한국기계가공학회지, 제20권, 제6호, pp. 114∼120(2021.06) ISSN 1598-6721(Print)
Journal of the Korean Society of Manufacturing Process Engineers, Vol. 20, No. 6, pp. 114~120(2021.06) ISSN 2288-0771(Online)

https://doi.org/10.14775/ksmpe.2021.20.06.114

Effect of Injection Temperature Condition on Root Mean Square and Peak-to-Valley of F-theta Lens

Yong-Woo Park*, Seong-Min Moon**, Sung-Ki Lyu**,#

*Department of Convergence Mechanical Engineering, Gyeongsang National University
**School of Mechanical & Aerospace Engineering, Gyeongsang National University

사출온도조건이 에프세타 렌즈의 표면조도와 표면형상에 미치는 영향에 관한 연구

박용우*, 문성민**, 류성기**,#

*경상대학교 대학원 융합기계공학과, **경상대학교 기계항공공학부

(Received 17 January 2021; received in revised form 29 January 2021; accepted 31 January 2021)

ABSTRACT

This study is focused on the root mean square and peak-to-valley based on the injection conditions of the f-theta lens, one of the main components of laser printers and laser scanning systems. The f-theta lens of an aspherical plastic lens requires ultra-preaction. Injection molding is typically used for the mass production of aspherical plastic lenses. In the injection-molding method, the resin in the lens shape is filled with the resin after melting the plastic pellets at a constant temperature and then cooled. It is necessary to maintain a uniform injection molding system to produce high-quality lenses. These injection-molding systems are influenced by different factors, such as pressure, speed, temperature, mold, and cooling. It is possible to obtain a lens that exhibits the optical characteristics required to achieve harmony. We investigated the root mean square and peak-to-valley caused by variations in temperature, a critical parameter in the melting and cooling of plastic resins generated inside and outside the injection mold.

Key Words : Laser Scanning Unit(레이저 스캐닝 유닛), F-theta Lens(에프세타 렌즈), Injection(사출성형), Root Mean Square(표면조도), Peak to Valley(표면형상)

1. Introduction

The laser scanning system of the laser copy machine or laser printer plays a role in delivering the digital signal of a computer to the laser scanning unit and converting digital data to light information. The key components of the laser scanning unit include the f-theta lens, polygon mirror, cylinder lens, collimator lens, laser diode, laser regulating circuit board,

Corresponding Author : sklyu@gnu.ac.kr
Tel: +82-55-772-1632, Fax: +82-55-772-1578

and case. The key technology in the laser scanning unit is to deliver the photo dot coming from the las er diode to the drum through an accurate optical pat h. A collimator lens is used to prevent the scatterin g of the diffused beam coming from the laser diode and convert it to a parallel beam. The beam coming from the cylinder lens is gathered in the sub-scannin g direction to form an image on the polygon mirror face, and the beam is then diffused again and is ma de incident on the f-theta lens. The f-theta lens is n amed thus because the width of the diffusing beam to the drum is determined by the tangent value of t he polygon mirror angle and focal distance f. This f -theta lens is a aspherical plastic lens that demands high precision. The injection molding method is wid ely used for the mass production of the aspherical p lastic lens. The injection molding system is compose d of a resin drying device that dries plastic pellets; an injection molding machine that melts, charges, an d compresses a certain amount of resin; a mold in t he shape of a lens; a temperature adjusting device t hat keeps the internal and external temperature of th e mold constant; an unmanned ejection robot that a product; and a resin self-feeder. To produce a high-quality lens, the uniform injection molding system must be maintained constant to obtain the lens with desirable optical characteristics. Noh studied the syst em design of a laser scanning device using A3[1], Y oo conducted the research on the injection molding of the laser scanning unit optical system[2],RobertEco nductedtheresearchontheoptimizedscanning[3],and Park conducted the research on the numerical analysis of the injection molding of the aspherical lens for the photo pickup device[4].A part from these studies, nu merous researchers have been continuously performin g various studies for improving the performance(Roo t mean square, Peak to Valley etc.) and characteristi cs(Injection temperature, Injection mold condition et c.)[5–10]. In this study, the characteristics of the f-thet a lens under different temperature conditions of the injection molding were investigated.

