The door pocket of a vehicle is a component that lends itself to lightweight construction materials subjected to flexural stress. A life-cycle analysis of the developed NF-PP microsandwich was performed on door pockets for a four-door vehicle (© Daimler)

Lean Material Mix for Lightweight Interiors

Microsandwich Made from a Fiber-Reinforced PP Nonwoven and a PET Foam Core for Vehicle Interior Trim Components

The first series application of the lightweight material microsandwich in 2018 will reduce the weight of vehicle interior trim components by up to 50 %. The efficient one-shot process on existing manufacturing systems offers cost-effective component production by virtue of its short cycle times, as illustrated by the example of a door pocket.

Rising demands imposed by customers on the safety, comfort and functionality of modern vehicles keep driving the growth in the number of accessories for vehicle interiors and exteriors. These increase the vehicle's intrinsic weight, and so are in direct conflict with auto makers' aims to lower vehicular weight to accommodate novel and conventional drive technologies. One solution here is to employ lightweight structures based primarily on new material concepts inside the vehicle [1, 2]. Thus, a specially developed combination of a polypropylene (PP) hybrid nonwoven and a polyethylene terephthalate (PET) foam permits efficient production of interior trim components in a lean sandwich structure. The core of the 3-mm-thick sandwich material is a PET foam mostly finding application in the rotor blades of wind turbines at the moment. Large-scale deployment of this thin sandwich structure, also known as a microsandwich, can shave more than 5 kg off the weight of various trim elements in vehicle interiors alone. As the individual layers are freely configurable, the de-

»

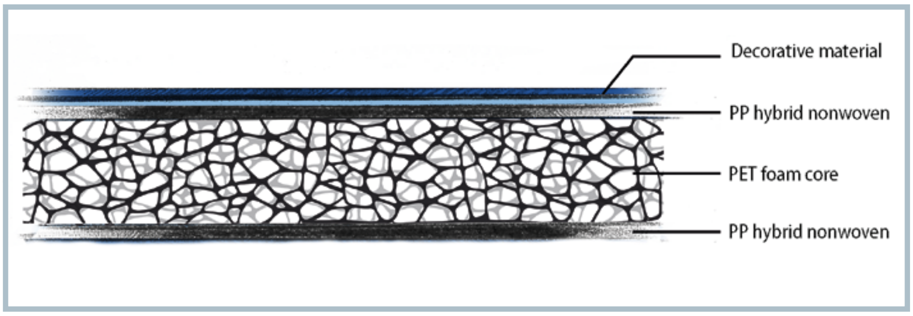

Fig. 1. Material structure of microsandwich composite systems consisting of PP nonwoven and a PET foam core including decorative material (© Daimler)

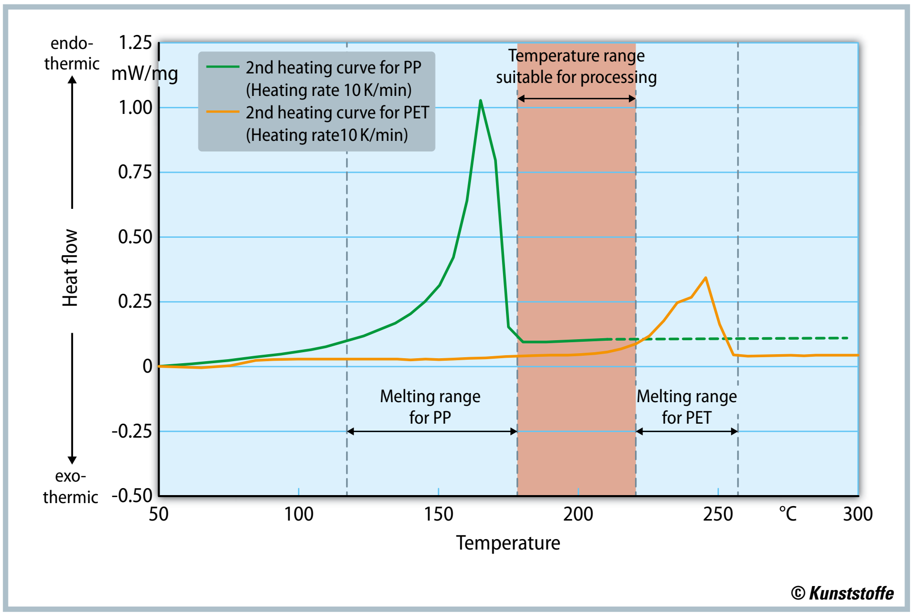

Fig. 2. Results of dynamic scanning calorimetry (DSC) performed on the PP and PET materials under N_2 atmosphere (source: Daimler)

