Overmolding with Polycarbonate and Polycarbonate Blends

Since Covestro's – formerly Bayer MaterialScience – first patent on it 60 years ago, Makrolon® polycarbonate (PC) has found use in a wide variety of PC-on-PC overmolding applications ranging from ultra-tough, multi-colored truck taillight lenses to IR cameras that allow firefighters to see into smoke-filled rooms. Housings for medical devices often have insert-molded PC lenses or screens surrounded by tinted or opaque material.

The main challenge when overmolding PC onto PC or other rigid substrates is managing the shrinkage stresses inherent in the process. Excessive stresses can lead to distortion or stress cracking over time. This article addresses ways to manage stresses in plastic-on-plastic insert molding and multi-shot molding applications using Covestro PC, PC blends, and TPU elastomers.

Plastic-on-Plastic Insert Molding

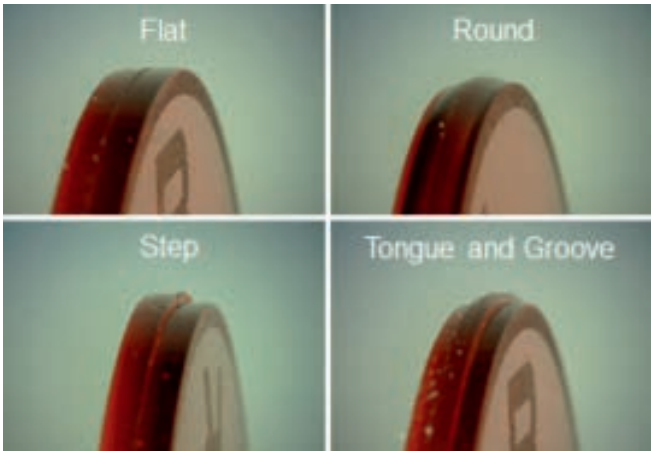
Insert molding involves placing a previously molded or fabricated part into a mold and then overmolding additional plastic onto or around it. For example, a lens or window molded in the morning could be placed into a different mold in the afternoon to form a housing with an insert molded window or lens.

Typically the second material is injected around the first. This is challenging for rigid, creep resistant plastics such as PC. The presence of the insert inhibits shrinkage that would normally occur in the overmolding material as it cools and solidifies. This generates long-term tensile stresses in the overmolding material, which can lead to stress cracking over time.



Bayer conducted a study to investigate the effect of edge design and insert preheating temperature on residual stresses in PC overmolding. The study used a coaster design (preceding photo) with a red, circular PC insert measuring about 57 mm in diameter. The insert was manually placed into a second mold that overmolded PC around it to form the remainder of the 102 mm diameter coaster.

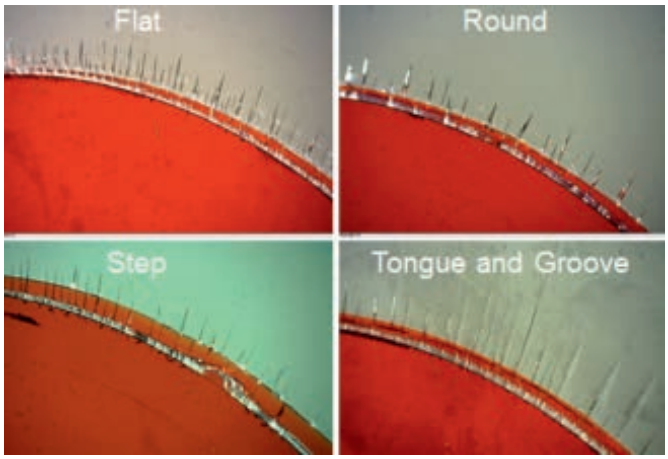
Inserts were molded with four different edge designs: flat, rounded, stepped and tongue & groove. The flat edge design relies on adhesion between the insert and the overmolded plastic. The other designs provide some measure of mechanical interlock in addition to adhesion.



