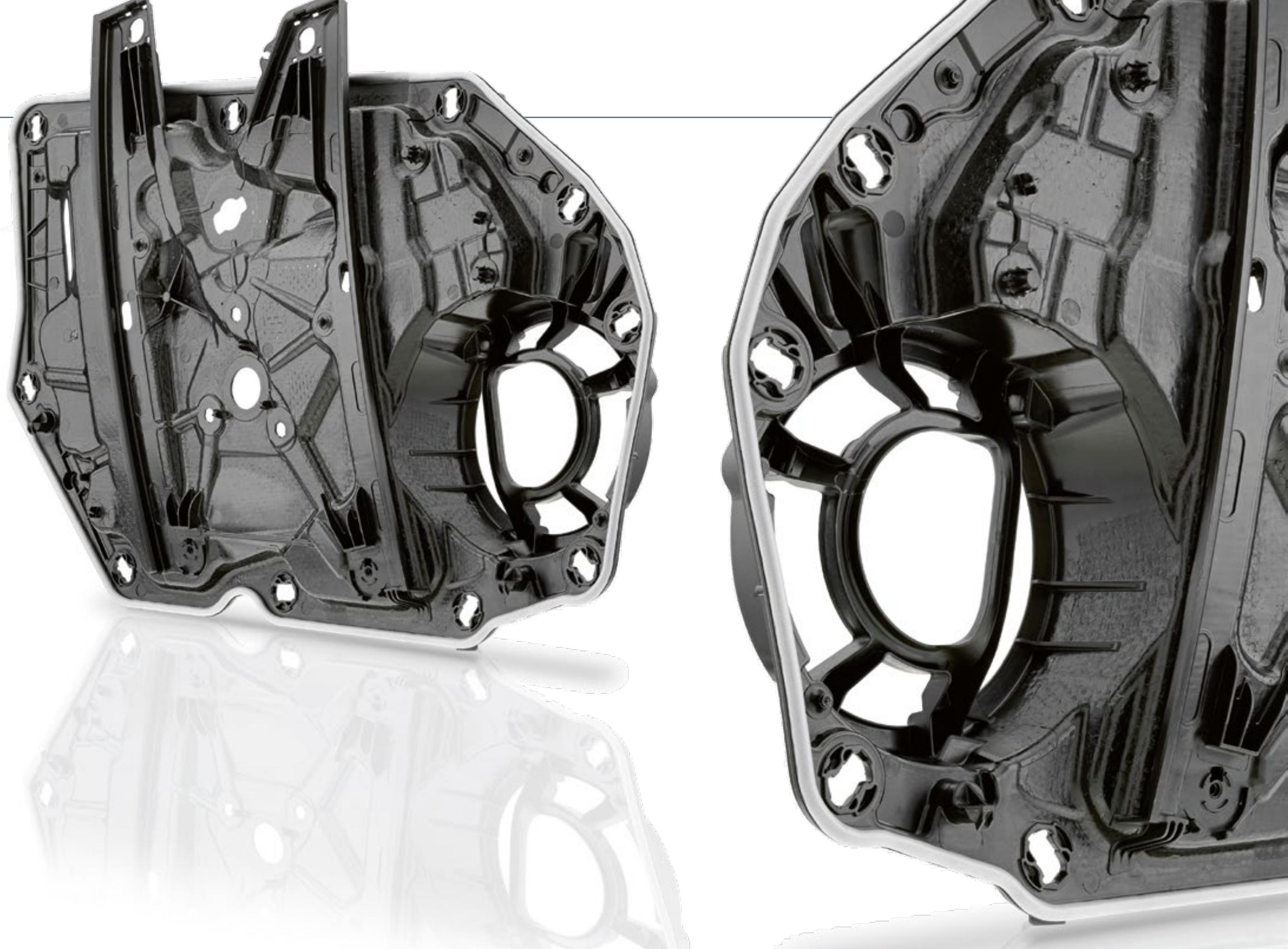
© Brose | Krauss Maffei

Large-series Production of Thermoplastic Door Module Carriers

From the beginning of 2018, Brose has been delivering more than one million door module carriers annually to the automotve sector. Those are produced with the Krauss Maffei Fiberform Technology. Thanks to the use of continuous fiber-reinforced thermoplastic organosheets, reduced wall thicknesses and an integral design, the module reduces weight by 1.6 kg per vehicle compared to a standard injection molded component, and it is also more crash-proof.

