Automotive Display: A Matter of Form

Large-Area Curved Plastic Panels with Integrated Displays

Harmoniously integrating displays into the lines of a vehicle cockpit has always been a real challenge. Continental now uses a combination of film insert molding, in-mold decoration and injection-compression molding to produce large, three-dimensionally formed plastic panels.

Two displays are seamlessly integrated into the continuously 3D-formed instrument panel (© Continental)

The display increasingly sets the tone of a vehicle cockpit. Most current car models already have two full-color, graphic-capable displays. The instrument cluster usually consists of a large display (full digital cluster, FDC). In addition, there is usually a second display in the center console, which presents a wide range of content that is not directly relevant to driving, such as navigation, infotainment and operation. It often has a touch function. For years, the trend has been toward increasing the number of displays, as well as their diagonals and resolution.

Precisely harmonizing the technical properties of such side-by-side displays (white point, color temperature, color coordinates and black homogeneity) represents one major challenge. Another is to integrate the display surfaces harmoniously into the lines of a cockpit. Glass-based displays turn out to be somewhat intractable in this respect. The curvature that can be achieved is in the range from about 800 to 3000 mm radius. Flexible displays such as AMOLED (active matrix OLED) are significantly more promising. However, AMOLED displays must have a protective layer to make them suitable for the comparatively harsh use in vehicles with touch operation.

Continuous 3D Plastic Panel

To solve this challenge, Continental has developed a continuous 3D plastic panel (**Title figure**). It protects the two 12.3 inch AMOLED displays that it covers against mechanical damage. In addition, the partially printed panel can be merged seamlessly into the surrounding surface, so that the entire curved surface acts like a single continuous instrument. To produce this special interior trim, multiple special production processes were combined with one another for the first time. So-called high-pressure forming (HPF) is used, e.g., for forming the two-dimensionally printed film to the three-dimensional contour of the final part. This is subsequently inserted into a mold and back-molded. This process is called film insert molding (FIM). With in-mold decoration (IMD), the hard coating is applied to the part while it is still in the injection mold in a roll-to-roll process. In combination with injection-compression process, this ensures very low stress conditions in the

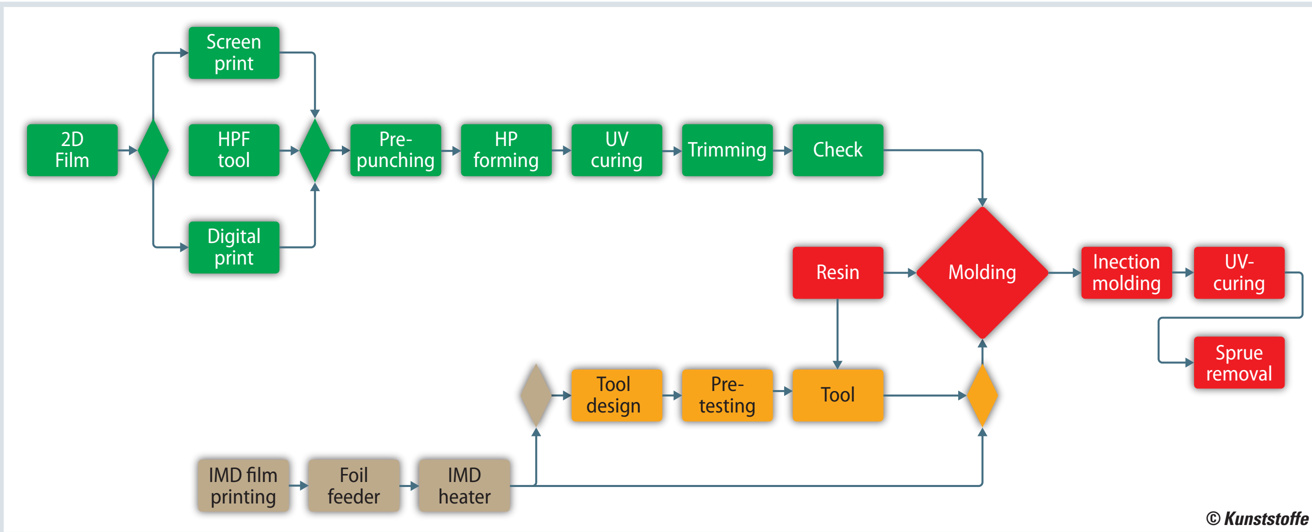

Fig. 1. The plastic panel is manufactured in two separate processes, which are then merged together (source: Continental)

part. The technical challenge in developing this production process resulted from the dimensions of the panel: the displayed pattern measures around 200 mm x 700 mm. These dimensions cannot be processed by either IMD or FIM processes with >100 mm forming height. At the time of their commissioning, some of the machines used were unique in the world.

The 3D instrument panel is constructed of three functional layers. The reverse side is formed by a printed film (FIM) with 375 µm thickness, the front side is a 15 µm-thick hard layer, which is applied from a transfer film (IMD). The core of the part consists of 2.1 mm-thick polycarbonate (PC), which is injected between the FIM film and the IMD film at the front. It subsequently remains in the mold under homogeneous pressure and temperatures of initially 300 °C during the cooling phase. Despite the size of 200 mm x 700 mm, the roughly 2.5 mm thick end product only weighs 350 g.

