High quality interior surfaces produced in a SkinForm process

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Abstract

The new SkinForm process is based on a combination of two technologies: injection moulding and reaction moulding. It was developed in a joint project involving close cooperation between Sarnamotive Schenk GmbH, Krauss-Maffei Kunststofftechnik GmbH and Rühl Puromer GmbH. As a method for manufacturing vehicle interior trim parts with high-quality surfaces, the SkinForm process offers an attractive cost/benefit ratio and also opens the way for new design concepts.

The goal of the project was to support automotive manufacturers' ability to offer mid-range and economy class cars with high-quality interior features, in line with rising consumer expectations. Cost was a major consideration, as the market is unlikely to accept prices higher than those for parts from conventional production. The three partners have developed a cost-competitive, mass production solution for vehicle interior trim, which also has considerable potential for adaptation to other applications.

Specifying surface quality for vehicle interiors

The commercial success of a new car model is influenced to an increasing degree by the design of the vehicle interior, because its features and its look and feel play a growing role in consumer purchase decisions [1]. In developing the interior components for new models, manufacturers need to consider not only technical specifications, but also "soft" factors. The trend towards "feel good" cars makes it imperative for plastics processors and their partners to achieve a balance between the demanding specification profile for a component and the need to keep costs competitive. Features once exclusive to top-of-the-range models have now become standard in mid-range and economy class vehicles. In these categories, however, margins are far smaller and higher costs cannot be recovered even through higher production volumes.

It is rarely acceptable for a new component to cost more than the version it replaces.
Manufacturers are reluctant to make the necessary investment in the new technologies and they face competition from countries with lower manufacturing costs. At the same time, the customization options being offered by automotive manufacturers require the production of different variants for many components. For example, in the most basic version, an item of seat trim might comprise two or three components. With the inclusion of storage features and mountings for electric motors, the component count for seat trim in a highly customizable luxury class vehicle could easily be higher than ten components.

Properties that people generally expect in all vehicle interior components are pleasant feel (haptics) and impeccable appearance (optics), long service life and UV resistance. Many parts are soft-coated to avoid giving consumers the impression that they are buying "cheap plastic". Surfaces close to the floor need to be highly scratch-resistant to withstand the wear and tear caused by people getting in and out, loading and unloading, and driving the vehicle.

Where components touch, radii are often very tight due to the very close fit and minimal gap tolerances. All the processes used to produce surface finishes (back compression moulding, back injection, painting, etc.) must function without causing distortion to the decor or the graining. Otherwise there will be visible differences between the appearance of adjacent parts.
These examples make clear some of the challenges facing automotive components suppliers, which influence the component development and production.

Sarnamotive Schenk GmbH is a first-tier automotive components supplier of many years standing. The company produces interior trim parts with a strong focus on seat trim. In early 2003, Sarnamotive Shenk joined forces with Krauss-Maffei Kunststofftechnik GmbH and Rühl Puromer GmbH to develop a new process for producing parts with high-quality surfaces. The primary aim was to develop an alternative process especially for floor-level seat trim. Previously these parts were produced in a two-step process: injection-moulded from ABS and then soft-coated. As with other soft-coated seat trim components, this produces pleasant haptic properties, but the coating layer, which is usually only micrometers thick, is very susceptible to scratching. This quickly degrades the attractive optics.

Fig. 2:
Study for an added-value SkinForm seat belt cover for the Mercedes Benz E-class (Source: all pictures except (1) by Krauss Maffei)

Combining thermoplastic substrate and PU surface in a one-step process

In addition to high scratch-resistance and zero warpage as described above, the three partners defined further development goals for the new process:
• Surface with pleasant leather-like haptic properties
• Surface finish as thin as possible
• Process must lend itself to mass production
• Suitable for complex, highly curved surfaces with tight radii
• Suitable for parts with apertures
• No post-mould finishing of parts
• Suitable for complete modules made up of different parts
• Costs no higher than those of a soft-coated part
• One-step process

Evaluating existing methods against these criteria disqualifies most processes: soft-coated and TPE surfaces are not sufficiently scratch-resistant, film or imitation leathers often tend to warp when applied to parts with three-dimensional geometries in in-mould labelling processes. One process that meets most criteria is flow-coating a pre-shaped part with a PU skin. Flow coating is used today to produce decorative profiles and covers. As a two-step process, however, PU flow-coating is relatively cost intensive. For this reason, its use tends to be restricted to small volume production or luxury components. The table below compares the advantages and disadvantages of currently available processes.