In 1966, Brose was the first manufacturer to introduce door modules to the market that combined essential functions on one carrier plate. In addition to window regulators, these functions included the latchmodule, central locking, loudspeaker and wire harness. The family-owned company gradually developed from a component supplier for window regulators to a system integrator for complete doors.

Vehicle doors will always remain an important component in the automotive

Authors

DR.-ING. MESUT CETIN is Group Leader Product Management at the Krauss Maffei Automation GmbH in Oberding-Schwaig (Germany).

MICHAEL THIENEL is Expert for Door Systems Predevelopment and Door modules at Brose Fahrzeugteile GmbH and Co. KG at Hallstadt (Germany).

industry, no matter whether the vehicles are powered by electricity or conventional internal combustion engines. An automobile door usually consists of three main components:

- door outer shell
- door module carrier
- door inner shell.

The outer shell of the door is usually made of a material with good paintable properties and is as visible to the customer as the inner shell of the door with which the passengers comes into contact in the car. A component that is out of sight but important and functional is the door module carrier. This is where the loudspeakers, latch module, wire harnesses, window regulator, window attachment and guidance and crash sensors are integrated, Figure 1.

The history of the door module development, Figure 2, is comparable to other automotive components. Initially, the carriers were made of metal, which had to be shaped into the correct shape. The guide rails were connected to the carrier in a separate process step so that the materials firmly bonded. Over the years and in the course of the consistent further development of the injection molding process and materials, many automotive components in steel and aluminum design have been substituted with plastic materials. This is also what happened to the door module carrier, which was manufactured as a compact injection molding component without fiber reinforcement and then with short fiber reinforcement. The window guidance was first mounted on the carrier in a later, separate step before they came to be fully integrated in the injection molding process. The latter is still common practice among many automotive component suppliers.

> The process combines the thermoforming of organosheets and injection molding.

Despite the continuous further development of the door modules, the high cost pressure for OEMs and their suppliers in the production of components calls for high functional integration with very short cycle times at the same time. In addition, the weight is to be constantly reduced. The electrification of the drive as well as increasing demands on comfort and safety in the automotive industry are leading to an increase

