한국기계가공학회지, 제20권, 제9호, pp. 20∼27(2021.09) ISSN 1598-6721(Print)
Journal of the Korean Society of Manufacturing Process Engineers, Vol. 20, No. 9, pp. 20~27(2021.09) ISSN 2288-0771(Online)

https://doi.org/10.14775/ksmpe.2021.20.09.020

Effect of Injection Molding Conditions of Effective Surface Properties of F-theta Lens

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사출 성형 조건이 에프세타 렌즈의 유효면 특성에 미치는 영향

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(Received 20 June 2021; received in revised form 16 July 2021; accepted 18 July 2021)

ABSTRACT

The effective surface of lens was studied for injection molding process and to enable mass production of f-theta lens, which is the primary component of laser printers and laser scanning systems. Injection molding is an optimal method if f-theta lens is frequently used for the mass production of plastic lenses as an aspherical lens that requires ultra-precision. A uniform injection molding system should be maintained to produce high quality lenses. Additionally, to maintain these injection molding systems, various factors such as pressure, speed, temperature, mold and cooling should be considered. However, a lens with the optical characteristics of an f-theta lens can be obtained. The effects of melting and cooling of plastic resin on the effective surface of f-theta lenses and the numerous factors that affect the injection molding process were studied.

Key Words : Laser Scanning Unit(레이저 스캐닝 유닛), F-theta Lens(에프세타 렌즈), Injection Molding(사출성형), Effective Surface(유효면), Mold(금형)

1. Introduction

Laser scanning systems of general printers and laser multifunction printers convert digital data to light information when data are transferred in the form of digital signals to these laser scanning units. Core components of laser scanning units include an f-theta lens, polygon mirror, cylindrical and collimator lens, laser diode, laser control circuit board, and case. Laser scanning units are operated by transferring light dots produced from a laser diode to a drum through proper light paths; this operation constitutes the most essential technology of these units. A collimating lens is used to transform a diffuse beam produced from a laser diode into a collimated beam by prevent

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ing diffuse beam scattering. To form an image of the collimated beam produced from the collimating lens on the surface of a polygon mirror, a beam produced from a cylindrical lens should be concentrated in a sub-scanning direction. The beam image produced from the cylindrical lens is formed on the surface of a polygon mirror through this process, and the beam is spread again and incident on the f-theta lens. The term “f-theta lens” was coined based on the principle that an angle of a polygon mirror and the tan value of focal length f are used to calculate the width of a diffuse beam on a drum. This aspheric lens requires high precision, and injection molding is frequently used to produce these aspheric lenses in large quantities. An injection molding system consists of the following: a resin dryer that can dry a plastic pellet; an injection molding machine that melts, fills, and compresses a certain amount of resin; a mold that has the shape of a lens; a temperature control unit that maintains constant internal and external temperatures of this mold: a self-driving robot to take out product; and an automatic resin supply unit. Performance of an injection molding system should be stably maintained to produce high-quality lenses that have desirable optical properties. Noh[1] designed a system of a laser scanning unit based on A3, and Yoo[2] analyzed the application of injection molding to an optical system of a laser scanning unit. Robert E[3] examined optical scanning, and Park[4] conducted a numerical analysis for applying injection molding to an aspheric lens used in an image pick-up unit. Accordingly, numerous studies[5~17] have been conducted to enhance the performance and properties of injection molding. This study analyzed the effects of injection molding on the properties of the effective surface of an f-theta lens.

2. Injection molding

Injection molding is a process in which resin is melted at a high temperature in a mold and cooled to form a specific shape. As high temperature and pressure generate stress in a lens during injection molding, these conditions are regarded as factors that hamper optical properties. In particular, f-theta lenses are thicker than general injected objects, and the thicknesses of these lenses are irregular. For this reason, hydraulic injection molding machines cannot overcome packing issues, thus frequently generating short shots. To solve this problem, this study used an electric hydraulic injection molding machine (sodic), which is shown in Fig. 1. Injection molding was also performed with a sufficient amount of packing time to prevent a short shot, and supportive devices such as an injection material dryer were utilized to minimize variables that might occur in the injection process.