The goal of the joint development project was a one-step process with no post-mould processing. The three partners each contributed their special strengths to the project: Sarnamotive Schenk concentrated on the design of components and moulds, Krauss-Maffei developed the machine and control systems – with its in-house reaction- and injection-moulding expertise, the company was ideally qualified for the task – and Rühl Puromer took on the challenge of developing the PU skin system (commercial name: puroskin™). Inter-company cooperation was effective from the start, thanks to a rapid and fair definition of working conditions and excellent communications which kept all partners informed about progress and results. Every member of the development teams was always in possession of the latest information, and short, clear decision paths guaranteed the necessary fast decisions.
Table 1: Every decor process has advantages and disadvantages. The aim in process integration and new process development is a dense range of benefits

<table>
<thead>
<tr>
<th></th>
<th>Injection moulding</th>
<th>Softcoating of moulded parts</th>
<th>Insert moulding</th>
<th>In-mold lamination of imitation leather and soft touch films</th>
<th>Multicomponent moulding, esp. overmoulding with TPE/TPU</th>
<th>Flow coating with PU skin in two-step process</th>
<th>SkinForm process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leatherlike haptic properties</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>+</td>
<td>0/+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Scratch resistance</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Complex surfaces with extreme three dimensionality and tight radii</td>
<td>+</td>
<td>+</td>
<td>0</td>
<td>0</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Apertures</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>0/+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>No warpage of decor material or grain</td>
<td>0</td>
<td>0/+</td>
<td>-</td>
<td>0/+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Enhanced surface as thin as possible</td>
<td>0</td>
<td>+</td>
<td>0/+</td>
<td>0/+</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Soft-touch</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>+</td>
<td>0</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Partial soft-touch</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>+</td>
<td>0</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>No post-mould processing</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
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<td>No preforms</td>
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<td>+</td>
<td>-</td>
<td>0/+</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Suitable for mass production</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Conceal injection moulding defects</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>0/+</td>
<td>+</td>
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<tr>
<td>Minimal part warpage</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td>One-shot process</td>
<td>+</td>
<td>-</td>
<td>(preforming inserts)</td>
<td>(trimming parts)</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
</tbody>
</table>

+ feasible
0 feasible with limitations
- not feasible

Structuring the project in this way ensured highly effective deployment of development resources and optimized the time factor, resulting in substantial cost savings.

All innovations face the same challenge: unless all parties are prepared to invest the necessary resources, process optimization will not take place, let alone new development.
The open and communication-intensive structure of this three-way partnership was a major factor both in keeping development costs low, and in sharing them as fairly as possible. In any development partnership, open knowledge is without doubt the best springboard to achieving a technology lead.

**Process steps**

The starting point for the new process was conventional multicomponent technology. Similarly, the choice of mould technology, eg, sliding table, rotary table, index plate, core-back or swivel platen systems, is dictated by part geometry, production volume and projected production cost [2].

For this project, the partners chose a simple sliding-table mould, which was designed and built in Sarnamotive Schenk's own mould-making facility. The design met all criteria for process stability and positioning accuracy of the rigid components.

In the SkinForm process, a PU mixing head is docked into the second cavity in the mould instead of a second injection unit. The thermoplastic substrate (glass-fibre-reinforced polyamide) is injection-moulded in the first mould cavity.

The component is injected centrally with a hot runner and needle shut-off nozzle. At the end of the cooling phase, the mould opens and the sliding table traverses into the second position where the PU system (puroskin) is injected using a type of film gate. Once the reaction process has completed, the mould opens and a linear robot removes the finished part from the ejector side.

The sliding table traverses back to the starting position to start a new cycle, while the robot transfers the demoulded part to a punch where the PU sprue is removed, after which the part is placed in a packaging unit.
The partnership project has already run trials of the SkinForm process for two seat-trim components for the current Mercedes Benz E-class. Total cycle time to manufacture a seatbelt buckle cover, the application shown at the K2004, is approximately 90 to 95 seconds.

The injection-moulding process takes up about one third of the cycle time. Reaction time for the puroskin is 40 to 45 seconds. With a sliding-table system, parallel processing allows cavity 2 to be prepared for PU casting (release agent is applied and the cavity vented) while the injection, holding and cooling phases are taking place in cavity 1.
Cost-effective machine and mould technology

The injection-moulding machine is a KM 160-750 CX. The clamp force required for the SkinForm process is the same as for standard injection moulding of a comparable product, so there is no outlay for a new injection-moulding machine.

Fig. 4: CAD concept for a SkinForm system showing the KM 160-750 CX, the linked PU storage unit and integrated linear robot with packaging system.