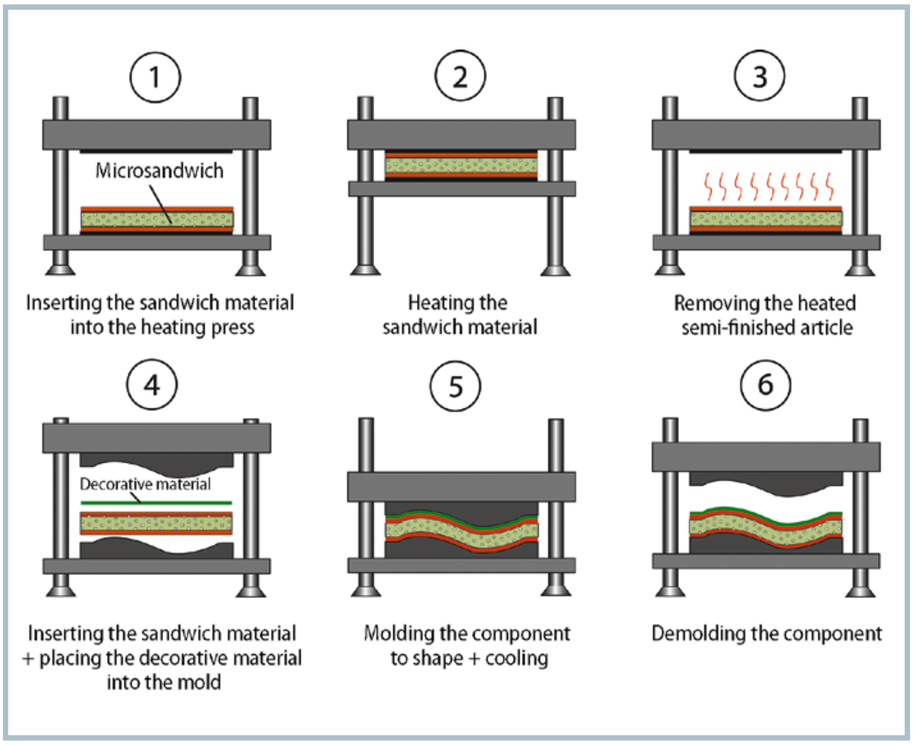

Fig. 3. Steps in the production of microsandwich components (© Daimler)

sign can be tailored to meet the demands of specific components.

Foam Reduces Areal Weight

In many vehicles, nonwoven fabrics with an areal weight of 1200–1800 g/m^2 are used for flexurally stressed trim such as parcel shelves, door trim, trunk linings and backpanels. These often consist of a fibrous polypropylene matrix and at least one reinforcing component, with the choice of fabric – glass fibers (GF), natural fibers (NF) or polyester fibers (PES) – being determined by the thermomechanical requirements. Use of a modified composite structure of nonwoven fabrics with PET foam can lower the corresponding areal weights down to as far as 660 g/m^2. The thin-walled PET foam serves as the core of the sandwich, providing a functional material structure for components subject to flexural stress (**Fig. 1**).

The semi-finished sandwich is transformed into the finished part, including the decorative material, in a one-step compression molding process. Both textile outer layers such as knitted fabrics and polymeric materials such as polyvinyl chloride (PVC) and thermoplastic elastomers (TPOs) can be used as decorative material. The thermal properties of PP and PET enable the semi-finished article to be processed at temperatures between 180 °C and 220 °C (**Fig. 2**). This represents the range over which the PP in the outer layers is molten, whereas the PET foam core is still in the glass transition to melting range. PET does not attain the molten state until the temperature reaches about 220 °C. Below this temperature, it is possible to adjust other process parameters to prevent the cellular structure of the foam core from collapsing during the molding process, whereas the structural PET base material is moldable. Heat input into the semi-finished sandwich and the necessary thickness calibration are achieved in a contact heating press, which generates a homogeneous target temperature of 200 °C in the composite sandwich approx. 45 s after completion of the closing step (**Fig. 3,** steps 1–3). Transfer to the forming mold is then followed by the molding process to produce the component (**Fig. 3,** steps 4–6). The ease with which the PP nonwovens and the PET foam core can be thermoformed in the composite allows complex component

