Producing Large Exterior Parts with Integrated Functions and High-Quality Finishes

Facelift for Electric Vehicles

The combination of injection compression molding, direct coating and partial film insert molding enables a novel design for the front module of the BMW iX electric vehicle. Important in the development were extensive trials carried out by plastics manufacturer Covestro in its technical lab. On the material side, a base carrier made of polycarbonate flooded with polyurethane proved to be a successful combination.

Various production processes are combined to manufacture the front module of the BMW iX, known as the kidney. © BMW

The ShyTech design played a formative role in the development of the all-electric BMW iX. What this means is that functions such as the sensors for semi-autonomous driving should only be visible to the driver when he needs them. This requirement also had to be implemented in the development of the front module of the iX, called the kidney (**Fig. 1**). The electrical system also opened up additional freedom in the design of the vehicle front away from the classic radiator grille. The aim of the design was to develop an aesthetic front component with a three-dimensional depth effect that integrates certain driver assistance functions. At the same time, it was also to feature a multicolored Class A finish.

It also had to be ensured that the sensors function reliably under all operating conditions and that there is no icing of the outer skin above them, for example. In addition to the design goals, the high demands of the sensor technology also had to be met. For example, the radome had to be integrated seamlessly into the surface. All this required a finely tuned interplay between material, component and production development so it was only possible to realize this in close cooperation between the project partners.

Multicolor and with 3D Depth Effects

A 3D structure with prisms of varying depths was specified for the front component, which is incorporated in a transparent polycarbonate (PC) base substrate. Further finishing steps on the back of the component ensure a two-tone design. Together with the structure of the blank, they create the desired optical 3D depth effect. This approach results in wall thickness variations of up to 100 % on the back of the injection-molded PC base substrate. The volumetric shrinkage of the thermoplast also leads to some waviness in the surface of the component front. Consequently, it would not have been possible to achieve a Class A finish with conventional hardcoating processes. To solve this problem, integration of the direct coating (DC) process into the overall process was the obvious solution. In this process, the coating is applied with increased layer thickness in a closed injection mold.

This is where plastics manufacturer Covestro came into the picture. As one of the technological pioneers in automotive glazing from PC, DC for coating plastic parts and Film Insert Molding (FIM) for producing printed, functionalized and back-injected 3D film decorative components, the company has extensive experience in the relevant technologies. Over and above that, as one of the most important manufacturers of PC and polyurethane (PUR), the company was able to contribute its materials technology and application-specific expertise in these material families. This combined expertise played a major role in Covestro becoming a project partner for the front kidney of the BMW iX.

Successful Combination of FIM, DC and Injection Compression Molding

Together with BMW and other partners, a manufacturing concept was developed for the kidney that combines injection compression molding and FIM with DC. In this process, a 3D film insert is placed in an injection mold and back-molded with the transparent PC Makrolon AG (Automotive Glass-like) from Covestro. This produces a thermoplastic part with a partial film area, which is then coated with a transparent PUR coating system in the same mold using a RIM (reaction injection molding) mixing head (**Fig. 2**).

The coating layer is based on the materials Desmodur and Desmophen from Covestro. It imparts high scratch resistance to the component finish and is self-healing. Minor scratches simply disappear on their own after a short time. One benefit of the PUR reaction system is that it has little effect on the very good mechanical properties of the PC substrate. The PUR coating for the front panel meets all BMW's requirements for exterior components in terms of adhesion to the thermoplastic »

Fig. 1. The striking front panel of the BMW iX is made of the PC Makrolon AG from Covestro. Camera technology, radar functions and other sensors for the driver assistance system are all integrated into the large-scale component. © BMW

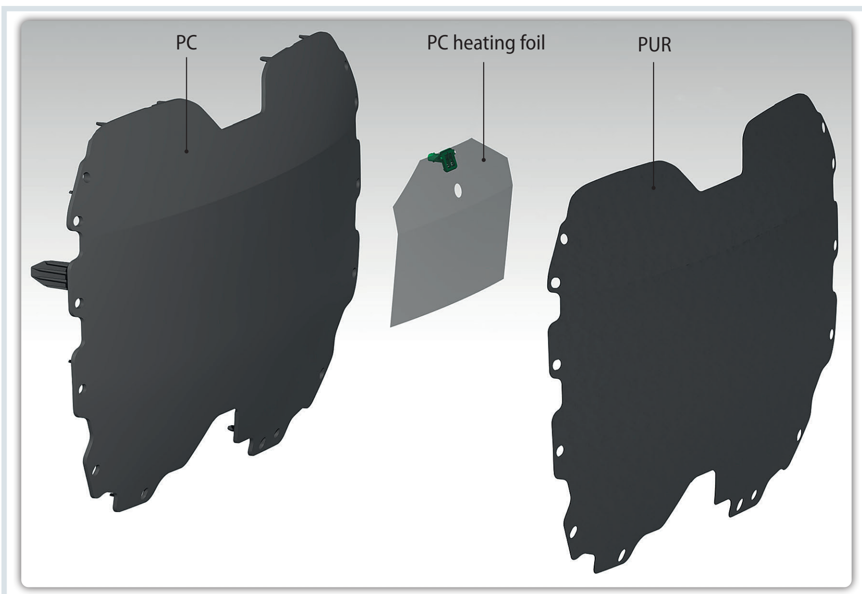

Fig. 2. A transparent and back-molded 3D film insert made of Makrofol UV244 with a heating function is integrated into the base substrate of the panel to keep the radar sensor ice-free. The entire part is coated with deep gloss PUR. © BMW

