The new central touchpad controller in the latest Mercedes-Benz C Class (figure: Daimler)

From Design to Volume Production

Successful Development Concept for the Touchpad on Mercedes-Benz Cars

Thanks to an innovative touchpad with a spherical surface, owners of current Mercedes models can now drive more safely. Unlike with previous models, they are no longer distracted from the road ahead by having to operate many different switches. This new development was made possible by the early and trusting cooperation of all partners involved in the project.

Driving has now become more than just a journey from A to B. Manufacturers of premium cars, in particular, want to offer their customers a package of technology, quality, and lifestyle. This ranges from engine technology and driver assistance systems through control concepts for various functions and instrument displays to design of the cockpit and complete interior. At the same time, new functions, infotainment and comfort systems, and internet services must be integrated into cars [1]. This gives rise to new challenges like intuitive control in order not to distract the driver, the creation of important spaces for design, and efficiency in the diversification of production.

Many manufacturers have taken an important step towards "clean up " the control element landscape and simplifying operation of the controls with the introduction of the scroll wheel (**Fig. 1**) as a central control element. On the other hand, smart phones and tablets with intuitive control (gesture control) on the touch display have become part of the everyday experience of the majority of the population. This was the starting point for the vision of the designers and engineers at Mercedes-Benz AG, Sindelfingen, Germany. But straightforward transfer of cell phone technology was not an option for reasons of driving safety.

Continually reading the traffic situation and reconciling it with their own intentions is a primary task of vehicle drivers. Searching for switches and looking at displays that are usually outside the driv-

er's field of vision to check selection of the required switch function can distract the driver from the road ahead. Finally, it is important to ensure durability because a car is not designed to last just two or three years. This applies particularly to the actual control interface.

Materials and Processes

The control interfaces of the touchpad must withstand mechanical abrasion during use and (often careless) cleaning with chemicals, creams or cleaning agents. Their original material properties should not essentially change throughout the entire period of service.

Of all the possible thermoplastic materials that could be used, PMMA (polymethyl methacrylate) has the highest surface hardness and scratch resistance. But, nevertheless, for applications with very high requirements such as the touchpad, even PMMA components must be given an additional coating to protect against scratching and chemically induced wear, such as matting and stress cracking. For this reason, the specialists at Mercedes-Benz chose an injection/compression molding process with integrated surface coating as the material/process concept for this application. The process is known by the brand name CoverForm (**Table 1**).

Criteria	Mineral glass	Hard coated film insert technology	Injection molding, painting, laser technology	Film insert, overmolding with CoverForm technology
Scratch resistance	✓ - ✗	✓	✗	✓✓
Flexible textures gloss/matt	✗	✗	✗	✓
Touch ribs	✗	✗	✓	✓
Glass optics with depth effect	✓✓	✗	✗	✓
Cost	✗	✓	✗	✓
Free-form surface	✗	✓	✓	✓
Media resistance	✓✓	✓✓	✓	✓✓
Scratch protection, symbols without post-finishing	✗	✓✓	✓	✓✓

Table 1. Selection matrix for materials to produce the touchpad surface (source: Daimler)

In conventional production of such components, a separate coating operation in a coating line follows the injection molding process. The whole process normally comprises 14 steps. The CoverForm process [2], developed by the materials specialists at Evonik Performance Materials GmbH, Darmstadt, Germany, in collaboration with experts in injection molding and reaction technology from KraussMaffei Technologies GmbH, Munich, Germany, does the same job in only four steps. The injection molded PMMA component is flooded with a reactive system directly in the injection mold in a second step and then thermally cured. After demolding, curing is completed with UV radiation. Although in-mold coating lengthens the cycle time by about 10 to 15 s compared with standard injection molding, many downstream processing steps are eliminated, such as cleaning the component surface or the application and flash-off of primer and hardcoat, which often lead to defects and reject parts. The whole process is carried out in a compact production cell. It takes up considerably less space and production time than conventional production methods and simplifies the logistics.

Fig. 1. Cockpit of the old C Class with many different switches in the center console (figure: Daimler)

The material system developed by Evonik comprises two components: the PMMA molding compound supplied in pellet form under the name Plexiglas cf and the liquid two-part reactive system cf30 for the scratch-resistant coating. The suffix cf denotes PMMA molding materials and reactive systems optimally tailored for this process. The solvent- and siloxane-free reactive coating system consists of monomeric multifunctional acrylates and a thermal initiator. Before processing, the system is cooled and homogeneously mixed into a "quasi one-component system". When stored away from light at the specified low temperatures, this mixture remains usable for a sufficiently long period of time. After curing, the molding material and reactive system form a tight interlocking bond without a phase boundary, since the reactive system penetrates into the substrate and is firmly anchored to it by chemical bonds. This surface continuity and the well matched refractive indices of the coating and plastic prevent optical interference that would be manifested as undesirable rainbow effects on the surface.