At room temperature, red inserts with the four edge designs were placed into the second mold and overmolded with clear PC. Samples of the finished coasters were then subjected to either a 3-minute 1:10 TnP solvent stress or a 3-minute 1:3 TnP solvent stress test to determine the level of molded-in stress. All four edge designs passed the 1:10 TnP test even when the exposure time was extended from 3 minutes to 15 minutes. The molded-in stresses appear to be well below the 20 MPa threshold limit of the 3-minute 1:10 TnP test. In the absence of chemical/environmental attack or additional applied stress, we would expect these samples to endure the overmolding stresses for a very long time, perhaps indefinitely.

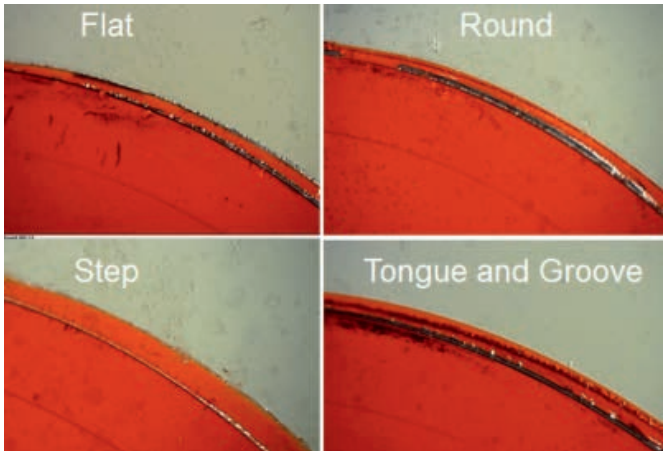
PC parts in medical applications can be exposed to sterilization procedures and disinfectants. They also require an

additional margin of safety. For these reasons, PC medical parts are often expected to pass the more difficult 1:3 TnP solvent stress test. This 3-minute test will cause parts to stress crack if the molded-in stresses exceed about 10 MPa. When subjected to this more difficult test, all of the samples, regardless of edge design, exhibited stress cracking in the clear PC. The overmolding stresses are apparently greater than 10 MPa. As a result, the samples could stress crack over time in some applications.



The photo above shows the stress cracks that appeared during the 1:3 TnP stress tests. As expected, the tongue and groove design, with its variations in wall thickness and stress concentrating corners, produced the most severe cracks. The round edge design produced the least severe cracks, but it was only slightly better than the flat and stepped edged designs. The inserts are fairly thick at 3.2 mm. In thinner parts, the thin features on the stepped and tongue and groove designs are likely to cause even greater stress problems.

Inserts are often preheated before overmolding to reduce shrinkage stresses. Heating thermally expands the inserts, so the insert and overmolded material can shrink together, to some degree, during molding. Hot inserts also slow down cooling at the interface between the materials. This allows more of the shrinkage stresses to relax and self-anneal during the cooling phase.



The preceding photo shows the 1:3 TnP solvent stress testing results for samples with inserts preheated to 121 °C prior to overmolding. The inserts were removed from an oven at the press and immediately placed into the mold. Preheating effectively reduced the overmolding stresses around the insert to within the stress threshold limit of the test. Preheating the inserts to 93 °C greatly reduced stress cracking in the four edge designs, nearly eliminating the cracks in the stepped and round edge designs. The flat and tongue and groove designs still had small but significant stress cracks.

The inserts in this study are round and free of stress concentration points around the perimeter except for in the edge profile. Square or rectangular inserts would tend to concentrate stresses in the corners, and may require higher preheating temperatures. Post-annealing can relax overmolding stresses, but it is usually better to avoid the stresses to begin with via improved design, insert preheating or multi-shot molding.

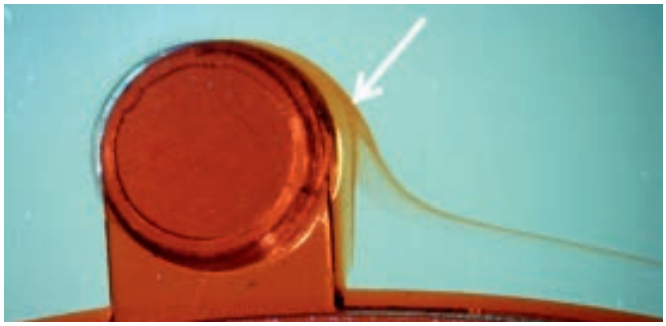
Multi-Shot Molding

The previous discussion focused on insert molding. Multi-shot molding is the preferred method for overmolding PC-based materials onto other molded substrates. The coaster test mold could have been designed for 2-shot molding in which a two barrel press would mold the red and clear in quick succession. The red inner piece would be molded first. Then the half of the mold retaining the red part would move to align with a different mold half to mold the clear PC.