2. Mold Design and Production

2.1 Mold Design

The mold material, relation between the top and bottom as well as the air vent of a lens, and gas vent act as im portant factors for the mold design used in molding a len s. The lens shape is not molded because gas cannot be e mitted form the mold. Moreover, eccentric tolerance, tiltin g tolerance, and thickness tolerance are the optical charact eristics that must be considered during lens mold producti on. For these, a precise processing machine, rather than a general processing machine, is used as a molding processi ng machine. For the f-theta lens, the mold base and asph erical core were designed to obtain the desired optical per formance. For the high-precision large-scale aspherical len s, demonstrating the optical performance and reproducibilit y of the mold is a highly difficult technology and require s an improvement in performance. In particular, a limit de sign that predicts the mold ability and defect of the lens should be conducted. Through the design quality check, th e production efficiency can be augmented. Fig. 1 presents the blueprint showing the shape of the f-theta lens. An f-t heta lens is a free curved surface aspherical lens in whic h the center part is thick whereas the outer part is thin. Therefore, it is predictable that its machinability and injec tion mold ability would be undesirable.

Fig. 2 shows the mold for molding the f-theta lens. The two-cavity parallel structure method was used for the space use and improvement of productivity.

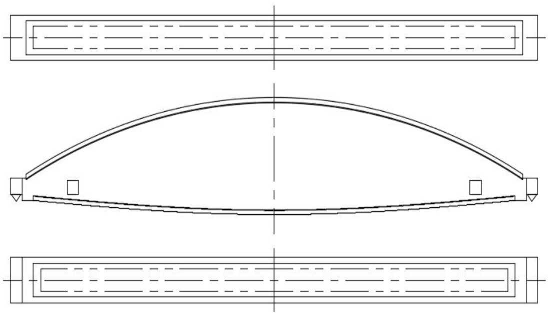


Fig. 1 Design of f-theta lens

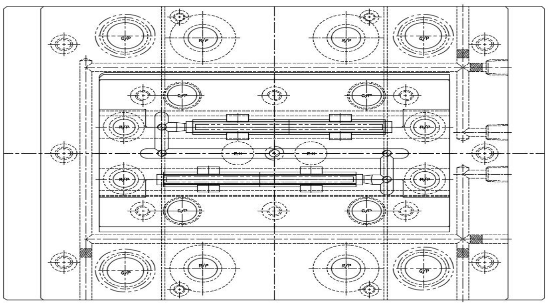


Fig. 2 Mold drawing of f-theta lens

Fig. 3 Mold design of f-theta lens

2.2 Mold production

Because the contraction of material occurs after inserting the lens material into the core of the mold and passing through the cooling procedure, the mold should be designed considering this contraction based on the mold and core blueprints. The f-theta lens mold and core manufactured following such procedure are presented in Figs. 3 and 4.

3. Injection Molding

Injection molding is a process in which the resin melted at high temperatures in the mold is subjected to a cooling stage, and its shape is materialized. In the injection molding, the high temperature and high pressure result in stress inside the lens, consequentially hindering the optical characteristics of the lens. The injection molding was performed using the injection machine (Sodick) depicted in Fig. 5, and the injection was performed by changing the temperature of the injection molding as tabulated in Table 1. Fig. 6 presents an output, that is, two-cavity f-theta lens

Table 1 Basic conditions for injection molding

No.	Spec.
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 e48r (Cyclo olefin polymer)
Color	Optical
Drying temperature	90 ℃
Filling time	17 sec
Cooling time	60 sec