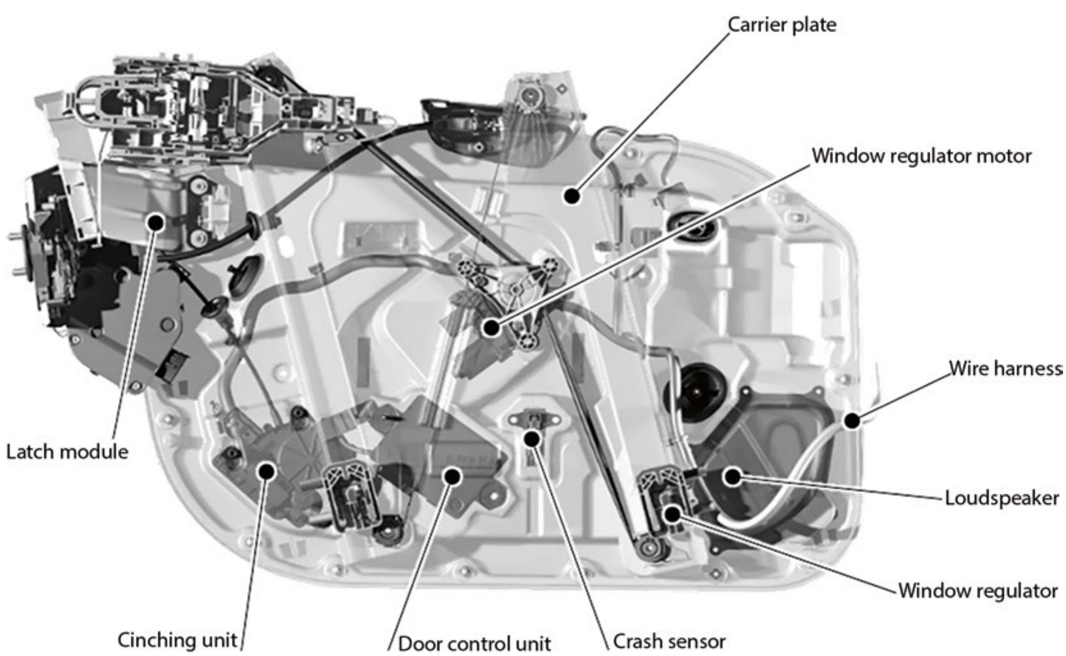

FIGURE 1 Configuration of a door module carrier (© Brose)

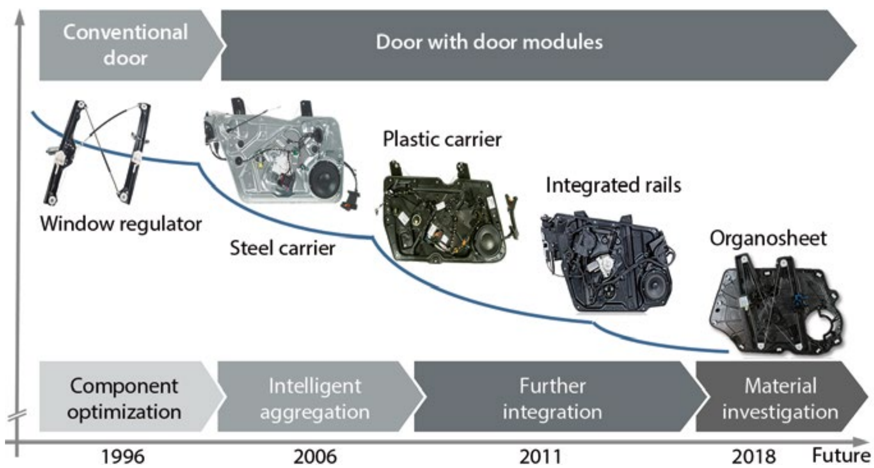

FIGURE 2 History of the development of door module carriers (© Brose)

