Experimental and Numerical Analysis on Recovery of Polymer Deformation after Demolding in Hot-embossing Process

H. Takagi[a], Y. Onishi[b], M. Takahashi[a], R. Maeda[a], Y. Iriye[b], T. Iwasaki[b], Y. Hirai[c]
[a] National Institute of Advanced Industrial Science and Technology (AIST), AIST Tsukuba-East, 1-2-1 Namiki, Tsukuba, Ibaraki, 305-8564 Japan
[b] Mizuho Information and Research Institute Inc., Kanda-Nishiki-cho 2-3, Chiyoda-ku, Tokyo, 101-8433 Japan
[c] Physics and Electronic Engineering, Osaka Prefecture University, Gakuen-cho 1-1, Naka-ku, Sakai, Osaka, 599-8531 Japan

In order to achieve high throughput hot-embossing process, recovery of polymer deformation after demolding (so-called spring-back) is quite important for process optimization[1]. Numerical simulation methods which can analyze the recovery have been desired. In this work, we experimentally examined recovery of polymer deformation by changing demolding temperatures. We also numerically simulated the process based on a visco-elastic model of polymer[2].

Examined hot-embossing process consists of 5 steps as shown in Fig. 1. In experiments, a mold with 200 μm wide line & space patterns, and 2 mm thick plates of cyclo-olefin-polymer (COP) were used. In numerical simulations, parameters for visco-elastic properties of COP derived from an experimental measurement[2] were used.

As shown in Fig. 2, higher demolding temperature resulted in smaller deformation in both experimental and numerical results. In experiments, only temperature of the mold side heater can be measured. Therefore, temperature of polymer in numerical simulation was determined so that calculated deformation for 60s pressing and demolding at 125 °C coincide with the experimental result. These indicate that recovery occurred during the cooling process after demolding in experiments, and it could be reproduced by numerical simulation. Fig. 3 shows influence of temperature in the press step on relative recovery. Relative recovery is calculated as $(D_{125}-D)/D_{125}$. Here D is the deformation for each demolding temperature and D_{125} is that for demolding at 125 °C. Although, by adjusting pressure, press time and D_{125} was almost the same in all the pressing temperatures, recovery is obviously smaller in lower temperature process.

These results demonstrate that numerical simulations using visco-elastic model of polymer can reproduce recovery of deformation after demolding. We expect that this simulation method will be a powerful tool for process optimization in high throughput hot-embossing process including roll-imprint.

---

1 T. Leveder et al., Microelectron. Eng. **84** (2007) 953
2 H. Takagi et. al., Abs. MNE 2007, (Copenhagen, 2007) 515.

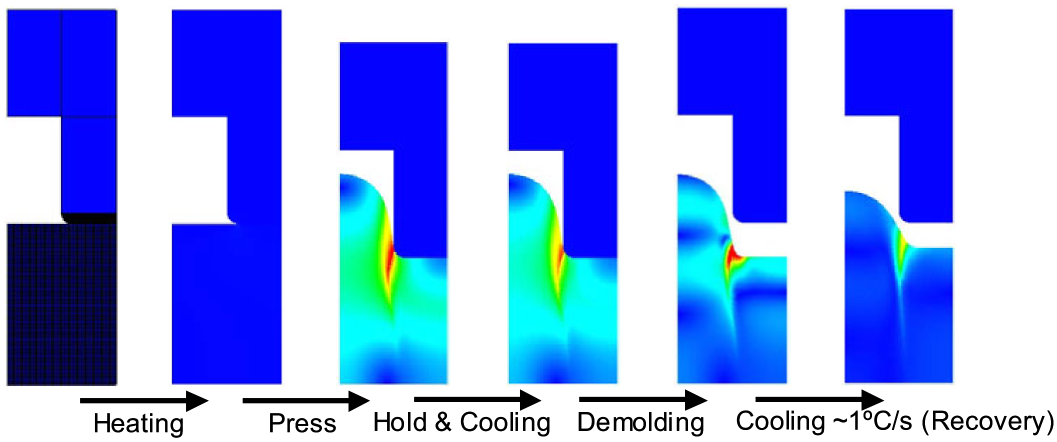

Fig. 1. Steps in the hot-embossing experiments and corresponding results of numerical simulations.