This integration would not be possible without extensive technical experience with all the manufacturing technologies used. With the combination of all the steps, together with the three-dimensional contour of the panel, it is actually a completely novel process. Continental benefited here from its many decades of experience in printing and forming films, for example for the dials of traditional tachometers. The automotive supplier's experience in injection molding optical and highly transparent components, such as mirrors for head-up displays and cover glasses was extremely important. The transfer application of thin films, too, has already been a large-series process for many years, for example for providing transparent indicator points with a luminous surface or producing high-quality piano black surfaces on plastic panels.

Finding the Right Raw Materials

Besides the manufacturing technologies, another major challenge was the choice of suitable raw materials. The automotive sector actually makes very severe demands on the materials. They include heat resistance, for example to direct sunlight or the heat emitted from the displays, dimensional stability, scratch resistance despite numerous abrasion strokes and optical quality that must be comparable to high-quality materials such as mineral glass. High impact strength is also necessary in order to prevent splintering of the cover glass, even in the event of head impact in the worst case. In addition, it must also be possible to integrate touch operation. As with every lifetime component in the vehicle, a fatigue strength of over 10 years, or 300,000 km is expected – and has also been exhaustively tested. Only specially selected materials therefore come into consideration.

Figure 1 shows an overview of the two strands of the manufacturing process. The upper strand generates the printed reverse side of the panel by FIM; the lower strand feeds the transfer film with the hard coating. Where the two strands meet, the two film layers are backmolded by injection-compression. »

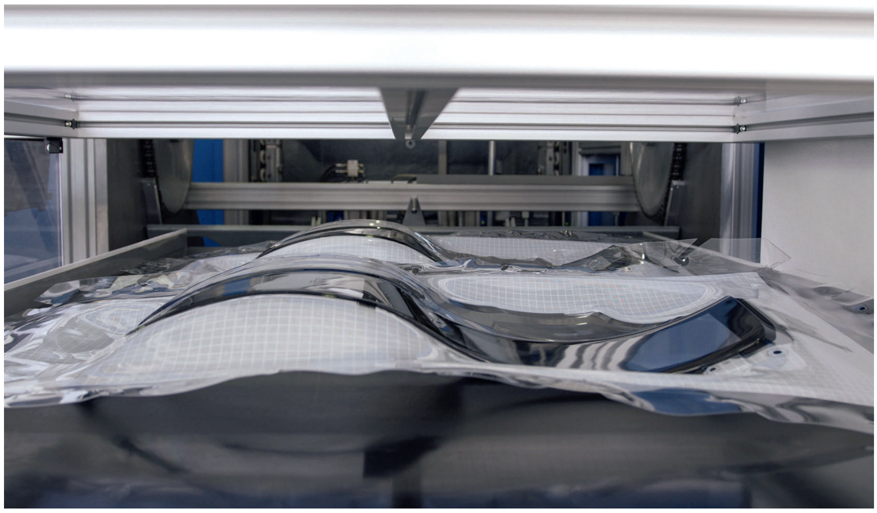

Fig. 2. The FIM machine for 3D heat forming of large-size polycarbonate arcs operates at 60 bar (© Continental)

At the beginning of the upper strand there is a large web of PC film (grade: Makrofol HF, supplier: Covestro AG, Leverkusen, Germany). The Makrofol HF is ideal for the purpose due to its high thermal resistance and transparency, as well excellent formability and elasticity over a wide temperature range. This 375 µm-thick film is first printed with functional and decorative motifs, as well as colored features, using a process combining digital and screen printing. Digital printing is used for creating challenging color gradients and graphic patterns. Even photorealistic prints can be implemented by these means.

3D Forming of Large Components

In an HPF machine, heating tiles heat the finished printed 2D film webs up to its glass transition temperature of 150 °C. Then the heated web is positioned over the 3D mold and the forming mold closes. Air pressure at about 60 bar applies the film to the 3D contour of the mold (**Fig. 2**). After removal from the machine, the formed film is cured under UV light. In the prototype production, the 3D blank is then trimmed to the part contour all round with a milling machine, and the required bores are drilled. This process produces the reverse side of the subsequent instrument panel. The HPF machine, from the manufacturer Niebling GmbH, Penzberg, Germany, allows genuine 3D forming of large-size parts with drawing depths of ≤150 mm at web sizes of 1150 mm x 650 mm. The forming tool was specially designed for this process.

On the lower strand of the production line in **Figure 1**, the transfer is prepared with the hard coating. This IMD film is fed to the injection-molding machine as roll material. With this manufacturing step, too, it was necessary to cross existing technical boundaries due to the three-dimensional and large-size design of the display panel.