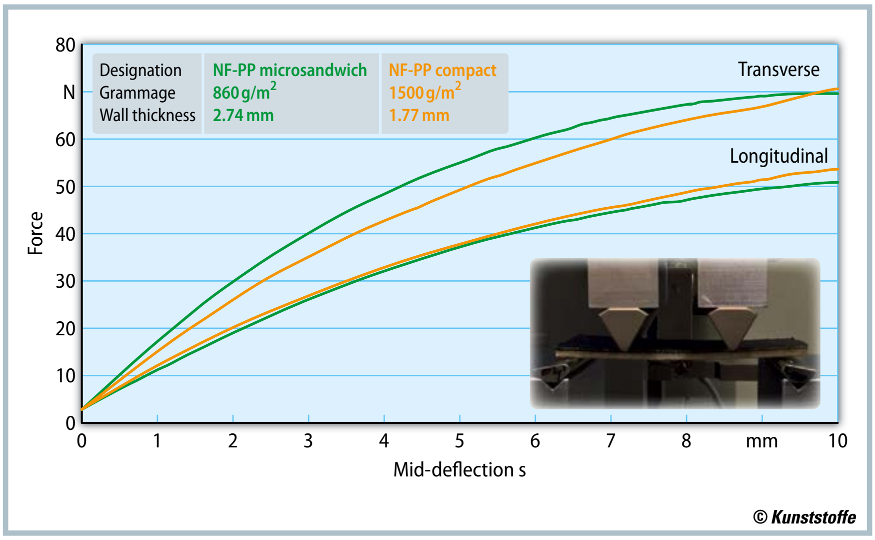

Fig. 4. Results of a 4-point bending test on sample components made from PP-NF compact or NF-PP microsandwich (adapted from DIN 53293) (source: Daimler)

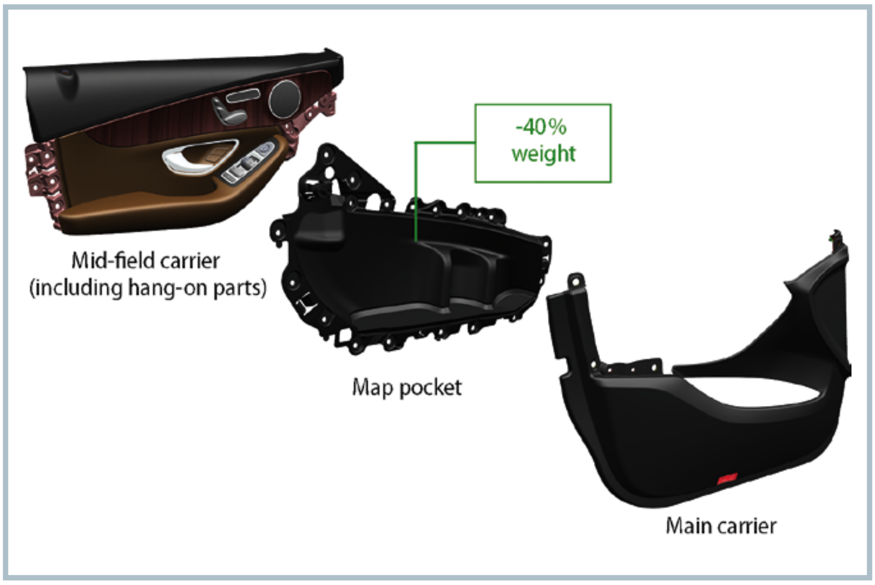

Fig. 5. Structure of door trim as illustrated by the Mercedes-Benz GLC (X253) (© Daimler)

geometries to be realized. As a result, the new microsandwich material can be used for numerous interior components. One example is the door pocket shown in **Figure 5**, with its complex edge and several changes of contour.

Combination of Material Properties Contributed by Cover and Core Layers

Unlike the case for compact nonwovens, the flexural strength of the microsandwich derives from both the properties of the lightweight nonwovens in the cover layers and, as per the parallel-axis theorem [3], the thickness of the sandwich. While the PET foam core maintains the spacing between the cover layers, the tensile and compressive loads that occur in the cover layers in the event of flexural stress are selectively absorbed by the lightweight PP nonwovens. **Figure 4** shows the slope of the force-displacement curve for a natural fiber-reinforced microsandwich composite with an areal weight of 860 g/m^2. It can be seen that flexural stiffness values comparable to those of a compact NF-PP mat with an areal weight of 1500 g/m^2 are achievable. The directional dependence of the force curves results from the production-induced orthotropic material response of the nonwovens. The areal weight of the support material can thus be reduced by more than 40 % for a mere 1 mm increase in component thickness. Furthermore, the ma-

»

The Authors

Christoph Menzel has worked as a PhD student in the “Advanced Engineering of Material Systems for Automotive Interiors” at Daimler AG in Sindelfingen, Germany, since 2015;
christoph.menzel@daimler.com

Dr. Benno Simon Stamp has worked in the “Advanced Engineering of Material Systems for Automotive Interiors” at Daimler AG in Sindelfingen since 2011.

Univ.-Prof. Dr.-Ing. habil. Prof. E. h. Prof. Lothar Kroll is Director of the Institute for Structural Lightweight Engineering at the Technical University of Chemnitz, Germany, and Cetex Institute as well as being CEO of the MERGE Federal Excellence Cluster.