The sliding table for the mould is mounted on the machine’s fixed platen. The core side of the mould is mounted on the moving platen. The PU mixing head is installed lower down. The mixing head can be attached in a position to suit the part design, because the PU components are pumped to the mixing head through flexible hoses. This can simplify part design compared with conventional 2C technology, where the second thermoplastic component is delivered by an injection unit in a predetermined position.
The PU metering unit is a RIM-Star MiniDos optimized for small output volumes. It is ideal for this application where the slim wall thicknesses require very small shot volumes. The metering unit is teamed with a type MK 5/8 ULKP 2KVV transfer mixing head, which can be replaced by a multicolour mixing head if required. The multicolour head allows colour changes on the fly, without stopping the production run. The compact reaction unit takes up a minimum of space beside the injection-moulding machine.

The operator programs the handling system using the separate robot menu. In this case, the robot is a linear robot from Krauss-Maffei's LR 100 series. Its movements can be parallel to and coordinated with those of the injection unit, metering unit and sliding table.

The injection-moulding machine's MC5 control also controls the robot and the PU metering unit. The set-up technician can monitor all processes on the operator panel display and intervene as necessary. This is a space-saving control solution for fully-automated processing in mass production applications. Links between the control modules for the thermoplastic and the PU machines ensure that PU metering is activated only when a PA substrate is in the cavity.
Because both the injection-moulding machine and the PU equipment come from the same engineering company, the development project benefited from the fact that only minimal adjustments to the two systems were required. With software, interfaces and other features based on a similar approach, it was easier to link control systems, machine design and commissioning. The fact that control and monitoring functions are linked in one software program is an important factor in achieving the high processing accuracy and process stability necessary for mass production.

**Partial soft-touch effects**

Puroskin is an aromatic, water-borne, two-component elastomer casting system. Foaming of the material produces a soft-touch effect that can be modified by changing the thickness of the PU skin. In addition, by controlling the hardness of the puroskin system itself, it is possible to produce a soft-touch layer that varies in hardness from one area to another on the same part. The SkinForm process achieves soft-touch effects comparable to the values achieved with free foam. The PU system used in the project has a density of 800 kg/m$^3$; hardness is 50 to 53 Shore A.

In the seatbelt buckle cover, the wall thickness of the PU skin varies locally between 0.8 mm and 4 mm. This unique and hitherto unachievable ability to define areas of different hardness over a single component gives the SkinForm process a clear advantage over other soft-layer techniques.

**Fig. 7:**

Wall thickness of the PU skin varies locally between 0.8 and 4 mm

PU reaction time is constant regardless of differing wall thickness, so the cycle time is not affected. This gives PU a decisive advantage over thermoplastic
elastomers. During development, Rühl Puromer put a lot of effort into matching reaction time to the injection moulding cycle. Their success ensures that total cycle time for the process is not extended unnecessarily. At the same time, it opens the way for other mould concepts, eg, rotary table designs.

A further advantage of puroskin is that wall thickness discontinuities will not show on the PU surface and neither will ribbing. This allows the designer to choose the most effective part design to meet safety requirements without having to consider whether reinforcing structures will be visible on the surface.

The surface is also resistant to abrasion and scratching, and retains its leatherlike haptics. This is where puroskin casting systems are superior to flexible or elastic thermoplastics (TPE/TPU). The adhesion of the skin to the PA substrate is very strong and equal to TPE applications. Last, but not least, the soft surface has the ability to dampen the clattering of objects on trays or in cubby holes.
Exact reproduction of different surface structures

The free-flowing PU system used for the puroskin makes it possible to reproduce very delicate surface structures precisely and lastingly – even with tight radii. As a coating process, it eliminates the problem of warping associated with many decors. If the design calls for it, the SkinForm process can be used to produce a variety of surface finishes and, for example, imitation decorative seams, on one and the same part. There is no problem in changing the graining for specific surface areas. There are almost no constraints on pigmenting the polyol and the moulded part needs no subsequent painting. The SkinForm process produces flashfree parts, so that no post-mould processing is required.

Rühl Puromer developed a UV-stable system (compliant with PV 1303 for seat areas) based on an aromatic isocyanate. Both the basic puroskin mix and its coloured variants comply with emission criteria (VDA 278 for VOC emissions and fogging). Total VOC emissions are under 130 ppm, total FOG emissions are under 140 ppm.

With its high values for elongation at break, the puroskin is an additional safety feature. In the event of the thermoplastic substrate shattering in an accident, the skin will contain the sharp splinters and prevent them from penetrating the passenger compartment. Elongation of the puroskin up to 260% is possible; after warm storage this rises to over 300%.

The economics of the process

For mass production, the process, the machines, material and peripherals must be carefully selected for their ability to meet component specifications at an acceptable cost. This applies even more strongly to new processes, where it would be unacceptable for unit prices to exceed prices for parts from conventional production.