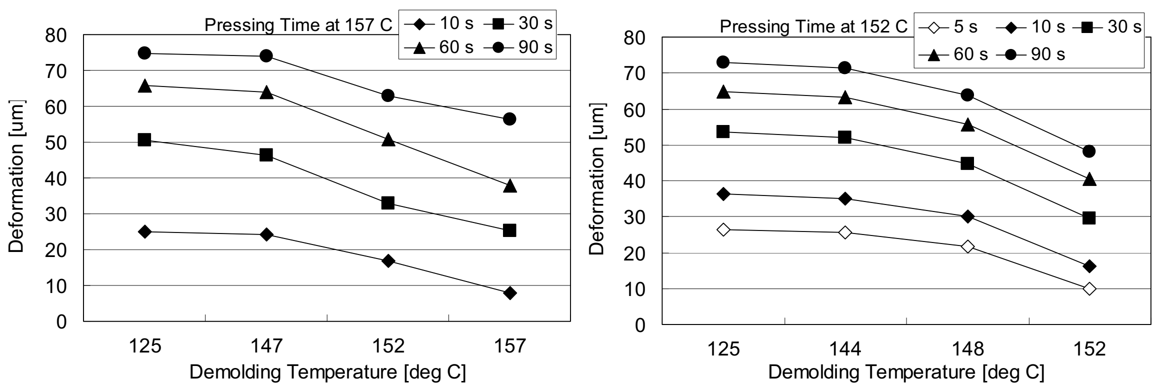

Fig. 2. Deformations of polymer after cooling (recovery) process depending on demolding temperature for various pressing time with pressure P=1.15 MPa. In experimental results (left) temperatures of the mold side heater are shown, and in numerically simulated results (right) those of polymer are shown.

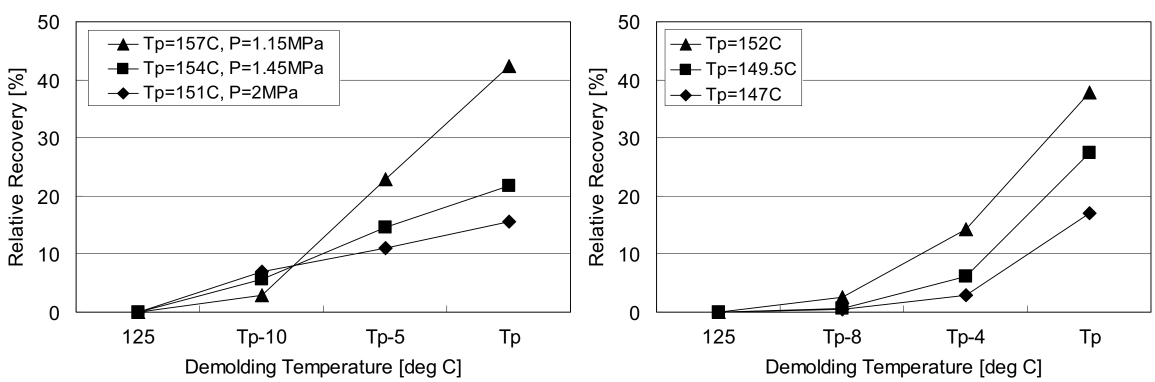

Fig. 3. Experimental (left) and numerically simulated results (right) of recovery normalized by the deformations for demolding at 125 °C. T_p means the temperature in the press step. In all examined T_p, pressing time was 60s and the deformations in case of demolding at 125 °C were approximately 65 µm.