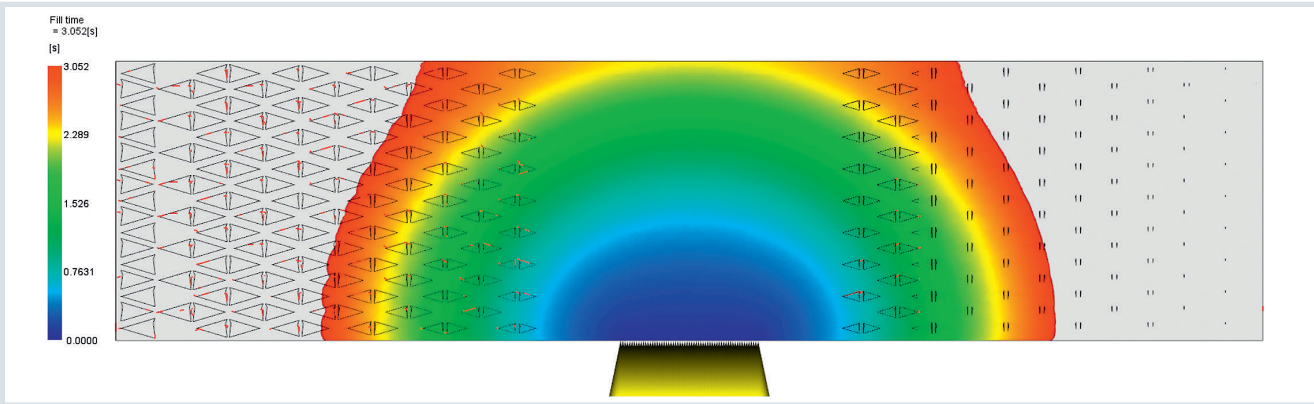

Fig. 3. Simulation of mold filling in the injection-compression molding process: the analyses helped to optimize the design of the geometry and wall thicknesses of the rear 3D design structure. © Covestro

substrate, abrasion resistance, color stability and weather resistance, among other things.

Integrated Heating Function Ensures Ice-Free Sensors

The partial 3D foil insert is placed in front of the radar sensor and fitted with heating wires and a plug connection on the back. The purpose of the heating function is to keep the radar sensor free of snow and ice in cold conditions. The insert consists of Makrofol UV244, a PC film from Covestro that is provided with UV protection. This ensures that the film does not yellow in the long term in the event of damage to the scratch-protection layer.

As previously mentioned, the back-molded material is made of Makrolon AG. This PC, which was specially developed for glass-like finishes in automotive exteriors, has been in mass production use in various components for many years. It boasts crystal-clear transparency. The material can be used to manufacture components with very good surface finish quality, which are characterized by high impact strength even at low temperatures. Its very high product quality and purity are based on the raw materials utilized and a dedicated production process that includes a filtration step for the melt. In addition, it contains only weathering-stable colorants to prevent fading of the component over the vehicle's service life.

Covestro provided detailed support to BMW in the development of the front panel throughout the entire project phase. For example, various development molds were trialed at Covestro's technical lab in Leverkusen, Germany. In the first step, a plate mold was provided with the design structure of the front panel in order to find the optimal wall thickness differences for the injection compression molding step. Important process-determining parameters were worked out and subsequently incorporated into the final component design. For example, it was possible to avoid air streaks resulting from the design structure. It was also important to determine the optimum distance between the foil preform and the gate and to check how process parameters affect the subsequent function of the heating foil.

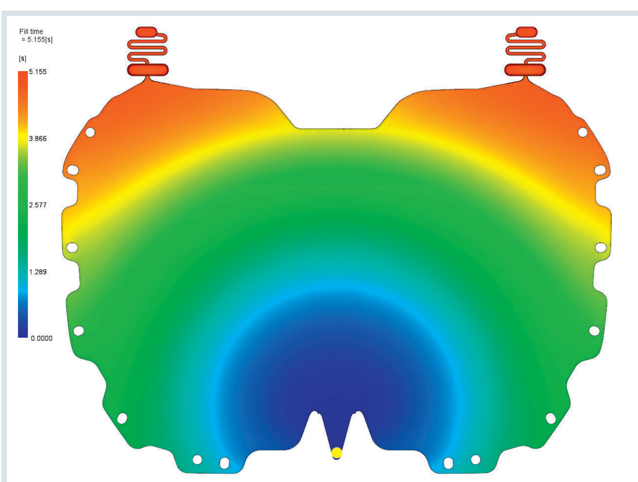

Fig. 4. Simulation of the time sequence of PUR filling using the series geometry of the kidney as an example: the investigations helped to determine both the optimum process parameters and the mold geometry. © Covestro