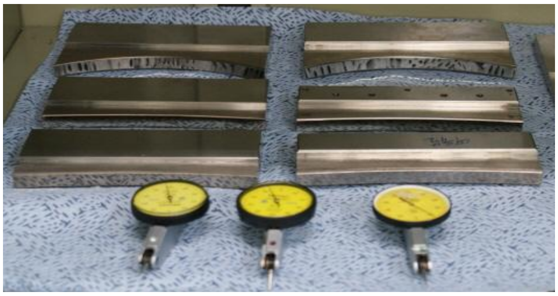


Fig. 4 Mold core of f-theta lens

Fig. 5 Injection molding process

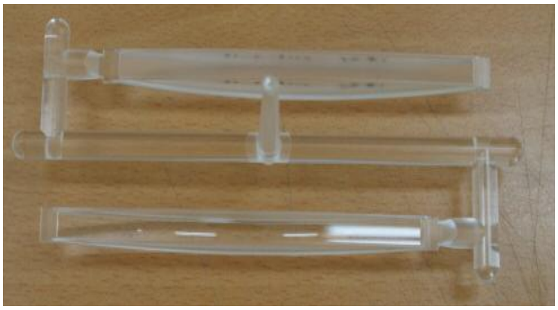


Fig. 6 Injection of f-theta lens

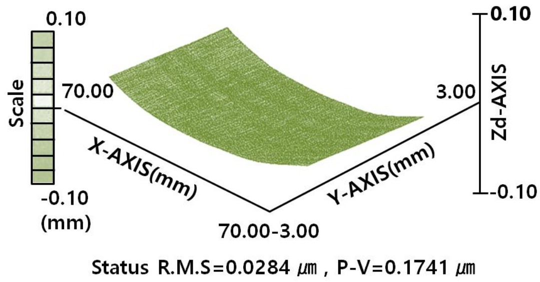
4. Results and Discussion

To produce the f-theta lens considering the mass productivity of the aspherical lens, the correlation between the surface roughness and surface shape of the f-theta lens under different injection molding temperatures was investigated. Figs. 8 (a) and (b) demonstrate the measurement results of the plane of incidence and that of the reflection of the f-theta lens mold core, respectively. The surface roughness of the core plane of incidence was 0.0284 ㎛, and the surface shape was processed to be 0.1741 ㎛, whereas the surface roughness of the core plane of reflection was 0.0387 ㎛, and the surface shape was measured to be 0.1988 ㎛. Unlike general jets, the thickness of the f-theta lens is not constant and high; hence, the high pressure cannot be held using the hydraulic injector, and molding cannot be completed. To overcome these challenges, an electric hydraulic injector was used in this study.

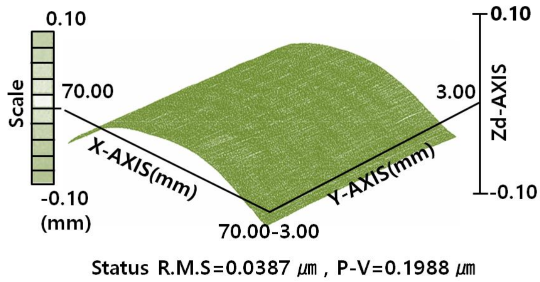
A sufficient pressure holding time was provided to ensure complete molding, and auxiliary equipment such as an injection material dryer was fully equipped to minimize the issues that could occur during the injection. Table 2 tabulates the sensor values with different temperatures. Based on the results, its effect on the f-theta lens injection was investigated. The sensors were attached on two spots on the upper left side, one spot on the right side, three spots on the lower left side, and the mold for measuring the temperature. As shown in Figs. 9 to 13, the surface roughness of the plane of incidence was measured by changing the f-theta lens injection molding conditions, and the surface roughness was observed to be 0.1542 ㎛, 0.1748 ㎛, 0.1655 ㎛, 0.1422 ㎛, and 0.1951 ㎛. The measurement results of the surface roughness of the plane of reflection were 0.1321 ㎛, 0.5987 ㎛, 0.4984 ㎛, 0.2731 ㎛, and 0.3086 ㎛. Similarly, the surface shape of the plane of incidence was measured at 2.9325 ㎛, 2.8694 ㎛, 3.0159 ㎛, 2.7125 ㎛, and 3.5215 ㎛, and that of the plane of reflection was processed to be 2.2984 ㎛, 4.8215 ㎛, 3.9589 ㎛, 1.1932 ㎛, and 2.1097 ㎛, based on the measurement values. The results demonstrated that the surface roughness and surface shape values of the f-theta lens varied depending on the temperature in the injection molding conditions. Such injection data are expected to be helpful for the mass production of the f-theta lens.

