Notes

Effect of the Holding Pressure on the Skin-Core Morphology of Injection-Molded Polypropylene Parts

In a previous paper,[1] an important role was attributed to the holding pressure in the buildup of a skin-core structure in injection-molded polypropylene (PP) parts. It was hypothesized that, schematically, the holding pressure acts as a quenching phenomenon, perturbing locally (at a 100–500 μm depth approximately) the crystallization and relaxation of orientation. Combined with melt orientation distribution and crystalline polymorphism effects, the holding pressure effects lead to a very complex skin-core structure as established from IR, WAXS, DSC, and microscopic observations on microtome sections. This previous work was, however, based on the comparison of samples differing essentially by the dynamics of holding pressure installation (among other parameters out of consideration here). The aim of the present letter is to report some results obtained with different holding pressures, all the other processing parameters being constant.

The experiments were made with the previously studied sample PP 12 ($\overline{M}_n$ = 53,000; $\overline{M}_w$ = 220,000), using a single gated (1 G) mold for tensile dogbone sample (according to the French Standard AFNOR NFT 51034). The measurements were made in all the cases in zone 5, e.g., at the end of the calibrated section of the sample, opposite to the injection gate. The mold temperature was 30°C.

Three holding pressures, respectively 0, 11, and 80 MPa, were studied.

Microtome sections of 20 μm thickness were analyzed by FTIR spectrophotometry using a gold polarizer for dichroïsm measurements. The crystallinity ratio X_c was determined from the empirical relationship:

$$X_c = 109 \cdot \frac{A_{997} - A_{938}}{A_{973} - A_{938}} - 31.4$$

The orientation factor of the crystalline phase, f_c, was determined according to Samuels.[2]

The X_c and f_c depth distributions are presented in Figures 1, 2, and 3 for respectively 0, 11 and 80 MPa holding pressures. Their main features are summarized in Table I.

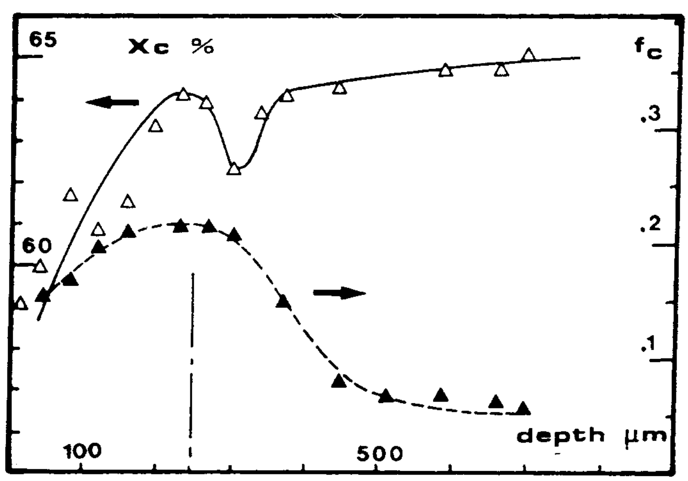

Fig. 1. Depth distribution of X_c (△) and f_c (▲) for the zero holding pressure.

Journal of Applied Polymer Science, Vol. 39, 1215–1217 (1990)
 CCC 0021-8995/90/051215-03$04.00

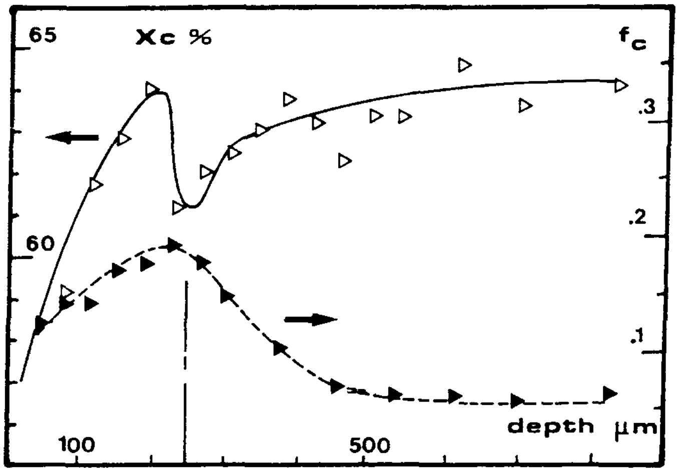

Fig. 2. Depth distribution of X_c (▷) and f_c (▶) for the 11 MPa holding pressure.

