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A Study on the Analysis of Injection Molding of F-theta Lens

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에프세타 렌즈의 사출 성형 해석에 관한 연구

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ABSTRACT

In this study, we investigate the injection molding of f-theta lens, an important element of the laser scanning unit of laser printers and scanning systems. The f-theta lens is an aspherical plastic lens that must be molded with a precision of seconds. An injection molding method is often used for mass producing aspherical plastic lenses at a low cost. In the injection molding process, costs related to forming and injection are included. Therefore, in this study, to determine the shrinkage and deformation of injection molded f-theta lens, we predict the pressure and temperature distributions. Further, based on the analysis of the predictions, we maximize the design efficiency and verify the cost and development period reduction.

Keywords : Laser Scanning Unit(레이저 스캐닝 유닛), F-theta Lens(에프세타 렌즈), Injection(사출성형), Resin(수지), Mold(금형)

1. Introduction

Laser scanning systems in multi function laser printers receive digital signals from computers by converting digital data to light information. The core components of a laser scanning unit are the f-theta lens, polygonal mirror, cylindrical lens, collimator lens, laser diode, laser control circuit board, and casing. The core technology of the laser scanning unit involves sending the emitted light dots to a drum via an accurate optical path. A collimator lens is used to prevent scattering of the different beams that are output by the laser diode and to render them as parallel beams. The parallel beams from the collimator lens are sent through the cylindrical lens to the surface of the polygonal mirror, from where they are reflected to the f-theta lens. The f-theta lens is so named because it spreads the beam on the drum according to the value of the tangent of the angular focal length f of the polygonal mirror. Thus, the f-theta lens is an aspherical, plastic lens that requires ultra-high precision. Injection molding is widely used to mass produce aspherical lenses at

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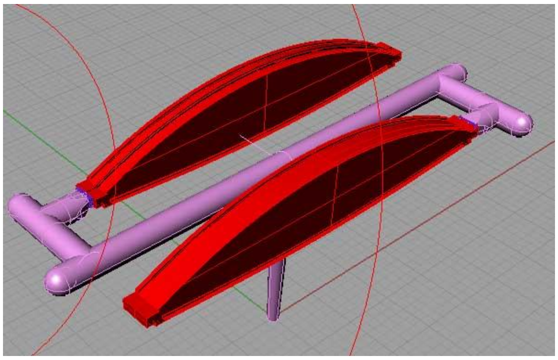
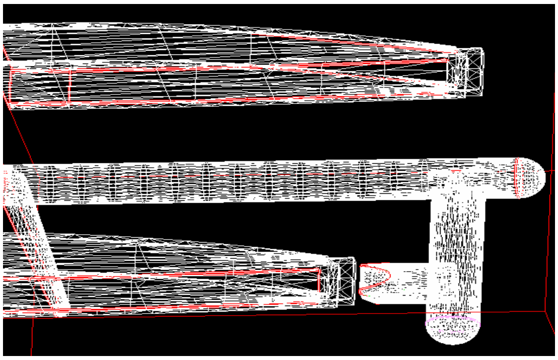
low prices. However, there is a possibility of defects, including short shot, deformation, and cracks. When such errors occur, additional die production and injection costs may be incurred. In this study, attempts are made to predict the pressure and temperature distribution causing contraction and deformation during injection molding of the f-theta lens to maximize system efficiency, reduce cost, and shorten development time. Starting from Noh's system design for laser scanning unit using A3[1], Yoo's injection molding of a laser scanning unit optical system[2], Robert E's study on optical scanning[3], and Park's numerical analysis for injection molding of an aspheric lens for a photo pick-up device"[4], many researchers have continued to focus on this research area to improve the function and properties of injection molding[5-11].

2. Interpretation of Injection Molding

Computer-aided engineering (CAE) analysis predicts the internal and external characteristics of the f-theta lens to enhance its optical properties. Further, there is a need to boost the productivity and proactively predict the problems that may be encountered during molding. The present study interprets the process of injection molding using the Autodesk mold flow Insight software. Stresses occur during the injection molding of the f-theta lens, which can cause changes in its internal material properties. The optical properties of the lens are impacted by two factors, namely form accuracy and internal material properties. The form accuracy may be judged from the completed form, but it is not possible to accurately judge the internal material properties. This is because the internal material properties are affected by the stress distribution during the injection process of the optical components. Therefore, an interpretation for calculation of the remaining stress that indicates the stress distribution and occurrence during mold filling, packing, and cooling, as well as the optical erification characteristics interfering with the optical performances of the lenses are needed. To this end, the liquidity of the polymer melt within the die is reviewed for its optical performance via interpretation of the injection molding process before lens production. The proposed method predicts the product injection and defects, while also reviewing the design quality, to minimize the correction count of the die and to maximize productivity. To interpret the injection molding process, f-theta lenses were modeled into grids, as shown in Fig. 1(a) and 1(b). The interpretation considers the mold filing, packing, and cooling processes. The material used in the study was ZEONEX, which is known to have excellent optical properties. The process conditions for injection molding are summarized in Table 1.