Before backmolding, the printed 3D film is inserted into the complex injection mold. The two mold halves together weigh over 16 t. In addition, due to the complexity of the mold, it has a certain built-in intelligence in the form of a programmable logic controller (PLC), which, among other things, supports operation by smartphone via WLAN. The PLC is responsible for monitoring and coordinating the over 60 actuators and sensors that are located in the mold. It independently handles interplay with the injection-molding machine and two other secondary peripheries. During insertion of the FIM, the IMD protection film (type: Bright View; supplier Leonhard Kurz Stiftung GmbH & Co. KG, Fürth, Germany) is positioned in the mold by a special film feeder. To fix the film in the mold, a twelve-part clamping frame concept is used. This fixes the film in the mold using a precisely defined sequence of velocity and position control (**Fig. 3**). The transfer film is now laid wrinkle-free in the mold under vacuum.

When the two films have been positioned, the mold halves are closed and

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- Read the German version of the article in our magazine *Kunststoffe* or at *www.kunststoffe.de* the films are backmolded with PC (grade: Makrolon Ai, supplier: Covestro) at up to 300 °C. Due to the high temperatures and pressures, the printed FIM and the transparent IMD protective coating become an integral part of the panel. To ensure that the subsequent panel has a uniformly high optical quality, the plastic is injected into the cavity while it is still slightly open, and it is then only closed fully after complete injection. This ensures a low filling pressure and a homogeneous pressure distribution during the cooling phase. Because of the resulting opening forces, the hydraulics of the machine must generate clamping forces of up to 1500 t. As the machine opens, the IMD transfer film is released from the front side of the 3D panel, while the hard layer (protective coating) remains on the PC.

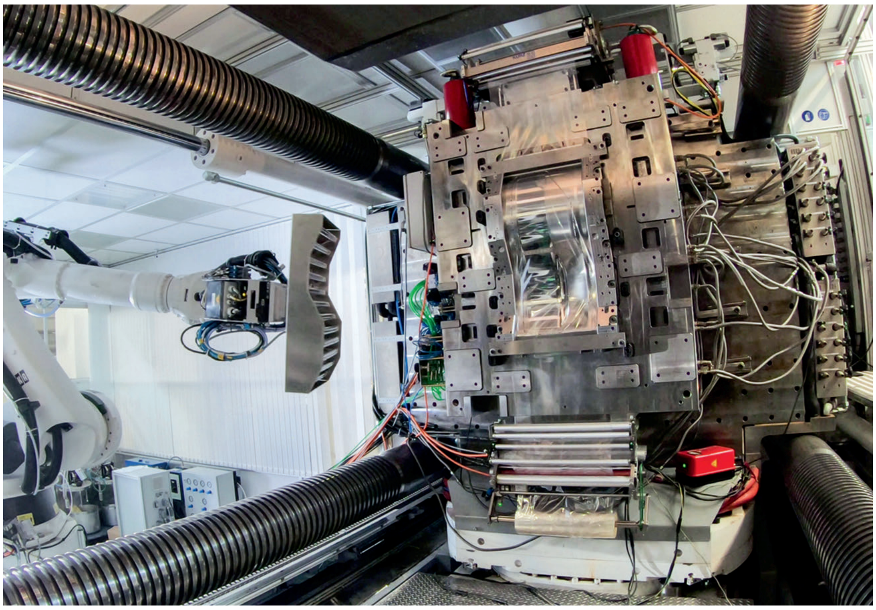

Fig. 3. The twelve-part tensioning frame for positioning the IMD film ensures precision fixing of the film before backmolding (© Continental)

Increased Tactile Feedback

The PC, with its glassy transparency, has high impact strength even at low temperatures and the good dimensional stability gives the 3D instrument panel its strength. After cooling, the IMD protective coating on the final panels is hardened under UV light. The sprues are subsequently removed and the panels are now ready for the optical dry bonding of the two 12.3-inch AMOLED displays.

Plastic panels allow additional 3D structures to be generated on the panel front side, which guide the driver's fingers during operation of the center console (**Fig. 4**). This allows digital operating elements, such as slide controllers for volume control to be replicated. These tactile orientation aids make good hand-eye coordination less critical. The driver can reduce the time he takes his eyes off the road, and maintains a better overview of the traffic situation. In addition, the 3D instrument panel can give the driver tactile feedback. For example, he feels it in his fingertips as soon as he has successfully performed a touch input. The visual check is therefore briefer or entirely unnecessary, which further increases safety. The instrument panel, which is 3D formed for design reasons, thus also supports ergonomic requirements on an operating interface in the vehicle.

Fig. 4. Surface topographies on the panel make blind operation of functions in the display easier (© Continental)

Advantages of the Combined Process

The manufacturing processes, comprising FIM-3D forming, roll-to-roll IMD coating and injection-compression, allow large-size instrument panels with high optical quality to be produced. Besides their low weight, they possess many key advantages. First, the combined process allows the integration of curved display surfaces, which principally shifts the center control better into the arc of reach of the driver's right hand. This makes the functions integrated in the center console display more ergonomic. The possibility of additionally generating three-dimensional structures on the surface of the panel makes operation during driving even safer and more intuitive. And finally, the process permits the seamless integration of individual AMOLED displays without visible transitions between the screen and panel surface. The result is a harmonious cockpit with attractive flowing curves. The innovative manufacturing technology with purpose-adapted machines has proven its effectiveness in the manufacture of prototype panels. The innovative process is therefore suitable for future series deployment. ■