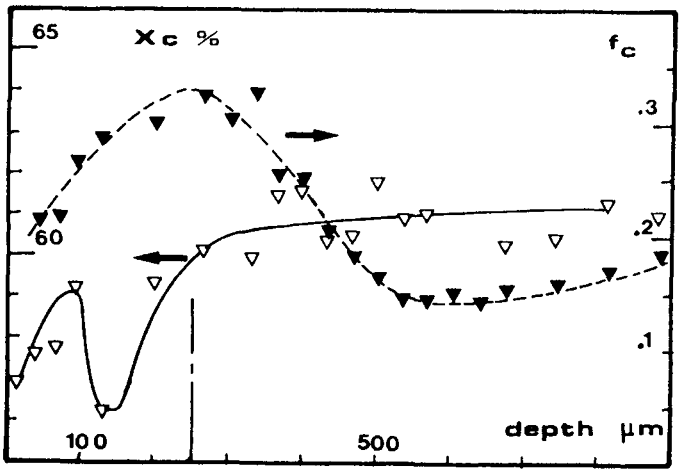

Fig. 3. Depth distribution of X_c (▽) and f_c (▼) for the 80 MPa holding pressure.

These results confirm clearly the role of the holding pressure which:

(i) Decreases globally, but essentially in the shear zone, the crystallinity ratio X_c. This is a consequence of the viscosity increase in the melt during cooling under pressure.[3]
(ii) Increases noticeably the orientation in the shear zone presumably by disfavoring the orientation relaxation, but does not modify its depth distribution. This phenomenon is especially observed between 11 and 80 MPa (Figs. 2 and 3).
(iii) Shifts noticeably the secondary maximum of the crystallinity ratio (and the associated minimum) towards the surface as a logical result of the quenching effect of the pressure on the crystallization of the oriented melt in the shear zone (Fig. 4).

It can be concluded that these observations confirm clearly the important role of the holding stage in injection molding. Its effects are especially noticeable in the region where the crystallization isotherm is located when the pressure is installed. In the usual molding condition, this region is located at 100–300 µm depth, this latter being a decreasing function of the pressure. The consequences of these effects on certain mechanical properties such as fatigue, are now well established.[4]

TABLE I
Morphological Characteristic for the Three Holding Pressures under Study

Holding pressure (MPa)	0	11	80
$X_{c\,max}$ (core)	65	64	61
$X_{c\,max}$ (skin)	84	64	59
$f_{c\,max}$	20	20	30
Depth of the first maximum of $X_{c\,max}$	250	190	90
Depth of the $f_{c\,max}$	250	250	250

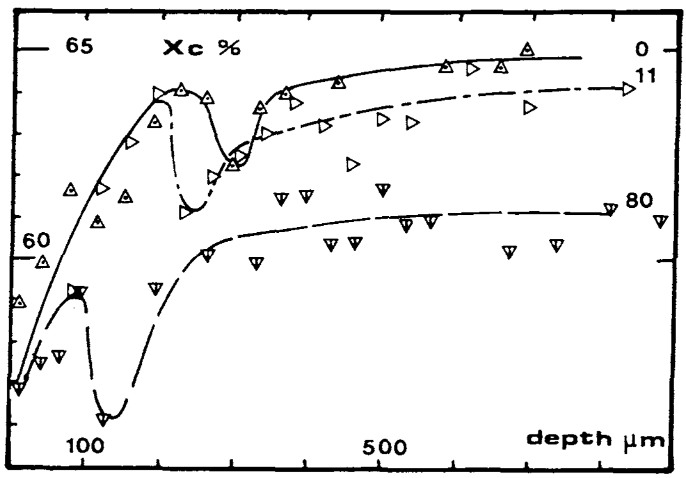

Fig. 4. Comparison of the X_c distribution for the three holding pressures (0, 11, and 80 MPa).

References

1. J. P. Trotignon and J. Verdu, *J. Appl. Polym. Sci.*, **34**, 1 (1987).
2. R. J. Samuels, *Structured Polymer Properties*, Wiley, New York, 1974.
3. F. N. Cogswell and I. C. McGowan, *Br. Polym. J.*, **4**, 183 (1973).
4. J. P. Trotignon and J. Verdu, *J. Appl. Polym. Sci.*, **34**, 19 (1987).

Received February 24, 1989
Accepted April 10, 1989

J. P. TROTIGNON
J. VERDU

ENSAM
151, Bd. de l'Hôpital
75640 Paris, Cedex 13, France

Received November 4, 1988
Accepted February 24, 1989