Experience from the Technical Lab Makes It Easier to Set up Mass Production

In the next step, all these findings were incorporated into the construction of a mold that was already designed for the FIM and DC processes. The first coated components with integrated film were produced on an injection molding machine with a sliding table. With these it was possible to reproducibly evaluate the quality of the finish and the visibility of the transition between the film and the PC substrate. Processing parameters could be optimized and important conclusions drawn about the correct positioning and fixing of the film in the mold. For the first time, it was also possible to assess how efficient the entire manufacturing process is. Important functions such as the behavior of the component under environmental conditions or the reliability of the radar function could be demonstrated realistically and the corresponding results validated by BMW's technical departments. Based on the experience gained, the company built a near-series prototype tool in original geometry. It was also tested in its entirety in the Covestro technical lab under near-production conditions. The experience accumu-

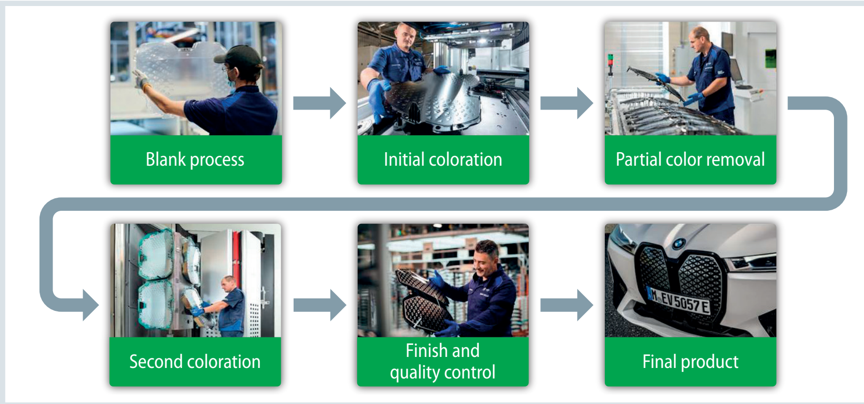

Fig. 5. The production process of the front module comprises several steps and procedures.
Source: BMW; graphic: © Hanser

panels made of PC since 2014. The latest culmination of this work will be on display at the K 2022 Plastics Fair in Düsseldorf, Germany: the concept of an injection-molded panel with additional design and functional features. These include FIM on both sides, elements for communicating with pedestrians and integrated functions such as edge-lit and hidden-until-lit functions that are only activated and backlit when operated. ■

lated in the various construction stages was a great help in smoothly setting up mass production at BMW in Landshut, Germany.

Simulations Reveal the Optimum Filling Pressure

As part of the project, Covestro carried out extensive simulations on the rheological behavior of both the injection compression molding material and the PUR reaction system during mold filling. This made it possible to minimize stresses in the injection-molded substrate, relocate weld lines to non-visible areas, avoid air traps and predict component quality in the back-molded film area (**Fig. 3**). For the PUR filling, simulations enabled the optimum filling pressure for the selected wall thicknesses to be determined and the vents for the PUR cavity to be positioned with millimeter precision (**Fig. 4**). In addition, Covestro has developed simulation methods to precisely predict shrinkage and warpage of the components flooded with PUR and the occurrence of air bubbles in the cavity during filling.

Multi-Part Production Line with Advanced Processes

In component production at the BMW plant in Landshut, a completely new production line was set up for the kidney of the BMW iX, incorporating a range of advanced technologies. The production layout was designed with particular attention to technical cleanliness. The focus was not only on the individual production steps, but also on the transportation and storage of all intermediate states of the component. To ensure optimum design of the value stream, all steps take place within the same production building. This prevents additional dirt and moisture from entering the process.

After the production of the blank described above on an injection molding machine with indexable inserts and integrated PUR unit, further production steps follow (**Fig. 5**): the blank is first painted black on the back and then laser-abladed in both the 2D and 3D areas. An annealing step follows to reduce local stresses. The second color is then applied by means of a PVD (physical vapor deposition) process. The process ensures a metallic appearance without impairing the radar function of the integrated sensors.

A topcoat is then applied to protect the PVD layer from environmental influences and provide the final coloration. In the end-of-line area, the component edges are sealed by a robot to protect the PC from environmental influences. Finally, all components are subjected to radar and heating checks to ensure that they function properly. A new production monitoring system records all relevant parameters, thus guaranteeing their traceability to the components and even to each individual production step.

K 2022: New Front Panel Concept Integrates Additional Functions

Covestro has been developing its own concepts for novel automotive front

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Further information on direct coating and the rheological simulation of the process can be found in ***Kunststoffe international*** 7/21 from page 50 and at: *https://en.kunststoffe.de/a/article-346596*

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