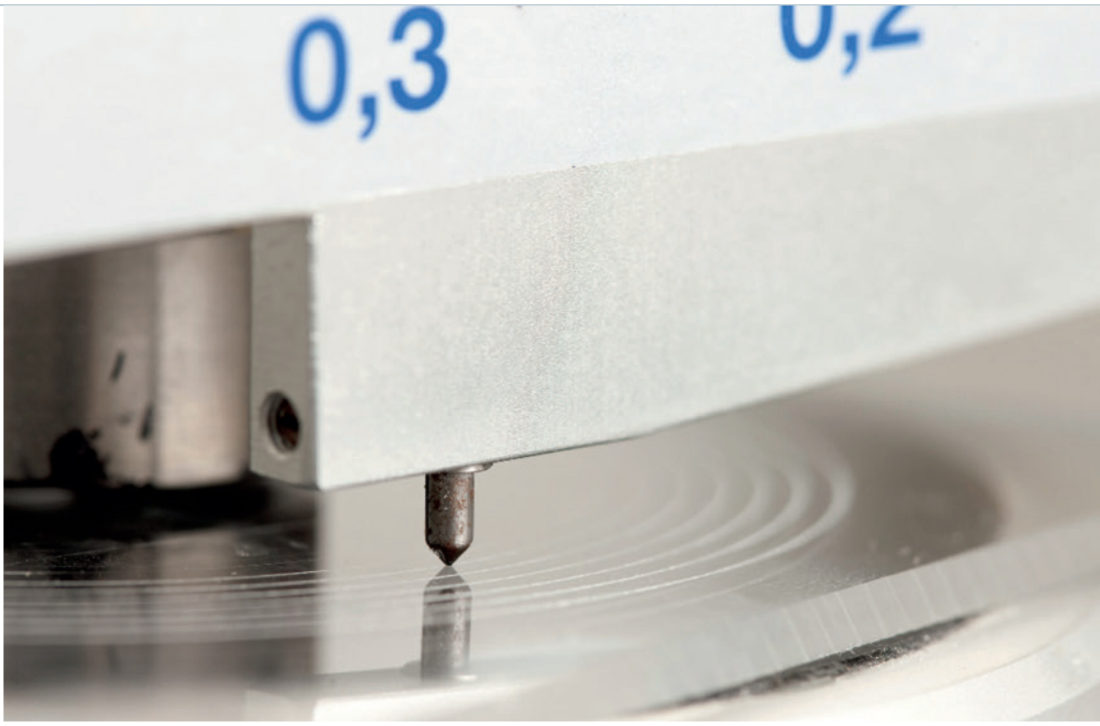

The surface exhibits high scratch hardness in the Erichsen test

PMMA. A newly developed coating system enables PMMA parts to be coated directly in the mold with a reactive system composed of multifunctional acrylates. The resulting surfaces are scratch- and wear-resistant as well as resistant to many chemicals. The method is intended as a cost-effective alternative to conventional coating.

Scratch-Resistant in One Step

SVEN SCHRÖBEL ET AL.

Transparent plastic parts can be found in numerous applications, for example as panels for household appliances, as covers for vehicle dashboard instruments or as display windows. Such parts can only stay perfectly transparent if the surface is not damaged by scratches or abrasion during use. This imposes very high demands on the optical quality, and mechanical and chemical resistance of the surfaces. PMMA has the greatest surface hardness and scratch resistance of all thermoplastics, yet even PMMA articles will not meet particularly high standards on scratches and other signs of wear unless they are coated. The classic way to accomplish this is to coat the parts with a scratch-resistant coating in an elaborate downstream working step.

The new CoverForm method from Evonik and KraussMaffei is a cost-effective alternative to the classic coating method. In the CoverForm method, PMMA parts are flooded with a reactive system while they are still in the injection mold. The surfaces of products made this way are highly scratch-resistant and are notable for their excellent wear and chemical resistance. Although flooding in the mold lengthens the cycle time compared to that of standard injection molding alone, CoverForm offers huge time savings when the conventional downstream coating of PMMA parts is included in the overall picture: CoverForm simply eliminates many of the time-consuming downstream processing steps. These include the cleaning of the part surface, and the application and flash-off of primer and hardcoat.