Fig. 1 Injection molding process

Table 1 Injection molding conditions

No.	Specification
Clamping force	140 Ton
Screw size	ϕ40
Plunger size	ϕ40
Cavity No.	1*2
Shot weight	70.12 g
Cavity weight	24.39 g
Resin	Zeonex (Cyclo olefin polymer)
Color	Optical
Drying temperature	90 ℃
Filling time	17 sec
Cooling time	60 sec

Table 1 shows values established for basic conditions for an injection molding machine used to perform injection molding of an f-theta lens. These include the specifications of the machine, cavities, materials, and a filling time. First, values for the injection molding machine were established for the first cycle of injection molding. Injection molding was then conducted based on these established values, and the molding results were measured. In addition, values for the injection molding machine were adjusted for the second through fifth cycles. Injection molding was performed based on these adjusted values, and the results were measured to assess the effects of injection molding on the properties of the significant surface of the f-theta lens.

Table 2 lists the established values for the injection molding machine. The upper-limit pressure was fixed as 1500 kg/㎠, upper-limit time as 40 s, rotation rate for measurement as 50 %, amount of suck back as 2 mm, velocity ratio for suck back as 30 %, delay times for injection and measurement each as 0 s, purging velocity as 30 mm/s, number of purging iterations as 5, retreat time required for an injection unit as 0 s and overall delay time as 0 s. Values related to pressure, cooling time, and back pressure were adjusted based on the injection molding properties of the f-theta lens, and experiments were conducted based on existing and adjusted values for the first to fifth cycles.

Table 3 shows the set values associated with the change in mensuration. The reference values for the first, second through fourth, and fifth measurements were set as 46 mm, 65 mm, and 66 mm, respectively. As distance values for S1 to S8 differed in terms of measurement criteria, it was estimated that these differences in values may affect the quality of the f-theta lens.

Table 4 lists velocity-related values established according to value adjustments. These values were calculated according to the criteria for measurement and adjusted values. Tables 5 and 6 list packing pressure contents. As resin is injected, melted, and filled in a mold under high pressure, pressure is applied in a reverse direction. For this reason, great pressure is applied until melted resin becomes solidified. In this regard, packing pressure has significant effects on the injections of lenses used in optical systems. In this study, the reference value for packing velocity was set as 8 mm/s.

Tables 5 and 6 list values related to packing pressure time and packing pressure, respectively. Regarding the opening and closing of a mold, the capacity of the injection molding machine was established as 100 tons. In addition, clamping forces for the first to third and fourth to fifth cycles of injection molding were set as 50 % and 60 % of the entire ratio(100 %), respectively. Conditions for opening and closing of a mold were determined based on these set values, as shown in Table 7. To protect a mold, the upper-limit torque was set as 15 %, protection time as 5 s, comparative numerical value as 0.15 mm, and standard numerical value as 0.30 mm.

Table 2 Temperature change during injection molding

Item		Number of condition changes				
		1st	2nd	3rd	4th	5th
Limit pressure(kg/㎠)		1500	1500	1500	1500	1500
Limit time(sec)		40	40	40	40	40
Pressure(kg/㎠)		800	920	910	1000	1000
Time(sec)	Cooling time	100	100	100	120	100
	Down time	0	0	0	0	0
Mensuration	Trun ration(%)	50	50	50	50	50
	Back pressure (kg/㎠)	80	80	20	20	80
Suck back	Amount(mm)	2	2	2	2	2
	Speed(%)	30	30	30	30	30
Delay time (sec)	Injection	0	0	0	0	0
	Mensuration	103	103	103	103	103
Purging	Speed(mm/s)	30	30	30	30	30
	Count	5	5	5	5	5
Injection unit (sec)	Retreat time	0	0	0	0	0
	Delay time	0	0	0	0	0

Table 3 Setting according to change in mensuration

No	Mensuration(mm)				
	1st	2nd	3rd	4th	5th
	46	65	65	65	66
S1	8	20	20	20	20
S2	10	22	22	22	22
S3	20	28	28	28	28
S4	20	32	32	32	32
S5	35	45	45	45	45
S6	35	55	55	55	55
S7	44	60	60	60	60
S8	44	62	62	62	64