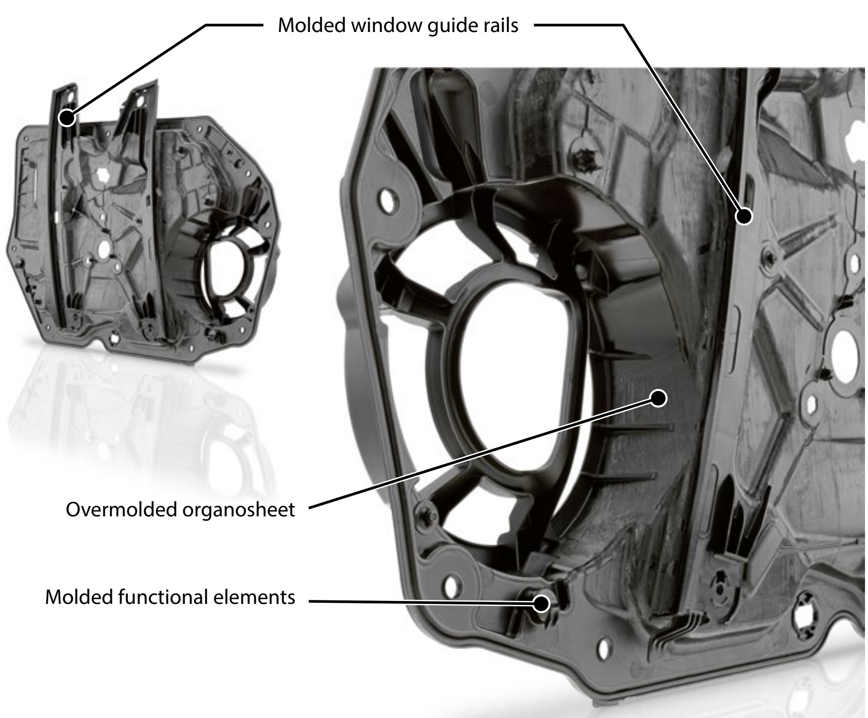

FIGURE 3 The developed organosheet door module carrier (© Brose | Krauss Maffei)

in weight that has to be offset by reducing the weight of other components. Besides the requirements mentioned above, the acoustics also come into focus. In the absence of combustion noises and with new sources of reduced sound such as the electric motor and the battery cooling, acoustic requirements both for the entire door and, consequently, also to the door module will have to be given increased attention in the future.

Organosheets in Door Module Manufacturing

In light of these facts and its longtime experience in the production of systems for doors and trunk lids, Brose has developed a new approach for the production of door modules. Compared to conventional production approaches and components, the door module is distinguished by a higher functional integration, better performance regarding stiffness and impact characteristics, reduced component weight and more freedom in acoustic design [1].

The property patterns mentioned above are owed to the use of continuous fiber-reinforced semifinished thermoplastic products. These sheets with continuous fibers of glass, carbon or aramide are embedded into a thermoplastic matrix, for example of polyamide (PA) or polypropylene (PP). These semifinished products are also called organosheets in the following. The developed process combines the thermoforming of organosheets and injection molding in one step. By using organosheets the mechanical properties can be increased. Wall thicknesses and plastic ribs can thus be reduced, leading to a weight reduction. With the organosheet door modules, it was possible to reduce the weight per vehicle by about 1.6 kg. Compared to a steel variant, the weight savings with four door modules per vehicle is up to 5 kg per vehicle. The combination with the injection molding process allows high functional integration and the production of complex component geometries. In comparison to conventional door modules, it was possible to eliminate a further assembly step by molding the window guide rails. More complex geometries, such as the integration of the speakers, have also been integrated into the injection molding process, Figure 3.

Manufacturing Process for Large Quantities

Since the end of 2017, the organosheet door module has been mass-produced globally at several locations for the Ford Focus C519 series, from year of manufacture 2018. Parallel to the development of the material, the process development at Brose also set in at an early stage. Compared to the fiber-reinforced compact injection molding process, the approach chosen here includes further complex process steps. The manufacturing process can be chronologically subdivided into the process steps of

- heating up and insertion
- thermoforming
- over-molding.

In this, the first two process steps are crucial for the entire process: the heating process, the