Table 2 Temperature change during injection molding

No.		Sensor position						
		1	2	3	4	5	6	7
1	Injection temp.	148	155	147	139	145	152	144
	Cooling temp.	148	155	147	139	145	152	144
2	Injection temp.	148	155	147	139	145	152	144
	Cooling temp.	132	133	130	128	130	131	131
3	Injection temp.	148	155	147	139	145	152	144
	Cooling temp.	136	137	134	131	134	136	135
4	Injection temp.	148	155	147	139	145	152	144
	Cooling temp.	136	149	131	130	132	147	135
5	Injection temp.	148	155	147	139	145	152	144
	Cooling temp.	136	149	131	130	132	147	135

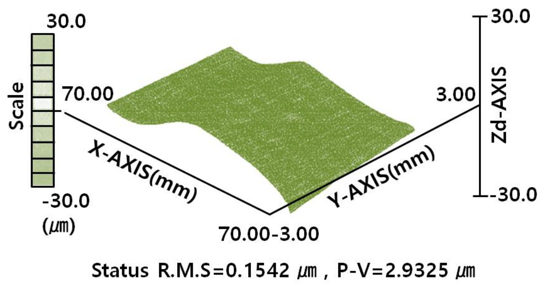


(a) Incident surface

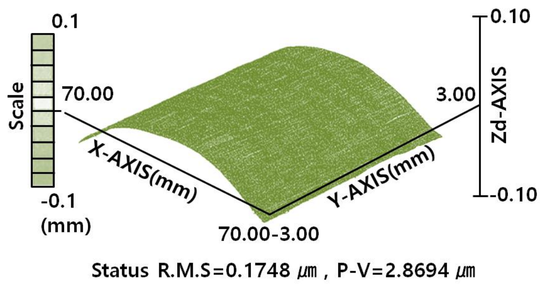


(b) Exit surface

Fig. 8 Result of f-theta lens core

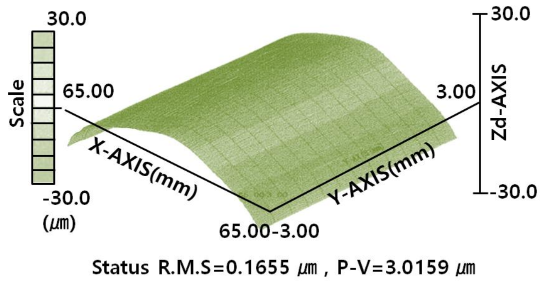


(a) Incident surface

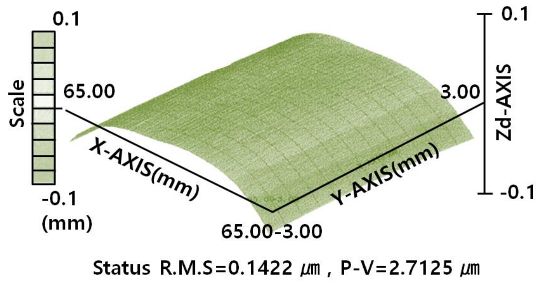


(b) Exit surface

Fig. 9 1st result injection of f-theta lens

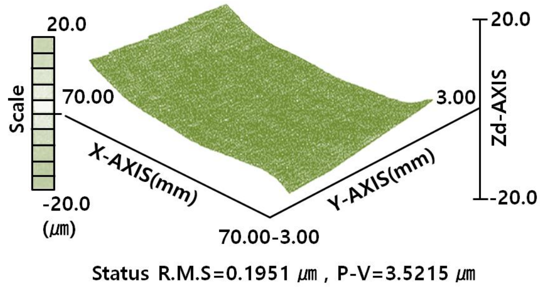


(a) Incident surface

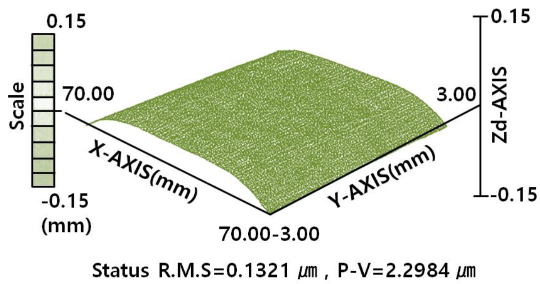


(b) Exit surface

Fig. 10 2nd result injection of f-theta lens

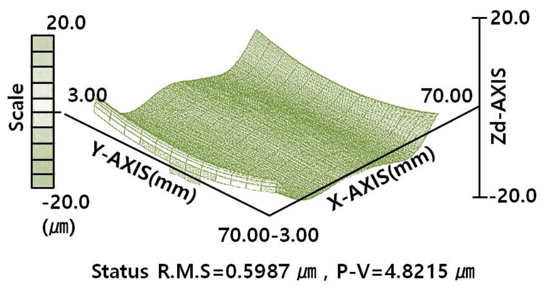


(a) Incident surface

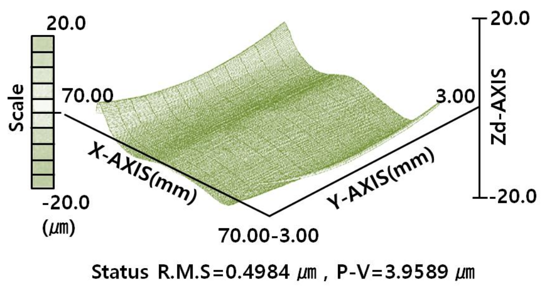


(b) Exit surface

Fig. 11 3rd result injection of f-theta lens

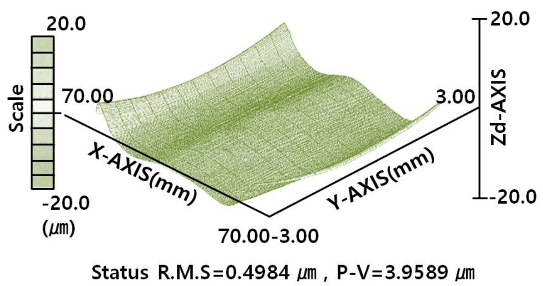


(a) Incident surface

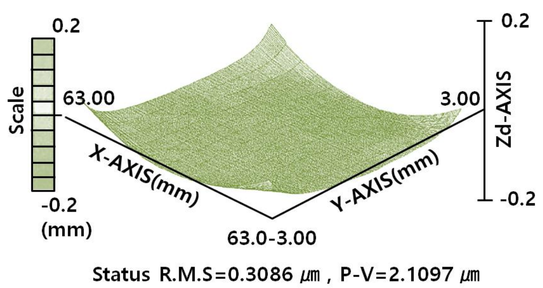


(b) Exit surface

Fig. 12 4th result injection of f-theta lens



(a) Incident surface



(b) Exit surface

Fig. 13 5th result injection of f-theta lens

5. Conclusions