Table 4 Setting according to speed change

No	Speed(mm/s)				
	1st	2nd	3rd	4th	5th
S1	8	12	15	6	6
S2	8	12	15	6	6
S3	8	12	15	5	5
S4	8	15	15	8	8
S5	12	18	18	8	8
S6	12	18	18	8	8
S7	12	18	18	12	12
S8	12	18	18	12	12

Table 5 Setting according to holding pressure time

No	Time(sec)				
	1st	2nd	3rd	4th	5th
T1	40	45	70	45	35
T2	30	70	60	6	70
T3	20	35	35	35	30
T4	10	10	10	10	10
T5	0	0	0	0	10
T6	0	0	0	0	0
T7	0	0	0	0	0
T8	0	0	0	0	0
T9	0	0	0	0	0
T10	0	0	0	0	0

Table 6 Setting according to holding pressure

No	Pressure(kg/㎠)				
	1st	2nd	3rd	4th	5th
T1	800	920	910	1000	1000
T2	700	850	800	900	900
T3	600	700	700	850	850
T4	500	600	600	770	770
T5	0	0	0	0	650
T6	0	0	0	0	0
T7	0	0	0	0	0
T8	0	0	0	0	0
T9	0	0	0	0	0
T10	0	0	0	0	0

Table 7 Setting according to mold opening&closing

Item	Close			Open		
	S1	S2	S3	S6	S5	S4
mm	50	20	10	305	250	10
%	32.7	8.7	4.4	20	10	2

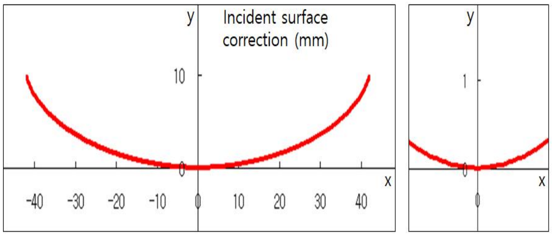
3. Results and Discussions

Research on injection molding is inevitably required to produce aspheric f-theta lenses in large quantities. Although injection molding is the optimal process for mass production, it can have negative effects on optical performance. The focus of this study was to analyze root mean square and peak to valley and the properties of a significant surface of an f-theta lens. Accordingly, it should be noted that the optimal values of root mean square and peak to valley for the core of a mold as derived from previous studies were applied as reference values in this study.

Figs. 2 and 3 show the first and second correction values for the incident surface, respectively, with Figs.

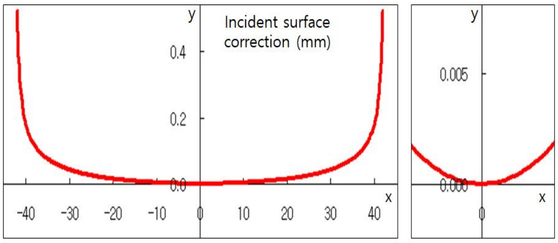
2(a)–(b) and 3(a)–(b) indicating the corresponding correction values for the flat surface and sides. Figs. 4 and 5 show the first and second correction values for the exit surface, respectively, Figs. 4(a)–(b) indicating the corresponding correction values for the flat surface and sides. These correction values were reflected in injection molding.

Figs. 6(a) to 10(a) and Figs. 6(b) to 10(b) show measured values for the incident and exit surfaces, respectively. Injection molding was conducted based on different conditions for injection molding of an f-theta lens. In the first cycle of injection molding, root mean square and peak to valley for the incident and exit surfaces were measured as 0.2155 ㎛ and 3.5988 ㎛ and as 0.2633 ㎛ and 4.1952 ㎛, respectively. The second to fifth cycles of injection molding were conducted based on the correction values. In the second cycle of injection molding, root mean square and peak to valley for the incident and exit surfaces were measured as 0.1895 ㎛ and 2.9156 ㎛ and as 0.2189 ㎛ and 3.9419 ㎛, respectively. In the third cycle of injection molding, root mean square and peak to valley for the incident and exit surfaces were measured as 0.1988 ㎛ and 2.5163 ㎛ and as 0.2774 ㎛ and 3.9748 ㎛, respectively. In the fourth cycle of injection molding, root mean square and peak to valley for the incident and exit surfaces were measured as 0.1855 ㎛ and 2.0495 ㎛ and as 0.2633 ㎛ and 4.1955 ㎛, respectively. In the fifth cycle of injection molding, root mean square and peak to valley for the incident and exit surfaces were measured as 0.1902 ㎛ and 2.6711 ㎛ and as 0.2165 ㎛ and 3.1953 ㎛, respectively. Through these measurement results, this study verified that root mean square and peak to valley for f-theta lenses can vary under different injection molding conditions. It is expected that the injection data obtained in this study can be effectively used for mass production of f-theta lenses.