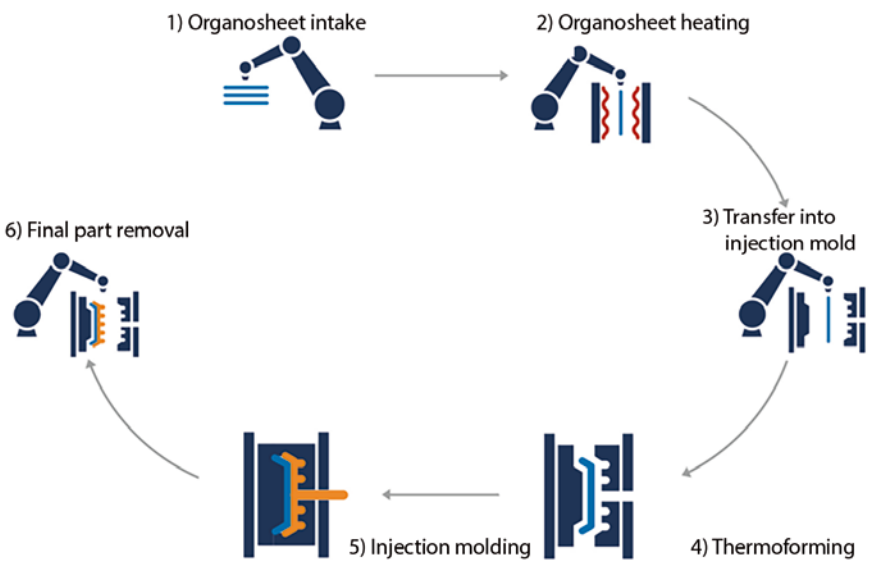

FIGURE 4 Process steps for manufacturing continuous fiber-reinforced lightweight design components (© Krauss Maffei)

insertion of the organosheet into the mold and the thermoforming of the organosheet into the desired geometry, Figure 4, (1) to (4).

There are various methods for heating up organosheets beyond the melting temperature of the thermoplastic matrix. From an economic perspective and with regard to high productivity, infrared heating technology has proven itself both in research and industrial applications. The essential advantages of the infrared technology versus alternative systems are in the lower investment costs and higher performance level of the infrared emitters, which allows for implementing significantly shorter heating times. This applies in particular to the organosheet thicknesses of 0.6 mm used here. The cooling behavior of the organosheet should not be underestimated and has to be included in the consideration. It varies depending on material thickness, type of plastic material, type of fiber and the speed of the organosheet transfer [3]. To find the suitable process parameters, numerous experiments were conducted on Brose's own tech center system, Figure 5. The aim is to keep the transfer path of the organosheet after the heating process as short as possible. Thus a fast cooling of the organosheet can be avoided and a good thermoforming with a good material bonding can be realized.

In addition to the short transfer path, the forming process of the heated organosheet was examined as well. The position of the organosheet at the end of the forming process and before the injection molding process is very important and crucial to the quality of the component due to the many cutouts and doubly curved areas. The grip position of the robot, the transfer position on the mold, the speed of the closing movement and the speed of the core-pulling units have a defining influence on the position of the organosheet. The requirements to the manufacturing solution as specified above are congruent with the standard concepts developed by Krauss Maffei for the series production of thermoplastic lightweight design components [2], Table 1.

Solution 2 or 3, Table 1, can be implemented here depending on the number of cavities. With regard to the required high quantities, door module carriers are usually produced in a double cavity. This is logical both for the front and the rear due to the symmetry of

