Surface Morphology and Mechanical Quality of Injection-Molded Polycaprolactam (Nylon 6)

The effect of injection-molding processing variables on the morphology and crystalline orientation of acetal homopolymers[1] and polypropylene[2] has been well reported. In particular, attention has been drawn to the existence of three distinct crystalline zones in these polymers and their profound effect on mechanical properties.

The surface structure of polyacetal and polypropylene moldings consists of a highly oriented nonspherulitic skin. The skin covers an interior which is almost completely composed of spherulites. For these two polymers, it has been demonstrated that variation in the heterogeneous nature of the molded part is responsible for most of the mechanical differences found in practice in tensile yield, impact strength, and shrinkage.

This communication outlines some preliminary observations of variation in mechanical quality of polycaprolactam moldings and how this is related to morphologic features.

MOLD TEMPERATURE

Heavy band moldings and standard tensile dumbbells of polycaprolactam were prepared by injection molding under carefully monitored conditions, i.e., melt temperature (220°–235°C), injection pressure (1000–2500 psi), and cycle time (up to 5 min) were recorded.

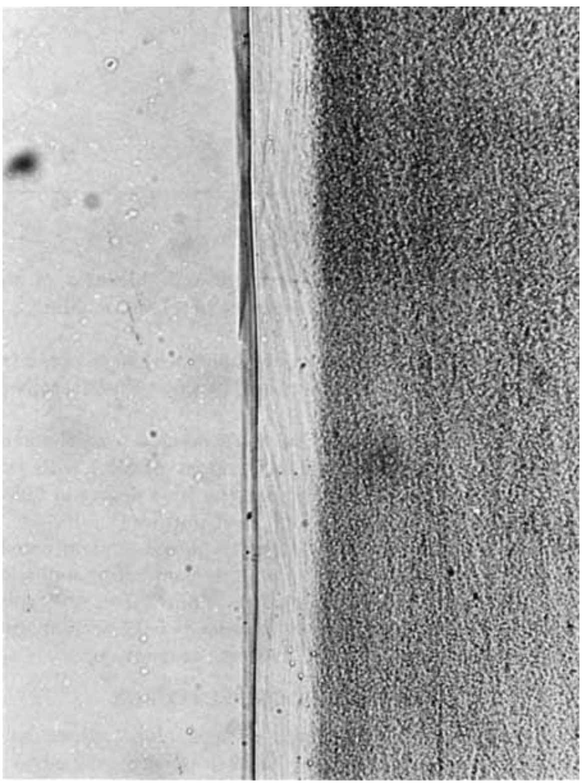

Fig. 1. Microtomed section of polycaprolactam taken from the external surface of a thick sectioned band molding. Mag. ×100.

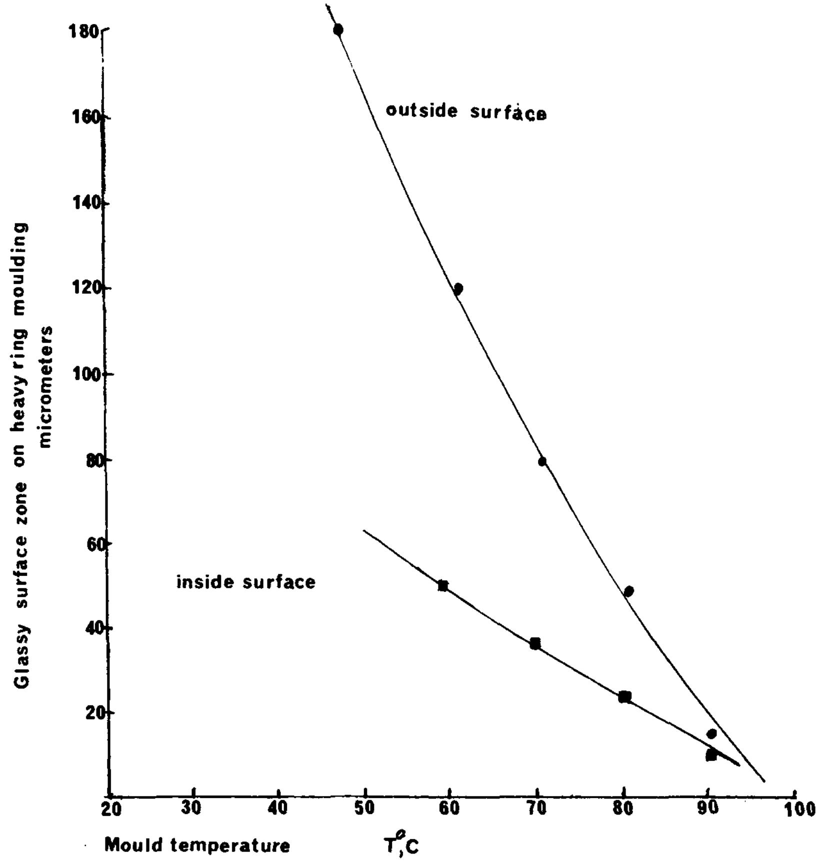

Fig. 2. Relationship between mold temperature and thickness of glassy skin on the internal and external surfaces of a band molding.

Microtomed thin cross sections (5 micrometers thick) were taken from the moldings at right angles to the surface and were examined by optical microscopy using transmitted light.

An example is shown in Figure 1, which was sectioned from the exterior surface of a thick polycaprolactam ring or band and is viewed parallel with the flow direction. Although optically featureless, the skin possesses a high degree of molecular orientation along the flow direction, as revealed by high birefringence.

Two refractive indices were measured directly on these microtomed sections using a polarizer in the microscope and a series of standard refractive index liquids. The axes selected were for light vibrating along the polymer flow direction (typical value n 1.570) and perpendicular to this (n 1.530) within the plane of the section studied. Normally, a first-order retardation plate was used to indicate orientation.

MORPHOLOGIC FEATURES

The existence of an intermediate layer or shear zone, where spherulites are row nucleated by shearing forces, as reported for both polypropylene and polyacetal, could not be established with certainty for polycaprolactam. If such a shear zone exists, it will be a very thin intermediate layer, sandwiched between the surface skin and the spherulitic core.

The fabrication of band moldings in a cold mold (less than 50°C) produced very erratic mechanical quality. It was found that such moldings were rather brittle during impact testing. This phenomenon is now the subject of a more quantitative investigation.

As in the case of polyacetal, it appears that mold temperature is the prime factor controlling the degree of orientation, thickness of skin, and mechanical properties of polycaprolactam, whereas with polypropylene it is melt temperature which is reported to play the main role.[2]

The above observations are preliminary and have prompted a further investigation into the complex relationship between morphologic structure and mechanical behavior. It is hoped that a greater understanding of the above properties of moldings will lead to a better assessment of their likely performance in service.

References

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