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Polycarbonate Microfoams with a Smooth Surface and Higher Notched Impact Strength

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ABSTRACT: Polycarbonate microfoams produced by physical blowing agents usually have an unacceptable surface quality. The surface is rough and the visual difference in the surface quality is striking. However, the surface quality can be improved by the gas counterpressure technology.

Polycarbonate has a high elongation at break but a low notched impact strength. Earlier, the microfoams showed higher notched impact strength, but a considerably reduced elongation at break. Foams produced by the gas counterpressure technology have both these positive mechanical properties.

KEY WORDS: polycarbonate, microfoam, gas counterpressure, surface roughness, impact property, morphology.

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INTRODUCTION

One of the most frequently heard concerns of microfoams produced by physical blowing agent has been their surface qualities. The surface quality of microfoamed components is striking, because, it drifts the fluid flowing out at the glaze front and the polymer bubbles are destroyed by shear at the surface of the mold. However, this surface quality can be improved by the gas counterpressure process.

By a gas counterpressure (GCP) in the mold the early foaming up of the gas-loaded polymer melt is prevented.

Break Behavior of Polycarbonate

The break behavior of compact polycarbonate is dominated by crazing and therefore by elastic material behavior at −30°C. The clipping deformation distortion behavior increases after approximately −25°C, so that the crazing and the clipping deformation distortion and therefore elastic-plastic material behavior characterizes the break-behavior at room temperature [1,2].

Furthermore the mechanical behavior of the polycarbonate depends on the temperature, thickness (with a tough brittle transition at thickness increases) and on the contribution of sharp notches (transition of the flat tension to the flat stretching condition) [3].

Norm test bars from polycarbonate according to DIN EN ISO 179 (Charpy), with the test bar geometry 1 and the notch geometry A, break already brittle at room temperature.

The MuCell Technology

Trexel's patented MuCell process is used to produce the injection-molded as well as some extruded microfoam parts. During the molding process small, precise amounts of supercritical N_2 or carbon dioxide gas is introduced as a physical blowing agent into the molten resin.

The Gas Counterpressure Process

The process sequence begins with the nitrogen gas being injected into the mold under precisely controlled pressure prior to the injection of any material (see Figure 1). The gas builds a pressure pad. Then the material is injected against that pad. The pressure inside the mold keeps the gas in solution on the flow front, which prevents the creation of surface swirls caused by the dissolved gas between the melt and mold

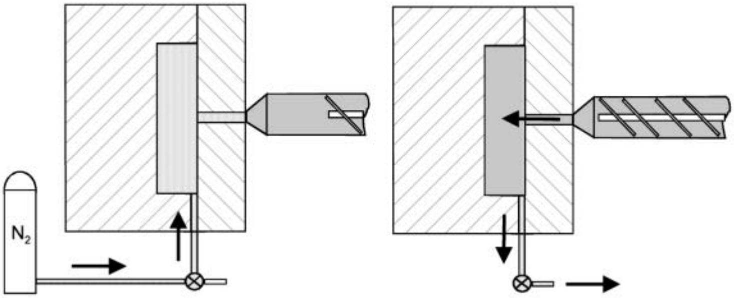

Figure 1. The gas counterpressure process.

without the gas counterpressure process. The gas maintains control by pressure as it is pushed back by the melt and can exit.

The gas counterpressure is not a new process. However, it has not been used by microfoaming with physical blowing agent till date.

EXPERIMENTAL

With an injection molding machine (ENGEL Victory 330H/80V/120 Combi), equipped with the MuCell technology (Trexel Inc., Woburn, MA), test bars were produced. Supercritical nitrogen gas (N_2) was used as the physical blowing agent. The mold was equipped with the gas counterpressure technology. The analyzed material was an unreinforced grade of Bayer's Makrolon PC.

The test bars produced with and without the gas counterpressure and different weight reductions were analyzed by the following tests:

- Surface roughness
- Morphology
- Charpy notched impact test (DIN EN ISO 179/1eA)
- Tensile test (DIN EN ISO 527)

RESULTS

Surface Roughness

The visual differences in the surface quality is striking. The test bars molded without the gas counterpressure have the surface appearance normally associated with MuCell (see Figure 2). The parts produced by the gas counterpressure process are very smooth and glossy

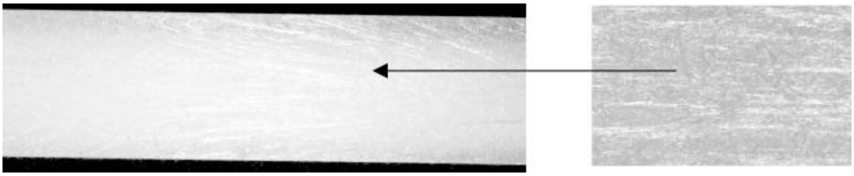

Figure 2. MuCell-surface, 5.5% weight reduction.