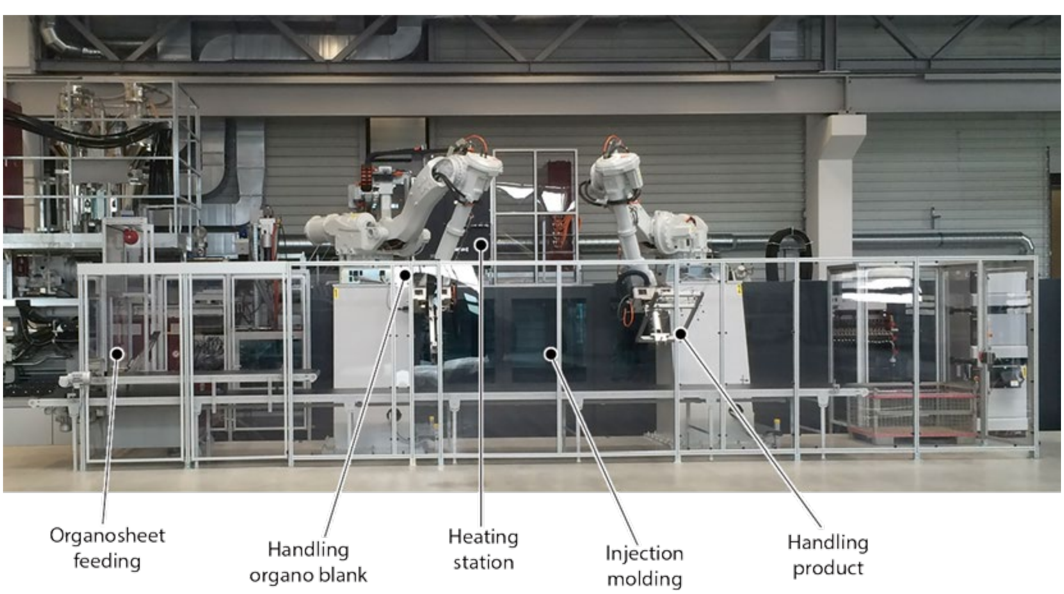

FIGURE 5 Numerous tests were carried out at the Brose tech center system to find the right process parameters (© Brose)

TABLE 1 Manufacturing concepts for the series production of fiber-reinforced thermoplastic components with the Fiberform technology for different fiber-reinforced semifinished product sizes (* FP: fixed platen) (© Krauss Maffei)

		Heating principle	Position of the heating station	Automation kinematic unit	Semi-finished product size (W × H) [mm]
Manufacturing solution	1	Infrared technology	Above the FP*	Linear unit with two kinematic units (LRX 250 TwinZ)	≤ 350 × 350
	2			Linear unit with two kinematic units (LRX 500 TwinZ)	≤ 850 × 850
	3			Two articulated-arm robots	≤ 1350 × 850

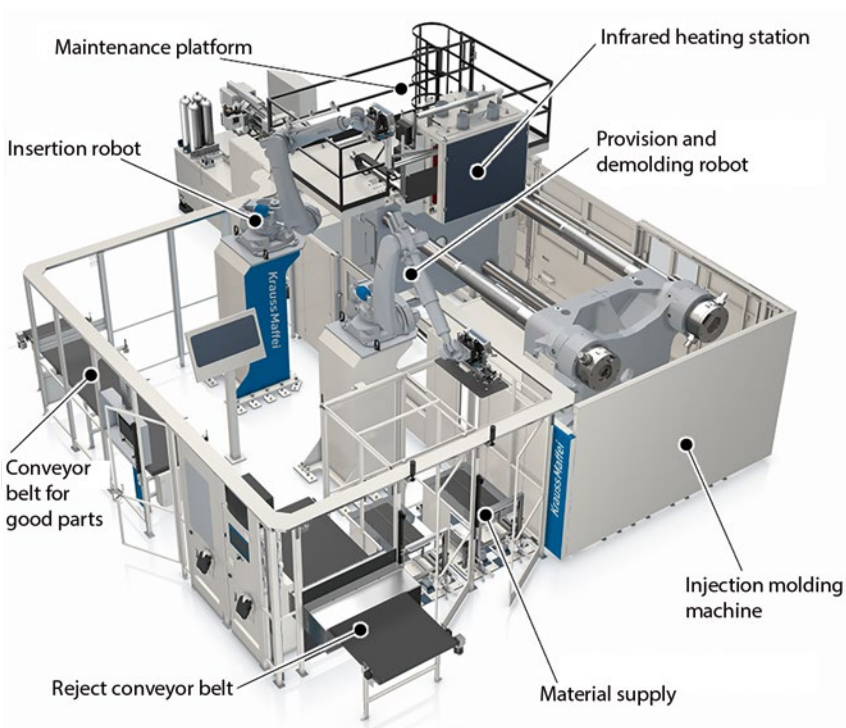

FIGURE 6 Krauss Maffei manufacturing solution for manufacturing door modules in organosheet design (© Krauss Maffei)

the doors of the driver and passenger side. The corresponding manufacturing solution from KraussMaffei for manufacturing the organosheet door modules is shown in Figure 6.

All Fiberform concepts from Krauss Maffei are characterized by the infrared heating station (IR oven) positioned directly above the fixed platen. For the thin organosheets of a thickness of 0.6 mm used here, an integrated sliding mechanism allows for positioning the IR oven directly above the mold cavity so that the organosheet can only be transferred to the mold by a vertical movement. Only this creates the very short transfer paths for inserting the heated organosheet into the mold that are required here. The transfer time is less than 2 s.