(a) 3D Modeling



(b) 3D Meshing of f-theta lens

Fig. 1 Subdivision of f-theta lens

Table 1 Injection molding conditions

No.	Spec.
Clamping force	140 Ton
Cavity No.	1*2
Cavity weight	24.39 g
Resin	Zeonex
Color	Optical
Drying temperature	90 ℃
Filling time	17 sec
Cooling time	60 sec

3. Result

The interpretation of injection molding of the f-theta lens helps understand the fluid flow of the resin, which determines the size and structure of the sprue and runner. Therefore, optimization of resin flow is possible and can be reflected in the die design. The pressure required for the f-theta lens extraction is a maximum of 4.214 MPa as shown in Fig. 2, and the molding is of good quality with a filling rate of 99.5% as shown in Fig. 3. The average temperature for molding injection is 284.1 ℃ as shown in Fig. 4. When the resin flowed into the lens, its flow front temperature was 280 ℃, which indicates that the injection molding is appropriate as shown in Fig. 5. The time required between removal of the lens from the mold since filling to 100% and achieving 90% cooling in the thickness direction of the lens was 402 s as shown in Fig. 6. The volume contraction during lens demolding is simulated so that the contraction at the middle of the lens is higher as shown in Fig. 7; the twisting of the lens (Fig. 8) is also noted to likely contract in the direction of the length. Weld lines are formed at the junction where the molten resin diverges into the cavity. The simulations showed that this diversion was 135° as shown in Fig. 9, which is acceptable for the processing incline. Air trapping is another possible defect caused by the stagnant air within the die that failed to escape.

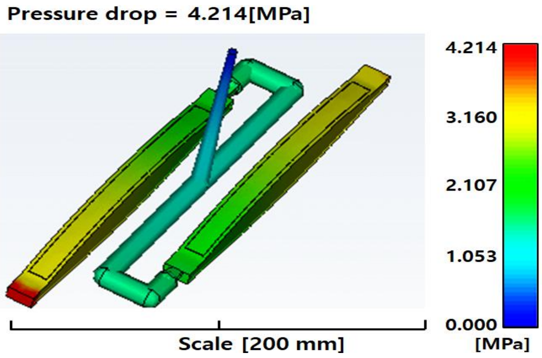


Fig. 2 Analysis result of pressure drop

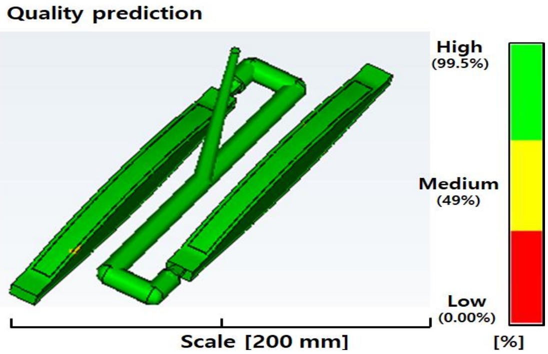


Fig. 3 Analysis result of quality prediction

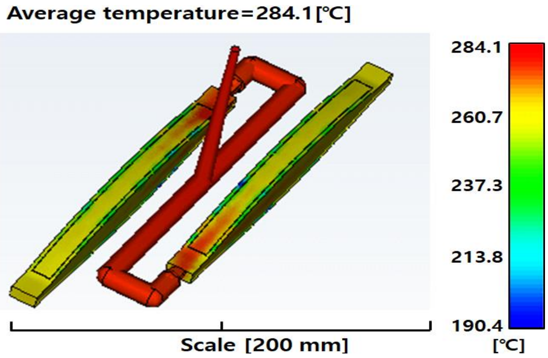


Fig. 4 Analysis result of average temperature

As shown in Fig. 10, this defect did not occur, and the molded product remained acceptable. The interpretation results of mold filling showed no balance problems as the filling was achieved simultaneously at both the planes of incidence and