In this study, it was identified that during the injection molding of the f-theta lens of the laser scanning unit, the surface roughness and surface shape of the mold core were affected by the change in the injection temperature condition. Based on the data obtained in this study, the performance fo the f-theta lens optical system will bo improved and its mass production will be reviewed at a later date.

1. The surface roughness of the incident surface of the mold core of the f-theta lens was measured at 0.0284 ㎛, and the surface shape was measured at 0.1741 ㎛. It was confirmed that this value satisfied the standard value within the range of 0.06 ㎛, which is the standard value of the surface roughness of the aspherical lens, which is the standard of the aspherical lens, and 0.3 ㎛, which is the standard value of the surface shape.
2. The surface roughness of the exit surface of the mold core of the f-theta lens was measured at 0.0387 ㎛, and the surface shape was measured at 0.1988 ㎛. It was confirmed that this value satisfied the standard value within the range of 0.06 ㎛, which is the standard value of the surface roughness of the aspherical lens, which is the standard of the aspherical lens, and 0.3 ㎛, which is the standard value of the surface shape.
3. The surface roughness of the incident surface due to the temperature change, which is the injection molding condition of the f-theta lens, was measured at 0.1542 ㎛ for the 1st, 0.1748 ㎛ for the 2nd, 0.1655 ㎛ for the 3rd, 0.1422 ㎛ for the 4th, and 0.1951 ㎛ for the 5th. It was confirmed that this value affects the surface roughness of the f-theta lens depending on the temperature.
4. The surface roughness of the exit surface due to the temperature change, which is the injection molding condition of the f-theta lens, was measured at 0.1321 ㎛ on the 1st, 0.5987 ㎛ on