Because the red inserts are still very hot when the clear shot is molded, there is no need for preheating as in insert molding. The freshly molded first shot is hotter than a preheated insert would likely be, so the resulting overmolding stresses are typically lower than can be achieved with insert molding. This 2-shot process can also deliver improved productivity and lower part cost if the production quantities are high enough to warrant higher mold and press costs.

Avoiding Problems and Defects

In both insert molding and multi-shot molding, the overmolding plastic can remelt some of the insert plastic, particularly when the insert has small or thin features that heat quickly. The following photo shows how the clear PC melted and washed out some of the PC on the red insert tab. This caused a red streak downstream of the tab. When the second material is dark and opaque, the defect is often hidden. When it is clear or light colored, the melt temperature, filling speed, gate location or part geometry can usually be adjusted to minimize the problem. To avoid excessive washout, the overmolding material should have a melt temperature equal to or lower than that of the insert or first shot.



Despite efforts to minimize it, the first shot or insert always has a head start on solidification and shrinkage. As the overmolding material shrinks onto or around the already solid insert, it can generate stresses and induce distortion, especially if the insert lacks sufficient stiffness. Often increased wall thickness or the addition of stiffening features such as ribs or corrugation can sufficiently reduce distortion.

In the coaster example, the insert and overmolded material only make contact along the edge, and the shrinkage stresses compress the red insert symmetrically. When the overmolded material overlaps large sections of the insert or substrate outer surface, distortion can be quite severe. We see this in applications such as AED defibrillators or rugged test devices which have portions of the outer surfaces overmolded with tough thermoplastic elastomers such as Texin TPU. These TPU elastomers typically provide excellent adhesion to PC and PC blends, and induce less shrinkage stress than rigid thermoplastics. Still, the overmolded outer skin lies on one side of the substrate wall. As the skin layer shrinks, it applies asymmetric stresses that act to pull the edges toward that side. The addition of geometric stiffening features to the substrate can often bring this distortion under control. In some instances, the skin layer can pass through holes in the wall to feed a skin layer on the inside surface. The presence of a skin layer on both the inner and outer surfaces of the substrate tends to balance the stresses and cancel distortion.

As plastic enters the mold cavities, the air in those cavities must exit, otherwise non-fill or gas burning can occur. Air typically escapes through vents machined into the mold around the perimeter of the cavity. In multi-shot or insert molding, portions of the mold seal off against the first shot or insert, usually with compression to prevent flash. The areas where the mold seals off against plastic are difficult to vent. The gate or gates should be positioned to drive as much of the air as possible to the perimeter vents in the mold. Vented pins, split mold inserts or porous metal can be used to vent air trapped at the insert/overmold interface. In some instances, the overmold cavity half can be designed with vents that allow air to escape over the plastic insert.

Summary

PC and PC blends can be molded onto themselves or other thermoplastic substrates via the insert molding process or the multi-shot process, though the latter is preferred. Preheating of the inserts can dramatically reduce overmolding stresses during insert molding, which can improve part performance. In the Covestro study, the tongue and groove edge design produced higher overmolding stresses than a flat, rounded or stepped design. To avoid excessive washout, the melt temperature of the first shot or insert should be equal to or higher than the melt temperature of the overmolding material. Careful part design, mold design and processing can greatly reduce the chance of overmolding problems such as washout, gas entrapment, and distortion.

Typical value
These values are typical values only. Unless explicitly agreed in written form, they do not constitute a binding material specification or warranted values. Values may be affected by the design of the mold/die, the processing conditions and coloring/pigmentation of the product. Unless specified to the contrary, the property values given have been established on standardized test specimens at room temperature.

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With respect to health, safety and environment precautions, the relevant Material Safety Data Sheets (MSDS) and product labels must be observed prior to working with our products.

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