Tailored to Each Other

In the CoverForm process (**Fig. 2**), PMMA is injected into the mold cavity and compressed (injection compressing molding). After a short cooling phase to consolidate the thermoplastic, the cavity is expanded by a few tenths of a millimeter and »

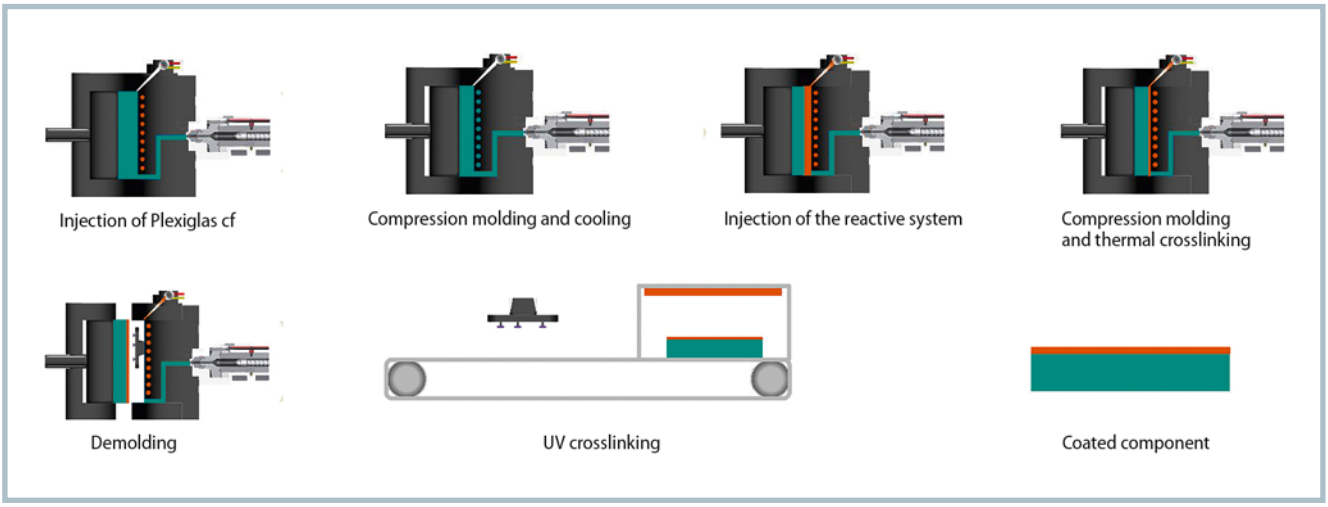

Fig. 2. Schematic diagram of the CoverForm process (figure: Evonik)

the coating is injected with microliter precision at exactly the required temperature so that the entire component surface can be flooded. In the following compression molding stage, the acrylate system is spread over the component surface in the desired coating thickness of about 30 µm. At the same time, the mold is heated very quickly to the starting temperature for crosslinking (polymerization). The reactivity is tailored so that, after thermal crosslinking and cooling, the molded part can be demolded by a robot without any problem and UV post-cured in the production cell within the injection molding cycle. It is this second crosslinking step that gives the component its final, excellent chemical and mechanical properties. Two-stage crosslinking also guarantees that the entire coating process lengthens the injection molding cycle by no more than 10 to 15 s. The actual curing process accounts for only about 1 s of this extra time, while the rest is taken up by heating and cooling.

The entire fine tuning of material properties and process technologies involved close cooperation between KraussMaffei and Evonik. For successful industrialization of the process, however, a suitable mold concept also had to be developed. Sealing the mold cavity from the low-viscosity coating component proved a major challenge. Sealing of steel on steel, as in the case of thermoplastic melts, is impossible since the coating immediately penetrates into the split/mold gap and clogs this up. Another partner, the moldmaker Foboha (Switzerland) AG, Muri, Switzerland, came on board and

Fig. 3. Comparison of the abrasion resistance (Crockmeter with wool felt 9N) of test parts made from PMMA (above) and parts produced by the CoverForm process (below) (figure: Evonik)

solved this challenge by integrating the Thermostop technology patented by KraussMaffei. A further challenge was to achieve the uniform coating thickness of 20 to 30 µm over the entire coating surface. This required the additional task of measuring the coating thickness of the chemically and optically very similar materials of the composite (**Fig. 3**).