In each case, two robot units decoupled from each other are defined as an automation kinematic unit. This allows for chronologically decoupling the heating of the organosheet and the demolding of the finished part, resulting in a further reduction of the cycle times. The material supply and the removal of the finished parts as well as the insertion of the semi-finished product is carried out by one robot. A transfer station with centering is in charge of the transfer of the organosheet to the insertion robot and the repeatable and correctly positioned transfer to the mold. All organosheets to be processed in the manufacturing cell are fed to the cell by means of two container systems. While one container system interacts with the supply robot, the machine operator can refill the other container without interrupting production. A Siemens high-end PLC is used as a higher-level control system for easy operation, troubleshooting and programming of the automation. The total cycle time for the production of door modules is less than 60 s. All important machines and material data are shown in Table 2.

Challenges and Future Solution Approaches

The application of organosheets in the automotive industry is becoming more and more common. However, while a substitution of metallic components with the aim of reducing weight is assessed positively, component costs are the decisive factor. A door module system further developed by Brose and presented at the International Motor Show (IAA) in 2019, Figure 7, is an example for the approach to reduce the component costs by increasing the number of component functions and enhancing the component stability.

The new window sill module transcends the traditional system limits of a door module. This is possible thanks to the material properties of the organosheet, which mainly determines the structural stiffness and crash safety of the extended door module. Further weight savings through integration or elimination of "body in white" components are the results.

Due to the implementation of textile structures (glass fabric) with local fiber reinforcements corresponding to the load paths, the contribution to the structural

FIGURE 7 The new Brose door module carrier concept (© Brose)

TABLE 2 Machines and material data of the production line for the manufacture of the door module carriers (© Krauss Maffei)

Injection molding machine	[-]	Krauss Maffei MX series
Clamping force	[kN]	> 1000
Injection molding material	[-]	PP LGF 30
Organosheet materials	[-]	King Ply Tepex dynalite
Mold cavity	[-]	Single or double cavity
Cycle time	[s]	< 60
Automation	[-]	Kuka KR120-KS + Kuka KR90

stiffness and crash performance is increased. The property patterns of the material combination enable an increase of the energy absorption capacity by 400 % compared to existing door modules. In comparison to the organic sheet door module presented here, Figure 3, the weight could be reduced by more than 1 kg per door – without increasing the costs. In total, this means 4 kg less weight for a four-door model. If the 5 kg weight savings already gained are added, the total reduction is 9 kg compared to a steel variant.

Summary

The new door module carrier developed by Brose is a showcase example of how continuous fiber-reinforced semifinished thermoplastic products should be used in combination with the injection molding process. Even in the development phase, a singular design to meet just a single requirement, such as weight reduction, was not an option. Rather, further important aspects such as the functional integration and acoustics were also considered in the design in order to achieve a comprehensive solution. This led to a component weight reduction up to 1.6 kg per vehicle compared to standard PP LGF 30 door module carriers without organosheet inserts.

Together with the manufacturing solution from Krauss Maffei, series production of organosheet door modules in very short cycle times (< 60 s) is guaranteed for quantities of more than one million per year. The manufacturing solution and the high functional integration of the new door modules was capable of meeting the requirements both for component costs and performance (stiffness, impact, acoustics).

References

[1] Müller, J.; Starost, S.: Akustikdesign bei Leichtbautürsystemen. VDI Conference: OEM Forum Fahrzeugtüren und -klappen 2019, Bad Gögging near Ingolstadt, Germany, 2019

[2] Cetin, M.; Herrmann, C.; Fenske, S.: Automation Concepts for Manufacturing Fiber-reinforced Thermoplastic Components. In: lightweight.design 02/2017, pp. 38–43

[3] Cetin, M.; Herrmann, C.; Schierl, S.: Highly Dynamic and Homogeneous Heating of Organosheets. In: lightweight.design 06/2017, pp. 54–60