysis. So the experiment results prove the simulation results.**

***Keywords* - ICM; Warpage; Light-guide Plates; Orthogonal Method; Parameters**

I. Introduction

Liquid crystal displays (LCD) have got a dominant position in the flat display field with the development of the LCD technology, the light guide plates whose function is to redistribute the light source energy over the planar surface is a key component of back-light modules which is an important component of liquid crystal displays [1-3].

The develop trend of light-guide plates is bright, thin and light, and the thin is important and difficult. For injection molding, when $L/t>150$, the products belong to thin-wall products. Here, L means the distance from the main runner to the farthest point of the products and t means the thickness of the products. Warpage is one of the key factors that affect the quality of LGP, and it is mainly caused by the different cooling, orientation and shrinkage. The direct reason is the different shrinkage that caused by different cooling, residual stresses and so on. Other factors that have influence on warpage mainly contain the structure of the mold, the properties of the material, the molding process condition and so on [4-13]. In this study, warpage is used to evaluate the quality of the LGP, and also an analysis of the micro structures' filling is done in the experiments. The molded part is a flat LGP, the length, width and thickness of the LGP is 48*mm*, 36*mm* and 0.3*mm* respectively. The micro structure on the surface of the model is hemispherical with diameter 100*um*, and the center distance of the micro structures is 200*um*, as shown in Fig.1.

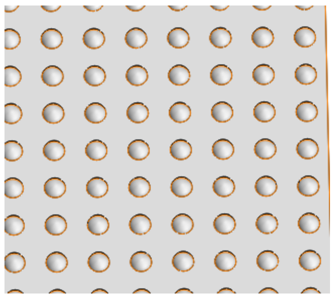
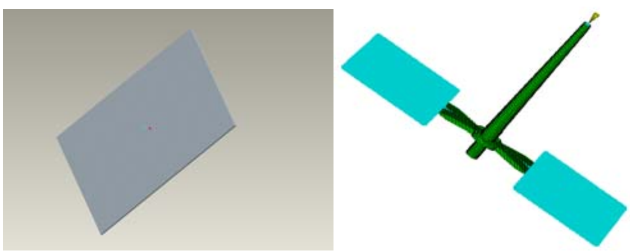


Fig.1 The micro structure

II. Simulation

A. Simulation Model

The modeling is shown in Fig.2. Fig.2 (a) shows the 3D model of the product. Fig.2 (b) shows the structure of the filling system which has a fan gate and a trapezoidal runner, the length of the main runner is 60mm.



(a)3D model of the products (b)The filling system

Fig.2 Simulation model

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B. *Simulation Material*

The Iupilon PC HL4000 is used in the simulation. As the *L*/*t* of the model is 187, the light-guide plates belong to thin-wall product. The main properties and recommend molding process parameters are shown in table 1.

TABLE 1THE PROPERTIES AND PROCESS PARAMETERS OF THE PC

Parameter	**Value**	**Unit**
Density	1.2	g/cm^3
Molten index	63	g/10min
Shrinkage rate	0.4-0.6	%
Dry temperature	120(4-8h)	℃
Melt temperature	280-340	℃
Mold temperature	80-140	℃
Injection pressure	50-150	MPa

C. *Selection of Orthogonal Factors*

Melt temperature, mold temperature, injection speed compression distance and compression speed are selected as the orthogonal factors. Table 2 shows the levels selected for each factor.

TABLE 2 EXPERIMENT FACTORS AND LEVELS

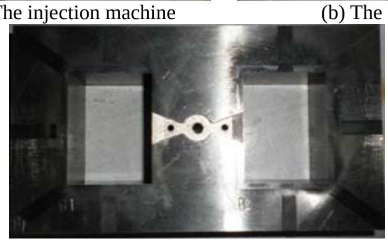
Factor		Level			
Factor code	Factor name	1	2	3	4
A	Melt temperature（ºC）	290	300	310	320
B	Injection speed （mm/s）	280	300	320	340
C	Mold temperature（ºC）	110	120	130	140
D	Compression distance（mm）	0.4	0.6	0.8	1.0
E	Compression speed（mm/s）	240	280	320	360

III. EXPERIMENT

A. *Experiment Equipments*

The Ecopower 55/130 of Battenfeld is used as the injection molding machine, and the injection compression mold is used in the experiment. The equipments are shown in Fig.3.

(a) The injection machine (b) The mold



(c) The moving die insert

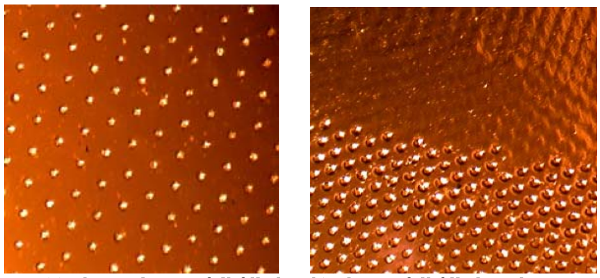
Fig.3 Experiment equipments

B. *Experiments Material and Orthogonal Factors*

Iupilon PC HL-4000 is used for the experiment and the orthogonal factors are same to the simulation.

C. *The micro structure of the products*

Iupilon PC HL-4000 is used for the experiment and the orthogonal factors are same to the simulation.



(a) The products is full filled b) The not full filled products

Fig.4 Micro structure of the products

The pictures of the micro structures of the products are shown in Fig.4. Fig.4 (a) shows the filling situation of micro structures whose cavity is fully filled, and the filling is very even. Fig.4 (b) shows the filling situation of micro structures that the cavity is not fully filled. From the picture, the material firstly filled the cavity, and then the micro structures.