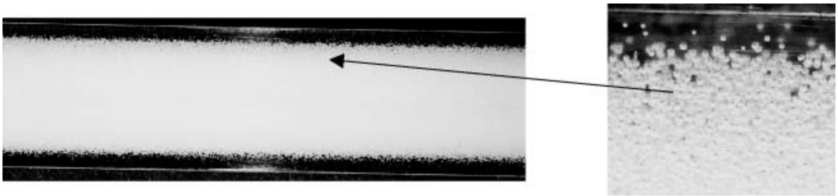

Figure 3. MuCell-surface with gas counterpressure process, 5.5% weight reduction.

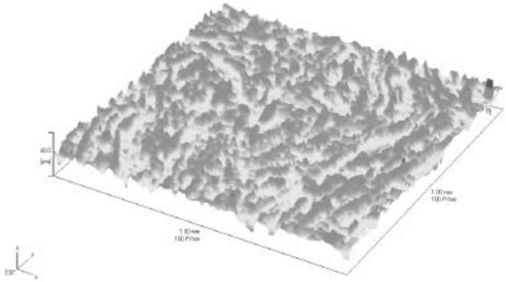

Figure 4. MuCell-surface, $Rz = 23.11\,\mu m$.

(see Figure 3). The thickness of the transparent surface layer can be varied by the process parameters.

The surface roughness without the gas pressure process is 23.11 μm (*Rz*), by 5.5% weight reduction (see Figure 4), while with the gas counterpressure, the surface roughness drops to 0.85 μm (Rz) (see Figure 5).

Morphology

The morphology of the microfoams and therefore the mechanical properties were influenced by the following production parameters:

- injecting speed
- kind of supercritical gas and concentration

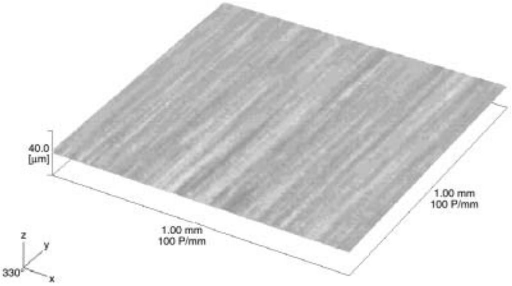

Figure 5. MuCell-surface with gas counterpressure process, $Rz = 0.85\,\mu m$.

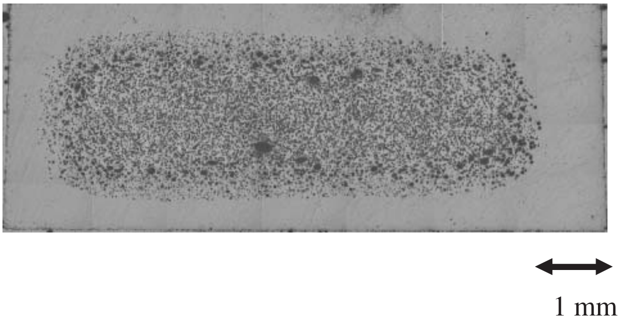

Figure 6. MuCell-morphology of PC, 12.8% weight reduction.

- melt temperature
- mold temperature
- weight reduction

and also by gas counterpressure.

In most cases, MuCell (with or without gas counterpressure) produces unanimously celled polymer microfoams. The microcells are almost spherical. The cell diameters lie approximately in the area of 5–50 µm.

The microcellular foams produced by injection molding are further characterized by a compact surface layer. They have a sandwich structure.

The MuCell test bars have a clear boundary between the microcellular core and the surface layer (see Figure 6). The test bars produced by gas counterpressure however do not always have clear boundaries. These can be foamed up to the surface, depending on the process parameters (see Figure 7). The main reason is the delay in starting of the foaming caused by the gas counterpressure.

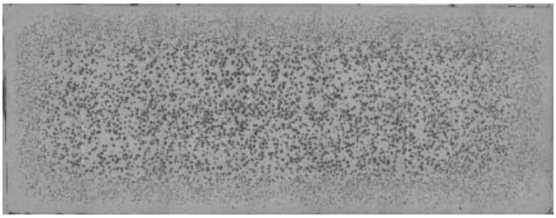

Figure 7. MuCell-morphology of PC with gas counterpressure process, 10.2% weight reduction.