The CoverForm coating material, developed by Evonik, is a solvent-free and siloxane-free, two-part reactive system based on multifunctional acrylates. It hardens under the influence of heat and UV radiation. The CoverForm thermoplastic molding compound is a specially designed PMMA which Evonik supplies exclusively under the name Plexiglas cf. Since these two systems have been tailored to each other, the coating material bonds outstandingly to the surface of the thermoplastic compound. →

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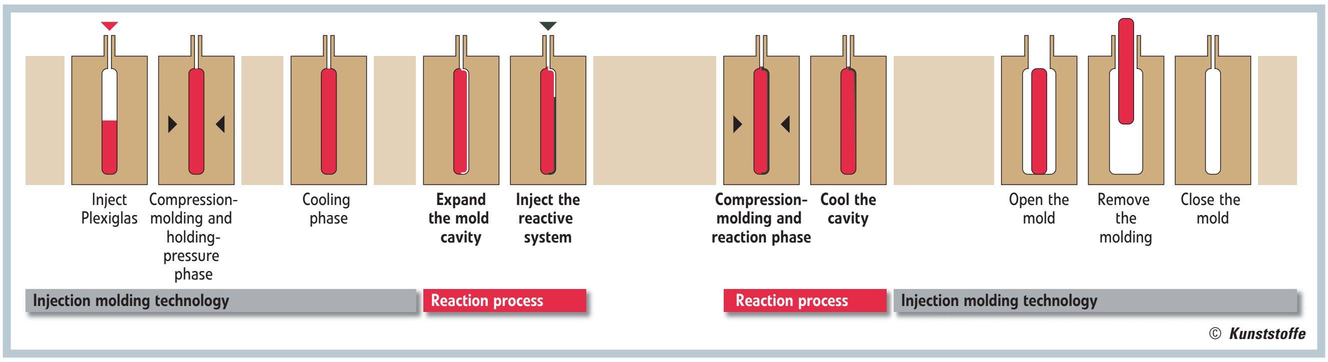

Fig. 1. Schematic representation of the CoverForm process

How It Works

In developing the CoverForm process, KraussMaffei combined its in-house expertise in injection molding with that in reaction process machinery. The outcome is an injection molding machine fitted with a flooding assembly. The liquid coating is introduced into the mold via an injector nozzle, which is integrated into the mold in the manner of a hot runner.

There are three phases in the production of the coated PMMA parts **(Fig. 1)**. First, the plasticized PMMA is injected into the mold and compression molded. The part is then allowed to cool inside the mold. Second, the cavity is enlarged to create a space for the surface coating. This gap is then flooded with the liquid reactive system. The mold then performs a further compression stroke. At the same time, the temperature of the mold increases and the coating material starts curing. Third, an industrial robot removes the coated part from the mold and places it in a UV-curing tunnel where the coating is post-cured **(Fig. 2)**. The sprue is removed by laser cutting **(Fig. 3)**.

Everything under Control

The CoverForm process utilizes dynamic mold heating (DMH), developed by KraussMaffei. Each mold half contains two heating planes. One is located very close to the cavity, while the other is slightly further away from it. In the default state, one heating circuit supplies all four heating loops in the mold. Mold heating and cooling are performed by switching the heating channels close to the cavity to a higher or lower temperature. The heating channels further away from the cavity keep the temperature level constant and serve as a heat store for effecting rapid temperature changes. The mold can thus be switched to different temperature levels very precisely and quickly.

Space-saving and Efficient Manufacturing System

Since the innovative CoverForm system solution integrates parts coating into the injection molding process itself, it offers numerous economic benefits. The coated parts are ready for installation as soon as they leave the manufacturing cell – unlike the case for the classic downstream-coating variant. CoverForm therefore eliminates all the logistics required for parts coating. It also boost the economics of the method because a CoverForm machine has a much smaller footprint than a coating line. The quality of CoverForm parts, too, leaves nothing to be desired. Since the mold is closed when flooding takes place, dirt cannot get between the part surface and the coating. What is more, the method keeps fluctuations in coating thickness to a minimum, thereby reducing consumption of coating material. Added to which, the rejection rates are low.