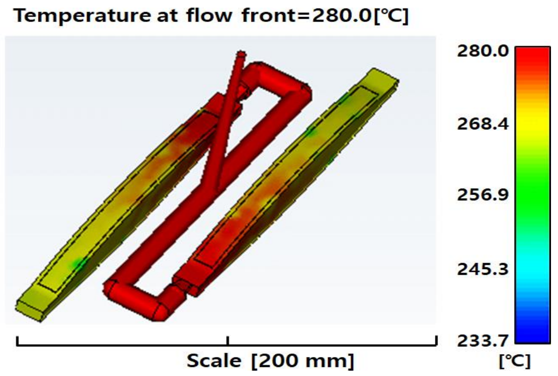


Fig. 5 Temperature at flow front

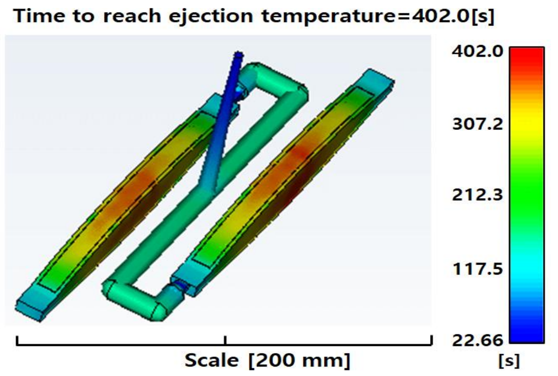


Fig. 6 Time to reach ejection temperature

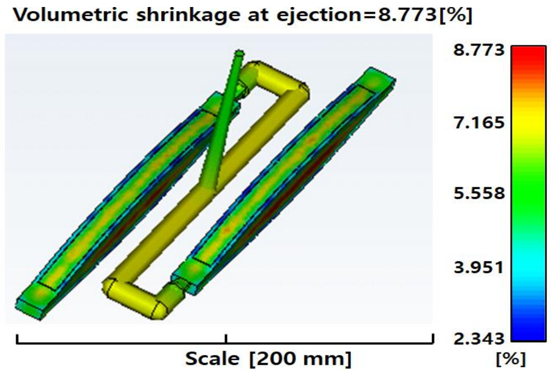


Fig. 7 Volumetric shrinkage at ejection

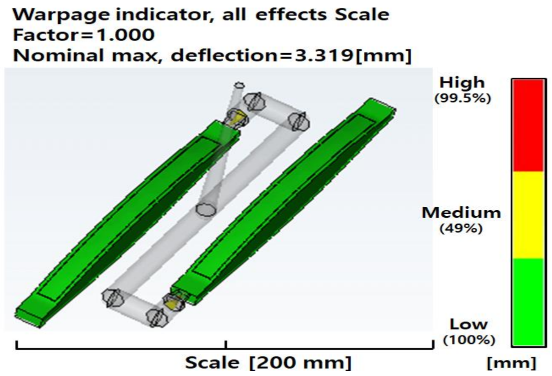


Fig. 8 Warpage indicator, all effects

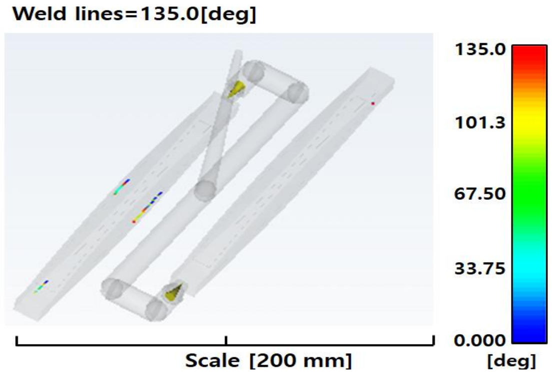


Fig. 9 Weld lines

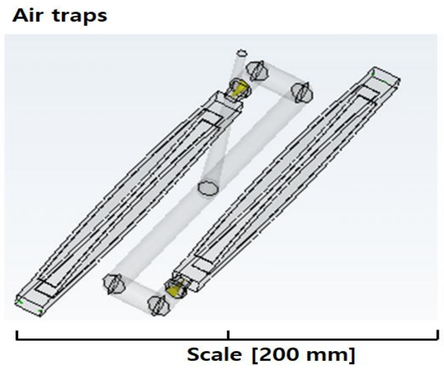
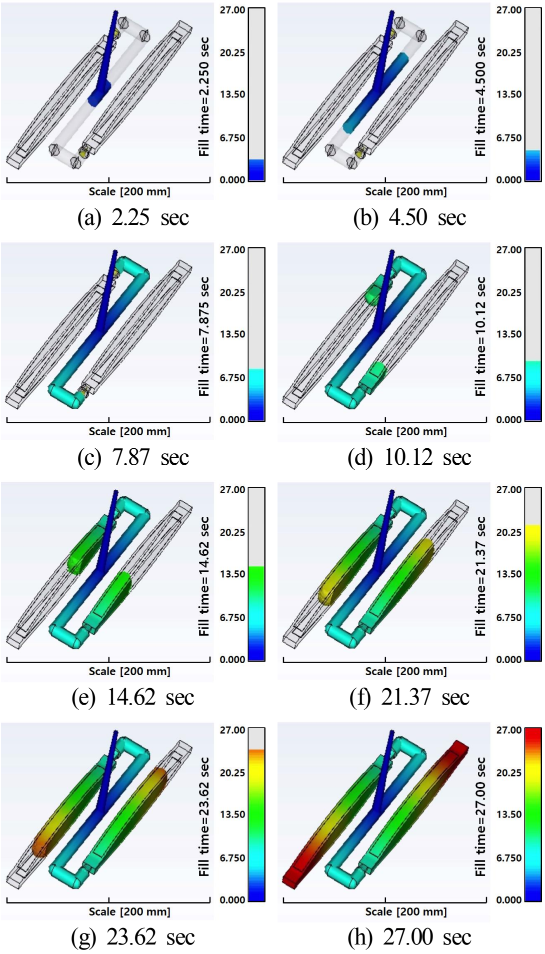