IV. RESULTS AND DISCUSSIONS

Table 3 is the orthogonal experiments and their results of simulation and experiment. Table 4 is the mean value and range of the simulation and experiment.

TABLE 3 RESULTS OF THE ORTHOGONAL SIMULATION AND EXPERIMENT

Experiment number	A	B	C	D	E	Warpage	
						Simulation	Experiment
1	1	1	1	1	1	0.2396	0.272
2	1	2	2	2	2	0.2375	0.251
3	1	3	3	3	3	0.2384	0.267
4	1	4	4	4	4	0.2377	0.272

5	2	1	2	3	4	0.2060	0.203
6	2	2	1	4	3	0.2217	0.233
7	2	3	4	1	2	0.2153	0.224
8	2	4	3	2	1	0.2267	0.235
9	3	1	3	4	2	0.2006	0.202
10	3	2	4	3	1	0.2031	0.198
11	3	3	1	2	4	0.2268	0.238
12	3	4	2	1	3	0.2312	0.245
13	4	1	4	2	3	0.1743	0.168
14	4	2	3	1	4	0.1836	0.182
15	4	3	2	4	1	0.1967	0.191
16	4	4	1	3	2	0.2088	0.215

TABLE 4THE MEAN VALUE AND RANGE OF THE SIMULATION AND EXPERIMENT

Factor	A		B		C		D		E	
	Sim.	Exp.	Sim.	Exp.	Sim.	Exp.	Sim.	Exp.	Sim.	Exp.
Mean1	0.238	0.266	0.205	0.211	0.222	0.240	0.217	0.231	0.217	0.224
Mean2	0.217	0.224	0.211	0.216	0.218	0.223	0.216	0.223	0.214	0.223
Mean3	0.215	0.221	0.219	0.230	0.212	0.221	0.212	0.221	0.216	0.228
Mean4	0.189	0.189	0.224	0.242	0.208	0.216	0.214	0.225	0.214	0.224
Range	0.049	0.077	0.019	0.031	0.014	0.024	0.005	0.010	0.003	0.005

According to the range of the factors, the most important factor that affects the product's warpage is melt temperature and the effect order of the parameters from the simulation and experiment analysis is same.

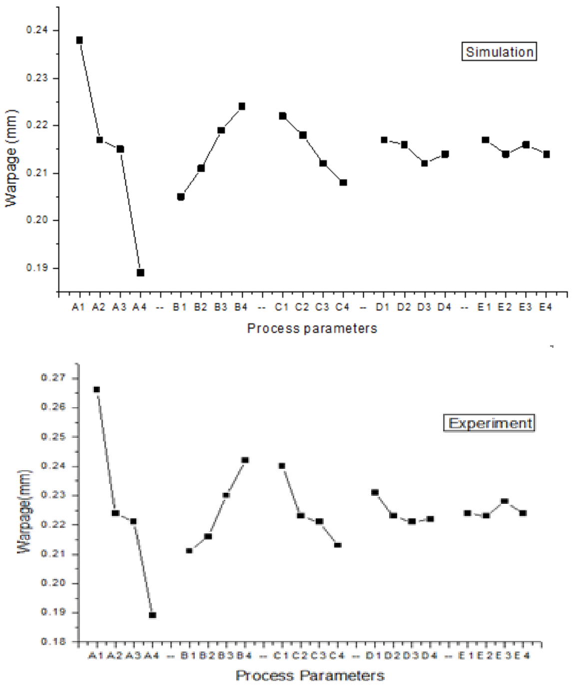


Fig. 5 The effect of the five factors on warpage

Fig. 5 shows the effect of all the five factors on the warpage of the light-guide plate. The effects of the parameters on warpage are listed as follows:

1) The effect of the melt temperature

It can be seen from the Fig.5 that with the increasing of the melt temperature, the warpage decreases clearly, it is mainly because of the good flow state that caused by the higher melt temperature, and the good flow state can reduce the shear stress as the melt flow and the internal stress caused by the uneven compression pressure. The warpage is mainly caused by the internal stress and the uneven shrinkage. So increasing the melt temperature to a certain extent can help to reduce the warpage of the products.

2) The effect of the injection speed

It can be seen from the Fig.5 that the warpage will increase as the increasing of the injection speed, it is mainly because that the thickness of the core is very small. During the process of injection, it may cause jet phenomenon which may cause the uneven distribution of the material before compression and the melt collision during the compression when the injection speed increases. So it is likely to cause internal stress. Therefore the greater the injection speed, the greater the warpage.

3) The effect of the mold temperature

The effect of the mold temperature on the warpage is similar with the melt temperature; the warpage will decrease as the increasing of mold temperature. It is mainly because that the melt will maintain a good flow state in a certain time which is good to decrease the internal stress of the product and the feeding during the compression process.

4) The effect of the other parameters

The compression distance and compression speed have a little effect on the warpage. It can be seen from the Fig.5, the best compression distance is 0.8mm which is about 2.5 times of the thickness of the products, the change of the compression distance increase the warpage. For compression speed, there is no obvious effect pattern and the effect is not obvious. It is mainly because that the thickness of the products is very small and the compression distance is very small too. From Fig.5, the best compression speed is 280mm/s.

V. CONCLUSIONS

The conclusion of this paper is given as follows:

(1) The main factor that affects the warpage of the products during the injection compression process is the melt temperature, the effect order of the parameters from simulation and experiment is melt temperature, injection speed, mold temperat- ure, compression distance, and compression speed.

(2) The best set of process parameter is A4B1 C4D3E2 with minimum warpage.

(3) The material firstly filled the cavity, and then the micro structures.

(4) In actual production, the melt temperature and the mold temperature should be increased in the allow range to get good quality for thin wall products.

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