All these advantages combine to make CoverForm a space-saving, cost-effective and efficient production system for PMMA parts that must exhibit high mechanical and chemical resistance.

Excellent Surface Properties

Tests on specimen parts confirm the excellent service properties of CoverForm surfaces. The Taber abraser test **(Fig. 4)** and the sand-trickling test were used to study the abrasion resistance of the coated parts. In the Taber test, the surfaces of the specimens are tested for sliding abrasion by two counter-rotating friction wheels. Abrasion-induced haze in the CoverForm specimens was 6.4 % after 500 cycles under a contact force of 500 g.

The sand-trickling test consists in allowing 3 kg sand of defined grain size to fall evenly through screens from a height of 1.6 m and onto the specimen, which is mounted on a rotary table at an angle of

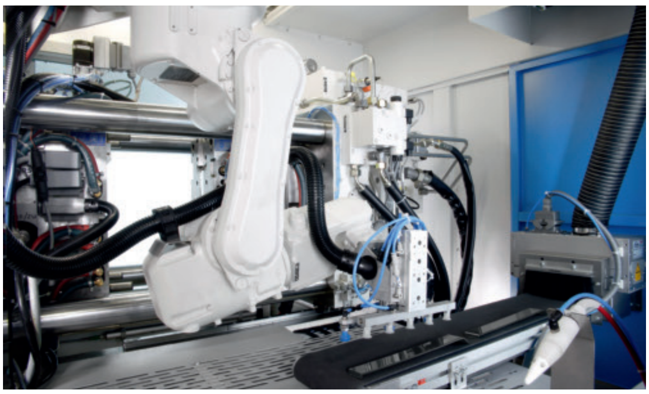

Fig. 2. Post-curing of the functional coating in a UV tunnel (using the example of a transparent display window)

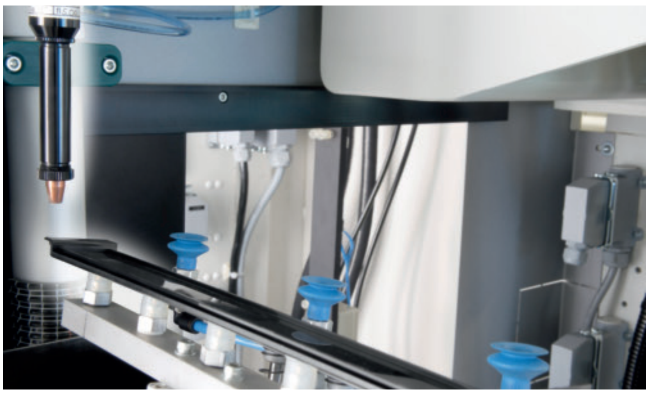

Fig. 3. Separating the sprue by laser (using the example of a transparent display window)

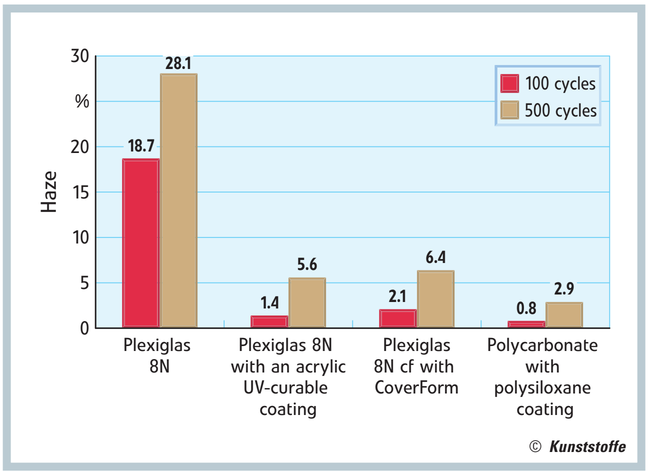

Fig. 4. In the Taber abraser test, CoverForm parts yield values comparable to those for Plexiglas 8N parts coated with acrylic-based lacquers

45°. The increase in luminance reduction serves as a measure of the light scattered by the damaged surface. The lower the luminance value, the less damage has been done to the surface by the sand. At 2.5 cd/lx m², the CoverForm surface is on a par with crown glass subjected to the same test.