the 2nd, 0.4984 ㎛ on the 3rd, 0.2731 ㎛ on the 4th, and 0.3086 ㎛ on the 5th. It was confirmed that this value affects the surface roughness of the f-theta lens depending on the temperature.

5. The surface shape of the incident surface due to the temperature change, which is the injection molding condition of the f-theta lens, was measured at 2.9325 ㎛ in the 1st, 2.8694 ㎛ in the 2nd, 3.0159 ㎛ in the 3rd, 2.7125 ㎛ in the 4th, and 3.5215 ㎛ in the 5th. It was confirmed that this value affects the surface shape of the f-theta lens depending on the temperature.
6. The surface shape of the exit surface due to temperature changes, which is the injection molding condition of the f-theta lens, was measured at 2.2984 ㎛ for the 1st, 4.8215 ㎛ for the 2nd, 3.9589 ㎛ for the 3rd, 1.1932 ㎛ for the 4th, and 2.1097 ㎛ for the 5th. It was confirmed that this value affects the surface shape of the f-theta lens depending on the temperature.

Acknowledgement

This study was supported by the Regional Leading Research Center of NRF and MOCIE(Grant number: NRF-2019R1A5A8083201).

REFERENCES

1. Noh, M. J., Hyun, D. H., Chang, H. S., Park, Y. W., and Park, C. Y., “System Design for Laser Scanning Unit using A3”, Journal of the Korean Society of Manufacturing Technology Engineers, Vol. 11, No. 4, pp. 71-72, 2011.
2. Yoo, K. S., Hyun, D. H., Chang, H. S., Park, Y. W., and Park, C. Y., “Injection Molding of a Laser Scanning Unit Optical System”, Journal of the Korean Society of Manufacturing Technology Engineers, Vol. 11, No. 4, pp. 102-103, 2011.
3. Robert, E., Hopkins and D. Stephenson, Optical Scanning(Marcel Dekker), pp. 27~82, 1991.
4. Park, K., and Han, C. Y., "Numerical Analysis for the Injection Molding of an Aspheric Lens for a Photo Pick-up Device", Journal of the Korean Society of Precision Engineering, Vol. 21, No. 11, pp.163~170, 2004.
5. Jeong, I. S., Ban, M. S, Son,, K. E., and Lee, B. B, “Development of Ftheta Lens for Laser Scanning Unit”, Technology and Innovation, Vol. 1, No. 1, pp. 13~19, 2013.
6. Rim, C. S., “The effect analysis of birefringence of plastic f-theta lens on the beam diameter”, Korean Journal of the Optics and Photonics, Vol 10, No. 1, pp. 15-20, 1999.
7. Bringans, R. D., “Application of Blue Diode Lasers to Printing,” Mrs online Proceedings Library(OPL), Vol. 482, pp. 1203, 1997.
8. Sakuma, N., “Aspherical Surface in the Laser Writing Optics,” Optical Design, No. 17, pp. 9-15, 1999.
9. Carmina, L., William, T. P. and Peter, P. C., “Athermalization of a Single-Component Lens with Diffractive Optics,” Applied Optics, Vol. 32, No. 13, pp. 2295-2302, 1993.
10. Minoura, K., “Historical Review and Future Trends of Scanning Optical Systems for Laser Beam Printers,” International Society for Optics and Photonics, Vol. 1987, pp. 264-273, 1993.
11. Park, K., and Han, C. Y. “Numerical Analysis for the Injection Molding of an Aspheric Lens for a Photo Pick-up Device,” Journal of the Korean Society of Precision Engineering, Vol. 21, pp. 163-170, 2004.
12. Klepek, G. “Manufacturing optical lens by injection compression molding,” Kunststoffe, Vol. 77, pp. 13, 1987.