Collaborative Development

Collaboration between Evonik and KraussMaffei began back in 2006. The partners in the project were clear from the begin-

The Authors

Dipl.-Ing. Udo Gayer leads the Interiors Team in the Production and Materials Technology Division of Daimler AG, Sindelfingen, Germany; udogayer@daimler.com

Dipl.-Chem. Bernhard Klein works as a Development Service Provider for Plastics Applications in Vehicle Interiors at Arzberger Consulting & Engineering, Kusterdingen, Germany; bernhard.klein@a-ce.de

Dipl.-Wirt.-Ing. Sven Schröbel is Senior Manager Business Development in the Acrylic Polymers Business Line at Evonik Performance Materials GmbH, Darmstadt, Germany; sven.schroebel@evonik.com

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ning that the technology could only be successful if material and process development went hand in hand. As early as 2007, the two companies presented a concept study of CoverForm at K2007 in Düsseldorf, Germany, which attracted a great deal of interest from trade visitors. Since the end of 2009, Evonik has operated a competence center at its Darmstadt site in Germany. There, customers and others interested in the technology can have samples and initial prototype studies produced.

Daimler and the automotive supplier Continental AG, Babenhausen, Germany, were interested in the new technology from early on. Evonik and KraussMaffei had already carried out numerous standardized tests that demonstrated the required material properties. There then followed further tests of the type normally conducted in the automotive industry. Since Evonik and KraussMaffei had very carefully analyzed market requirements at the beginning of the development and drawn up appropriate specifications, they did not have to alter the material system to meet the requirements of these potential customers [3]. But the infant technology now had to demonstrate the readiness for industrial application necessary for a Mercedes. The components passed through several sample phases in which the design requirements could still be significantly altered. For these intermediate steps, the process developers had once again to demonstrate that the altered design requirements could also be fulfilled with this technology.

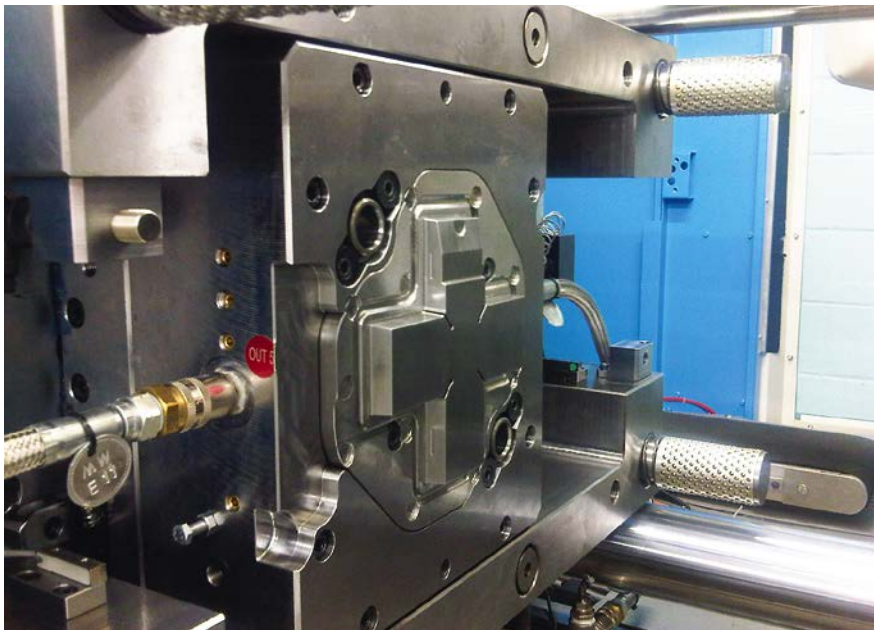

Fig. 4. The universal test specimen mold developed by Daimler was adapted for the CoverForm process in order to test important material properties, mold design principles, and process parameters at an early stage of development (figure: Evonik)

An important step on the way to industrial readiness was the adaptation of the universal test specimen developed by Daimler (**Fig. 4**) to CoverForm technology. This universal test specimen is a complex component used by developers to thoroughly test new technologies and materials intended for volume production of vehicle interior parts. In this way, the strengths and weaknesses of new technologies and materials can be identified at an early stage of development. The reactive system had to demonstrate on this test specimen that it could reliably cover structures, ramps, angles or ribs and was able to crosslink there. This test specimen also has surfaces that enable various surface tests to be conducted in accordance with Daimler Benz standards (DBL).