The partners thus went into the development project with a clear goal for cost structure. The reference value was the cost of a soft-coated part, as the soft-coating process currently sets the standard for buckle covers and other seat trim parts.
At first sight, the cost structure for soft-coating is comparable with the costs for the new SkinForm process. When part properties are compared, however, soft-coating falls behind, because the SkinForm process can produce a higher quality surface for the same cost. A soft-coat finish is not scratch-resistant in the long term and has the further drawback of being applied in a second step. This second step is often carried out at a different location, necessitating suitable transport and storage logistics. In addition, successful soft-coating demands injection-moulded parts with a very high surface quality. Small defects (e.g., sink marks, or the impression of the sprue or a rib) will be clearly reproduced in the coating. The other processes discussed below conceal these problem areas, reducing the number of rejects from the injection-moulding step compared with the soft-coat process.

One of these processes is insert moulding. This requires a lot of detailed and precise effort ahead of the injection-moulding process: special film inserts must be produced, preheated, thermoformed and punched, before they are placed in the mould. The two processes must be combined exactly to avoid different shrinkage effects. Logistics effort is also involved because the inserts must be moved to the injection moulding machine and precisely positioned in the mould. By contrast with the SkinForm process, insert moulding does not allow the soft-touch effect to be varied on a single part.

Back-injection and back-compression moulding of imitation leather, soft-touch film or textile decor material [3] certainly produces good haptics which can be individually selected, while careful choice and preparation of the decor material will ensure good scratch-resistance.

These processes reach their limits on parts with complex geometries and tight radii, where it becomes difficult or impossible to meet quality criteria and ensure that adjacent parts make a consistent optical impression (decor warping). The need to trim excess decor material is also a significant cost factor. Apart from the cost of the trimming process itself, disposing of the large quantity of waste produced increases manufacturing cost.
Conventional PU flow coating is the only process that produces surface properties approaching SkinForm quality. As a two-step process it has a significant cost disadvantage, which is exacerbated by various post-mould processing steps (deflashing). Aliphatic PU systems are often used for the coating. They are UV-stable, but are not capable of producing the required soft-touch effect because they cannot be foamed. A further drawback is their longer reaction time.

This brief discussion identifies the advantages of the SkinForm process compared with mainstream surface enhancement processes. Because of the superior decor properties, the SkinForm process even scores over the process which at first glance appears cheaper.

In Europe, and in particular in Germany, high labour costs represent a substantial share of the manufacturing cost and any post-mould effort adds to these costs. Unless a part is destined for a top of the range car or an individual model where customers actually expect a hand-finished vehicle, manufacturers will always reduce costs by reducing the number of process steps and increasing the level of automation. The right production automation helps to keep costs in check.

Fig. 9: SkinForm production unit with integrated automation on small footprint
Potential applications

The advantages of the SkinForm process open the way to many new applications where surfaces which are subject to heavy use also need to produce a high-quality impression. Automotive applications include substituting this simpler more cost-effective process for the complex laminating processes currently used to produce seat shells and headrest covers. Crash-relevant components, such as the steering column shroud, will profit from the high break-elongation values of puroskins. Seat shells, which are sometimes made of untreated ABS even for mid-range vehicles or luxury two-seaters can be enhanced without significant extra cost to match the overall quality level of the vehicle. Trim modules made up of several parts, such as door trim panels or centre consoles, can be produced and decorated using the SkinForm process with no risk of unsightly decor warping where adjacent parts meet. In these cases, difficult and time-intensive colour match testing can be partly eliminated.

There is also strong potential for launching SkinFormed parts in other industry segments: trim for in-line skates, and covers and trim sections for products such as cyclists' crash helmets, could all be enhanced at minimal extra cost. The process could be used to produce anti-slip surfaces for laptops and other telecommunication and IT products. Furniture, home appliances and electrical equipment are all potential application areas for the SkinForm process because it is capable of producing parts that satisfy increasing quality requirements within tight cost constraints.

Fig. 10: SkinForm seat belt cover fixed on car seat
Summary

The development of the SkinForm process opens up new ways of producing high-value premium surfaces at very competitive prices. Injection- and reaction-moulding are combined in a single process to produce highly scratch-resistant parts with optical and haptic properties comparable to imitation leather finishes. The ability to set the softness/hardness makes it possible to implement new, individual soft-touch effects, which can be varied for different areas of the same part. Designers have the widest choice of surface grain, even to the extent of different grains on one and the same part. Even with tight radii, the surface finish is reproduced exactly and with no risk of distortion. This is especially important for geometries which are complex, due, for example, to extreme three-dimensionality or the existence of apertures. The unit price for a SkinForm part is comparable to a similar part produced by soft-coating, but the SkinForm part with its "quality" look and feel clearly adds more value.

The three development partners, Sarnamotive Schenk GmbH, Krauss-Maffei Kunststofftechnik GmbH and Rühl Puromer GmbH are currently working on further improvements to the SkinForm process in order to broaden the range of potential applications and adapt it to widely varying specifications.

References