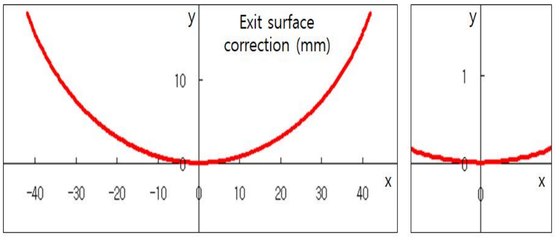
(a) Plan view (b) Side view

Fig. 2 1st correction of the incident surface



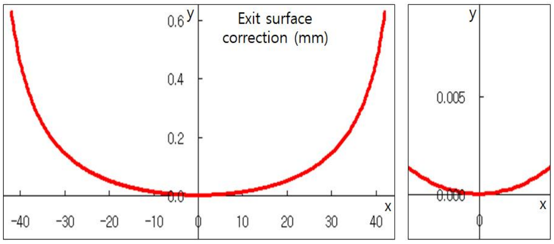
(a) Plan view (b) Side view

Fig. 3 2nd correction of the incident surface



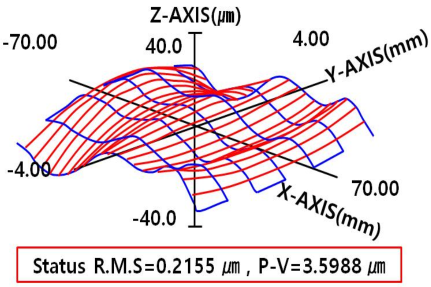
(a) Plan view (b) Side view

Fig. 4 1st correction of the exit surface

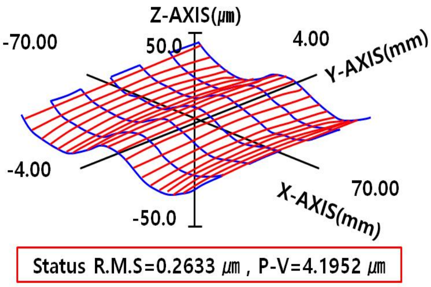


(a) Plan view (b) Side view

Fig. 5 2nd correction of the exit surface

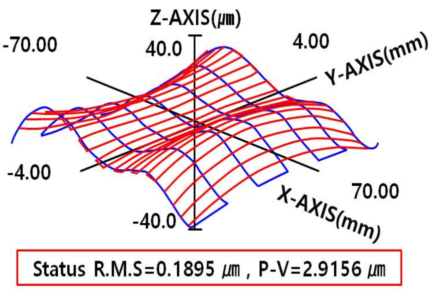


(a) Incident surface

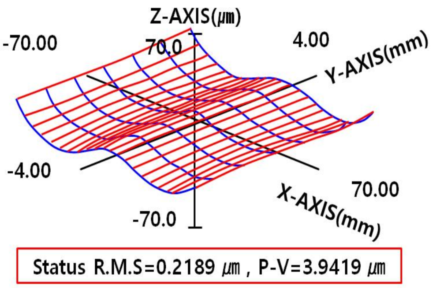


(b) Exit surface

Fig. 6 1st result injection of f-theta lens

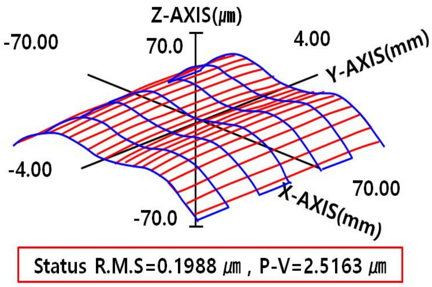


(a) Incident surface

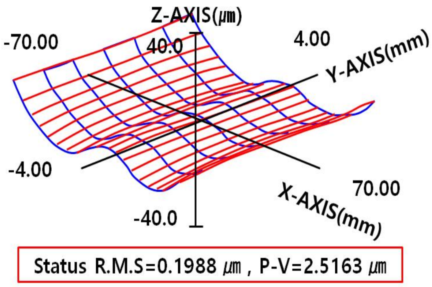


(b) Exit surface

Fig. 7 2nd result injection of f-theta lens

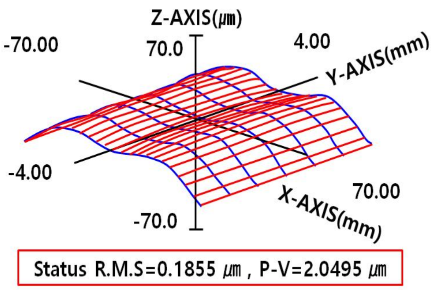


(a) Incident surface

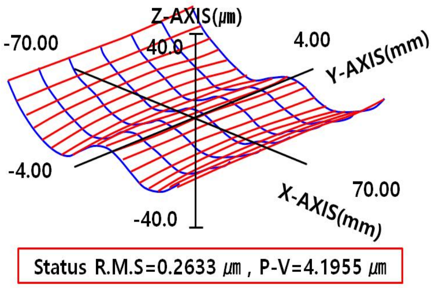


(b) Exit surface

Fig. 8 3rd result injection of f-theta lens

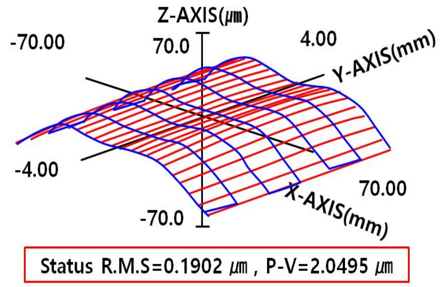


(a) Incident surface

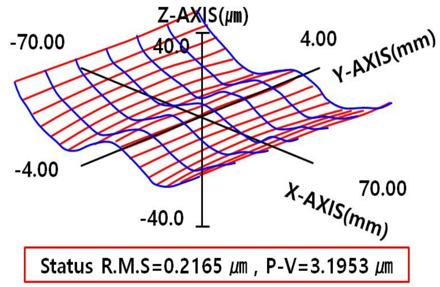


(b) Exit surface

Fig. 9 4th result injection of f-theta lens



(a) Incident surface



(b) Exit surface

Fig. 10 5th result injection of f-theta lens

4. Conclusions

This study analyzed the effects of injection molding conditions on root mean square and peak to valley to examine the optical properties of the significant surface of an f-theta lens used in a laser scanning unit. It is anticipated that data of injection molding for f-theta lenses can be used as a basis for enhancing the optical performance and mass production of f-theta lenses.