The scratch resistance of the CoverForm surface was further determined with the aid of pencil hardness and the Erichsen 413 scratch hardness tests. Pencil hardness is measured by clamping a pencil against the test surface at an angle of 45° and then pushing it over the surface. The test is repeated at decreasing pencil hardnesses until the tip fails to leave tangible scratches on the surface. The pencil hardness result for CoverForm was 7H, while that for uncoated PMMA and uncoated polycarbonate was just 5H and B respectively. Polycarbonate treated with polysiloxane returns a pencil hardness of H.

To determine the Erichsen scratch hardness, radial scratches are made in the specimen by a combination of different styluses and a lever arm with an adjustable weight **(Title picture, Fig. 5)**. The scratch hardness is quoted in terms of the smallest weight to leave a visible, continuous scratch mark after a single rotation of the rotary table. Scratch hardness can be determined from the depth of penetration in addition to inspection. The penetration depth is determined with a Talysurf Stylus Profiler (manufacturer: Taylor Hobson Ltd, Leicester, England). CoverForm parts in this test exhibited significantly lower penetration depth than comparable products made of PMMA with UV-curable coating or of PC with polysiloxane coating **(Fig. 6)**.

The chemical resistance of the CoverForm coating was examined in the suncream and hand-cream test as per PV 3964. The cream is applied to the specimens, which are then left in an oven for 24 h at 80 °C. The scratch resistance and adhesion of the coating are then determined. The tests showed that the cream does not change the scratch resistance or damage the surface. Furthermore, CoverForm surfaces treated with the cream scored a crosshatch ranking of GT 0. CoverForm parts also perform very well in weathering tests. After 4,000 hours' exposure in a xenon arc device, a crosshatch test on the surface again returned a value of GT 0.

Conclusion

CoverForm is a new method for producing PMMA parts whose surfaces must be highly scratch-resistant and chemical resistant. In the CoverForm method, coating occurs in the injection mold itself, and not downstream. This slashes manufacturing costs. Extensive material tests demonstrated the outstanding properties of the resultant surfaces. ■

Fig. 5. Testing scratch hardness as per Erichsen 413

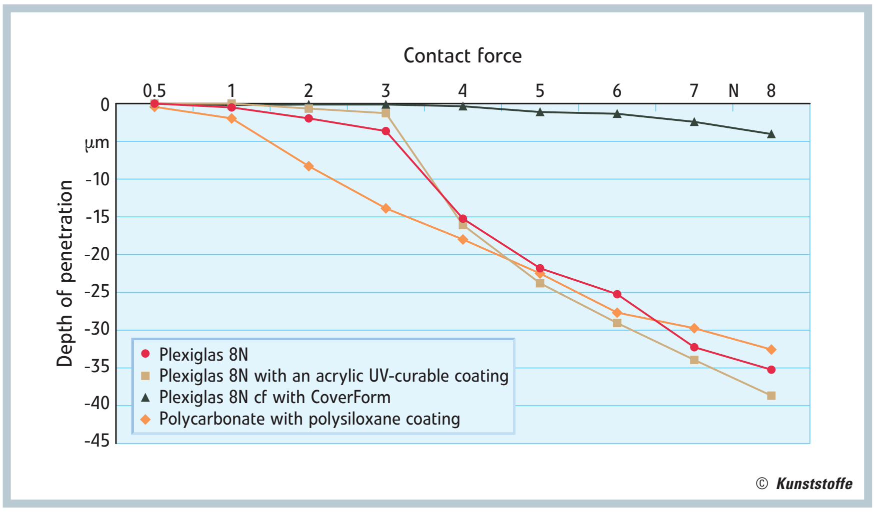

Fig. 6. The Erichsen scratch-hardness test confirms the mechanical stability of CoverForm parts

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