Fig. 10 Air traps

exit with no regions without injection. The maximum injection time was 27 s. The production of the f-theta lenses were achieved with 140 ton electric injection molding machines, with injection at a pressure of 90 MPa, clamping force of 140 ton, and a two-cavity die. Fig. 12 demonstrates the changes in pressure with respect to injection time, which was acceptable. Fig. 13 shows the changes



(a) 2.25 sec (b) 4.50 sec

(c) 7.87 sec (d) 10.12 sec

(e) 14.62 sec (f) 21.37 sec

(g) 23.62 sec (h) 27.00 sec

Fig. 11 Fill time of f-theta lens

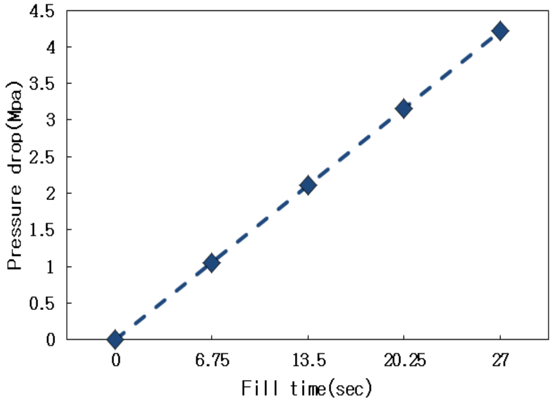


Fig. 12 Pressure drop vs fill time of f-theta lens

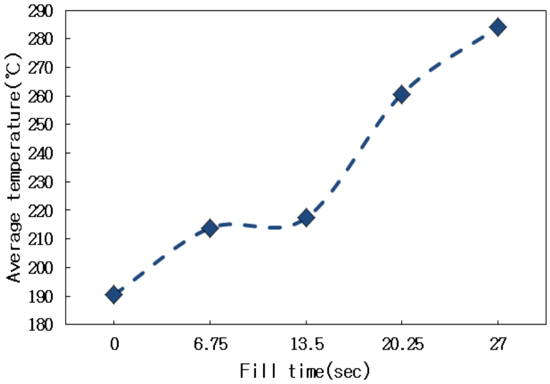


Fig. 13 Average temp. vs fill time of f-theta lens

in temperature with respect to the injection time, affirms appropriate changes.

4. Conclusion

This study involved interpretation of the filling and transformation processes of injection molding for f-theta lenses used in laser scanning units. The data from this study is expected to help improve the performance and die production of such lenses in the future.

1. The maximum pressure required for injection molding of the f-theta lens is 4.214 MPa, and the quality of injection molding was 99.5%, indicating that good filling is possible.
2. The average temperature required for injection molding of the f-theta lens was 284.1 ℃. The temperature at the flow front of the resin was 280 ℃ during filling, which indicated that the injection molding was acceptable.
3. The time required for the f-theta lens to reach the appropriate demolding temperature was 402 s from the time the lens mold was filled to 100% to the time when more than 90% of the cooling was achieved. The contraction in volume was highest at the center of the f-theta lens, and it was predicted that the twist in lens was horizontal.

4. Weld lines were formed at the junction where the molten resin diverged into the die cavity. The simulations showed this to be 135°, which is acceptable once processed incline. Air traps, which are caused by air bubbles that failed to escape the die, were also at acceptable levels.
5. The interpretation results of the mold filling showed no balance problems as the filling was simultaneous both on the planes of incidence and exit, with no regions without injection. The maximum injection time was 27 s.

Acknowledgements

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