1. In the first cycle of injection molding for an f-theta lens, root mean square and peak to valley for the incident and exit surfaces were measured as 0.2155 ㎛ and 3.5988 ㎛ and as 0.2633 ㎛ and 4.1952 ㎛, respectively.
2. In the second cycle of injection molding for an f-theta lens, root mean square and peak to valley for the incident and exit surfaces were measured as 0.1895 ㎛ and 2.9156 ㎛ and as 0.2189 ㎛ and 3.9419 ㎛, respectively.
3. In the third cycle of injection molding for an f-theta lens, root mean square and peak to valley for the incident and exit surfaces were measured as 0.1988 ㎛ and 2.5163 ㎛ and as 0.2774 ㎛ and 3.9748 ㎛, respectively.
4. In the fourth cycle of injection molding for an f-theta lens, root mean square and peak to valley for the incident and exit surfaces were measured as 0.1855 ㎛ and 2.0495 ㎛ and as 0.2633 ㎛ and 4.1955 ㎛, respectively.
5. In the fifth cycle of injection molding for an f-theta lens, root mean square and peak to valley for the incident and exit surfaces were measured as 0.1902 ㎛ and 2.6711 ㎛ and as 0.2165 ㎛ and 3.1953 ㎛, respectively.

Acknowledgments

This study was supported by the Basic Science Research Program through the NRF of Korea (NRF) funded by the MEST (NRF-2020R1A2C1011958).

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