As a result of their close cooperation, all those involved in the project were able to complete development of the process on-time according to the specifications of Continental, the current volume producer and electronics specialist, and Mercedes. The whole touchpad has to be extremely durable with a long service life. It is required to operate in a temperature range of -40 to +80 °C, withstand loads of 80 kg, and survive two million actuations unscathed.

Fig. 5. View into the cockpit of the new C Class with the intuitive touchpad (figure: Daimler)

In Volume Production since 2014

The Mercedes C Class that went into volume production in 2014 is the first model in which a touchpad with a spherical surface (**Title figure**, **Fig. 5**) can be used to control nearly all the functions that the »

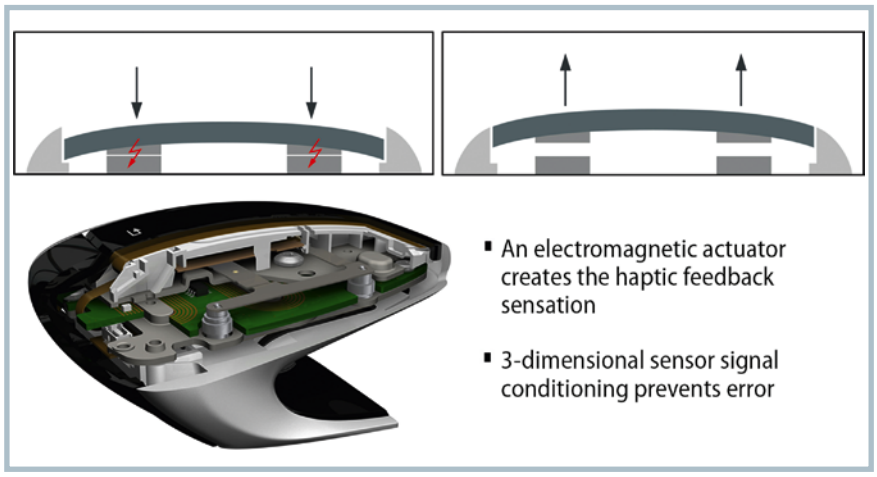

Fig. 6. Section through the C Class touchpad (below left) and schematic diagram of the electromagnetic haptic feedback system (above) (figure: Daimler)

driver is able to change. The system is called "Command online" by Daimler (The familiar scroll wheel is still retained to make the transition to the new system more acceptable for the user). At the time the new Mercedes-Benz touchpads were introduced, other touchpads fitted in cars still used flat surfaces like on notebook computers and offered no haptic feedback.

The newly developed touchpad, which is now fitted in almost all Daimler models launched on the market after the C Class, such as the V, S, GLC, GLE, and GT classes, has similar haptic feedback (called ForceFeedBack by Continental) (**Fig. 6**) to that of conventional switches. As a result, the driver is much less distracted when using the touchpad.

Interesting for Many Sectors

On the development path to production readiness, a series of pilot projects were also started to explore the use of this surface technology in entertainment electronics, household appliances, building services engineering, and clocks [4]. On the basis of the CoverForm process, Evonik and KraussMaffei together with glass finishing specialist Flabeg Deutschland GmbH, Nuremberg, Germany, produced reflection-free, scratch-resistant plastic covers [5] that could also be suitable for instrument displays in vehicle interiors. Since this process produces a surface that requires no further finishing, high reproducibility is ensured. The process also has the potential to produce adjacent glossy and matt areas on the same surface, while still retaining high scratch resistance and stability to chemicals [5].

Complete Solution for End Customers

For the industry partners involved in the development and volume production launch of the touchpad, CoverForm is an important innovation. The entire injection molding process, including scratch-resistant coating, takes place in a machine that is globally unique. The technical requirements are high – whether as regards the accuracy of the gap size for opening the cavity to flood the component or dynamic temperature control of the mold. This integrated process also makes an important contribution to the sustainability initiative of the VDMA (German Engineering Federation) [6].

For Evonik, the CoverForm process offers the possibility not only of supplying material but also of providing a complete solution for customers. Tests conducted at the Darmstadt competence center have now confirmed that CoverForm also works with other plastics, such as the copolymers ABS (acrylonitrile-butadiene-styrene) or ASA (acrylic ester-styrene-acrylonitrile).

This latest development shows how, by harnessing the potential of all project partners, customer requirements can be rapidly and effectively implemented in open, cooperative partnership. ■