Dr.-Ing. Roman Rinberg has been Head of Biopolymers and Natural Fiber Composites research in the Department of Lightweight Structures and Polymer Technology at Chemnitz University of Technology since 2012.

Dr. Tobias Blumenstock has worked at Daimler AG since 2002 and has been employed in the “Advanced Engineering of Material Systems for Automotive Interiors” in Sindelfingen since 2010.

Hubert Bieder has worked for Daimler AG since 1989 and has been Head of the “Advanced Engineering of Material Systems for Automotive Interiors” in Sindelfingen since 2007.

Service

References & Digital Version

- You can find the list of references and a PDF file of the article at ***www.kunststoffe-international.com/3360505***

German Version

- Read the German version of the article in our magazine ***Kunststoffe*** or at ***www.kunststoffe.de***

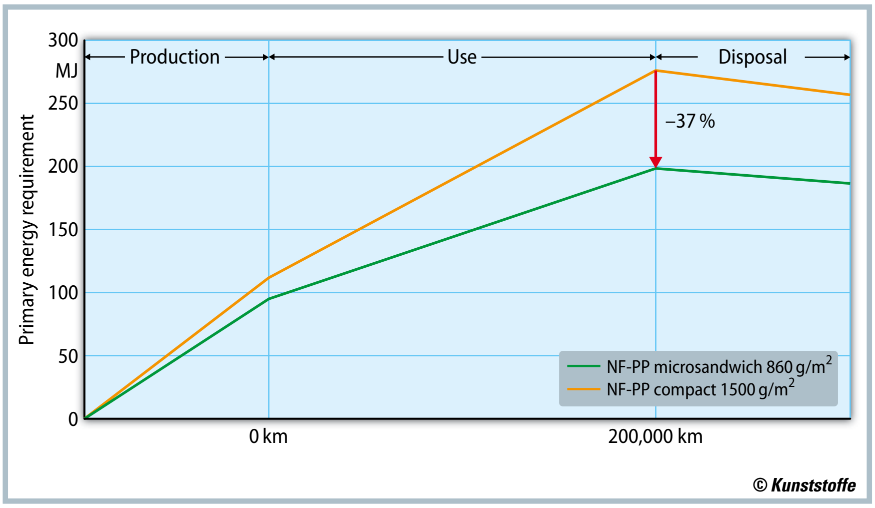

Fig. 6. Primary energy requirements of door pockets made in compact and sandwich construction across the production, use and disposal phases (source: Daimler)

terial system exhibits good fracture behavior under high-dynamic stress, because the combination of foam core and thin nonwovens leads to soft edges rather than to splintering. The closed-cell foam core also provides thermal insulation, which reduces heat losses in the passenger compartment.

Sample Application: Door Pocket

The life-cycle analysis of the PP/PET sandwich composite in comparison with that of conventional material systems is based on the total primary energy requirement for a four-door vehicle with four door pockets (**Fig. 5**) throughout the product life cycle.

Replacing a compact composite structure of NF-PP having an areal weight of 1500 g/m^2 by a natural-fiber-based microsandwich having an areal weight of 860 g/m^2 yields a weight saving of 0.5 kg per vehicle in the case of the four reference door pockets. Across production, use and disposal, it can be seen from **Figure 6** that the lightweight sandwich door pockets have a lower primary energy requirement at each phase of the product life cycle than the reference door pockets. The production phase takes into account raw material provision and manufacture of the semi-finished article and the component. The 15 % reduction in energy requirements during the production phase stems from the proportionally lesser amount of thermoplastic in the microsandwich composite. The greatest influence on ecological impact is exerted during the use phase, when the component weight directly affects fuel consumption. A weight reduction of 0.5 kg over a mileage of 200,000 km reduces the energy requirement for transporting the lightweight door pockets by 37 %, equivalent to a reduction in fuel consumption of 1.5 liters per vehicle [4]. When the door pockets are sent for thermal recycling as part of the lifecycle analysis, less energy is recovered from the lighter NF-PP microsandwich, but emissions of greenhouse gases are lower. As thermal recycling generates emissions in proportion to the weight, the lightweight construction can save an additional 1.5 kg CO_2 per vehicle in the disposal phase.

Conclusion and Outlook

The lightweight material microsandwich allows for production of lightweight components for vehicle interiors using an efficient manufacturing process which is based on existing production facilities at interior suppliers. The combination of PP hybrid nonwovens and a PET foam furthermore constitutes an economical lightweight material that can serve in a wide variety of trim components because it is easily molded into shape. The large-scale use of the microsandwich material for flexurally stressed interior parts in the vehicle offers a total weight-savings potential of more than 5 kg. In addition there are ecological benefits throughout the whole product lifecycle and positive secondary properties with regard to insulation and crash behavior. ■