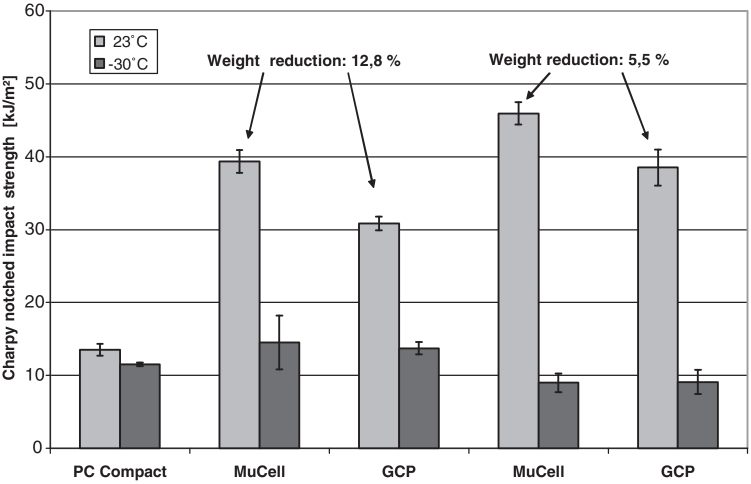

Figure 8. Charpy notched impact strength (DIN EN ISO 179/1eA) of compact polycarbonate, MuCell-microfoams and MuCell-microfoams produced with gas counterpressure (GCP).

Charpy Notched Impact Test

The Charpy notched impact test was carried out according to DIN EN ISO 179/1eA (test bar dimension $80 \times 10 \times 4\,\mathrm{mm}^3$; V 45° notch with 0.25 mm radius and 2 mm notch depth).

Figure 8 shows the Charpy notched impact strength at room temperature and −30°C. The compact polycarbonate broke brittle at both the temperatures. This is normal for polycarbonate. The microfoams showed, however, depending on the weight reduction and the production process, higher values at room temperature. The increased toughness is founded by the tough break behaviors of the thin compact surface layers of the polycarbonate microfoams.

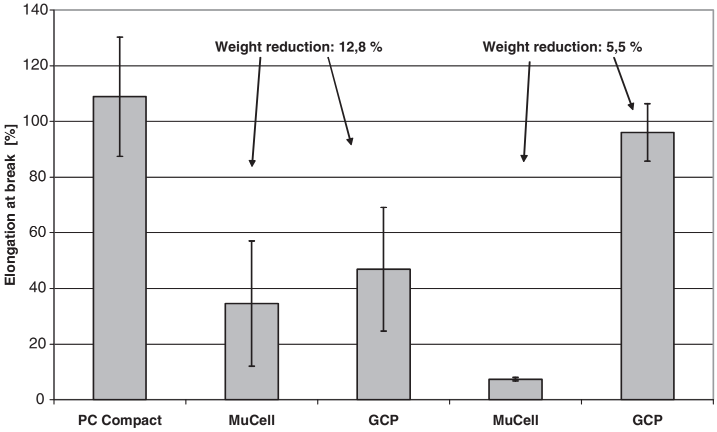

Figure 9. Elongation at break (DIN EN ISO 527) of compact polycarbonate, MuCell-microfoams and MuCell-microfoams produced with gas counterpressure (GCP).

At −30°C the polycarbonate microfoams also become brittle, because the thin compact surface layers are also brittle.

Tensile Test

The tensile test was carried out according to DIN EN ISO 527. Figure 9 shows the influence of foaming on the elongation at break. By microfoaming, the elongation at the break of the polycarbonate was reduced in all cases, depending on the weight reduction and the surface roughness of the test bars.

The elongation at break has been improved by the gas counterpressure technology because the surface roughness of the test bars was significantly reduced. The difference got clear at the tests with 5.5% weight reduction. The surface roughness worked like sharp notches. With a thicker surface layer, the test bars were considerably more break-sensitive opposite sharp notches and the elongation at break was reduced considerably.

A smooth surface and a thicker surface layer of the test bars which were produced by gas counterpressure effects a improved elongation at break, contrary to the conventional MuCell microfoams.

SUMMARY

The surface quality and the break behavior of polycarbonate microfoams can be considerably improved by the gas counterpressure technology considerably. The improvement of the surface quality by gas counterpressure in the MuCell process is also possible in PA, PP, TPE, and other polymers.

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