In-Mold Foamed Cores for Lightweight Design

Complex Sandwich Components for High-Volume Production

Until now, there has been no economic method for the mass production of complex composite components. But with a new, in-mold foamed, production-ready sandwich foam core based on polymethacrylimide, more than 50,000 complex 3-D sandwich components can be efficiently produced per annum.

Strut brace made from a sandwich component, showing the in-situ foamed core made from PMI foam, the braided core, and the finished component (figures: Evonik)

In sports, premium, and electric vehicles, e.g. the Alfa Romeo 4C or BMW i3 and i8, the high stiffness and functional integration of fiber-reinforced plastics are increasingly being exploited for lightweight design. Typical lightweight automotive components are currently being used in auto bodies, monocoques, and chassis struts.

When it comes to providing component stiffness, sandwich structures are unmatched. They consist of thin outer layers, e.g. made from carbon fiber-reinforced plastics (CFRP), combined with a lightweight but mechanically strong core, e.g. produced from plastic foam. With greater foam thickness, there is a disproportionately high increase in the stiffness of the component, while its weight remains minimal because of the low density of the foam.

But even before the component enters service, the sandwich core has important tasks to fulfill. During lay-up and curing, the core gives the rather floppy fibers or prepregs of the outer layers their shape and holds them in position so that they can absorb external forces in a targeted way. During the curing process, the core acts as a counterforce for the outer layers against the external pressure of the mold, autoclave, press or simply vacuum, depending on which process is selected. It is obvious that the core should withstand these pressures (which are usually combined with temperatures of between 80 and 180 °C) with little or no yielding, and must therefore have high thermal and mechanical stability, and if required, creep strength.

Ideally, the fibers should have a flat support during curing to prevent them sagging. Foam cores offer such a support, while the voids in competing honeycomb systems are weak points here. If the fibers sag, their strength cannot be fully exploited, so additional fiber layers have to be used, which increases the weight. Although the specific density of foams is somewhat higher than that of honeycombs, this weight advantage is canceled out for many components because they have to be stabilized with filling compound at outward ends or around inserts (e.g. for force transmission points).

Complex Geometry Directly from the Mold

One problem with core foams so far has been creating the required geometry. The higher-quality foams based on polymethacrylimide (PMI) or polyvinyl chloride (PVC) are produced as sheet semi-finished products, from which the final geometry is obtained by machining and thermal shaping. This is very time-consuming and costly, and in some cases the majority of the starting material is literarily turned into dust. This process is therefore really only economical for quite short production runs.

Polyurethane (PU) can be foamed directly in the mold in a chemical reaction and so the resultant foam has the final geometry. This technology therefore saves other shaping steps; the starting materials are also inexpensive. However, the thermal and mechanical properties of this structural foam are not optimum for modern production methods such as high pressure RTM or wet pressing, which are favored for the production of longer runs. In addition, there are health and safety issues associated with the production and handling of PU cores, because of possible sensitization by the isocyanate contained within them [1]. On account of the release agent used for demolding, the surface of these cores also has to be mechanically treated, e.g. sandblasted, before further processing.

Fig. 1. The demonstration component contains, by way of example, two different inserts and shows possible geometries with a defined surface structure that can be achieved with the newly developed PMI foam

Evonik Resource Efficiency GmbH, Essen, Germany, now offers an innovative PMI-based particle foam, Rohacell Triple F as an alternative. With this product, the familiar Rohacell starting material is pelletized, pre-foamed, and then finally foamed under heat in a component-specific mold. The foams so obtained are off-tool-parts and can be further processed immediately. Aftertreatments such as degassing, hole filling or flame treatment/sandblasting to remove release agents are not necessary. In production from pellets, no process-related material waste occurs and material utilization is nearly 100 %. Inserts positioned in the aluminum mold, such as connecting elements, can be overfoamed so that they are then accurately fixed in the foam core. The surface of these closed-cell foam cores shows optimum reproducibility. Slight graininess at the particle interfaces ensures good adhesion to the covering layers (**Fig. 1**).

Wet Pressing and RTM Possible

The foam cores so produced are suitable for further processing by wet pressing or HP-RTM. Depending on the set density, temperatures of up to 140 °C or pressures of up to 20 bar and more are feasible. This makes it possible to achieve the fast cycles required for high-volume production runs. All currently used resin types, such as polyester and epoxy resins, as well as thermoplastics, such as polypropylene or polyamide, are suitable matrix materials for the covering layers. Depending on requirements and customer specifications, the density (and hence mechanical properties) of Rohacell Triple F can be set within a range from 75 to 200 kg/m^3 (**Fig. 2**). In comparison with integral foams, which have relatively high strength at the foam surface but decreasing density and mechanical properties towards the cen- »

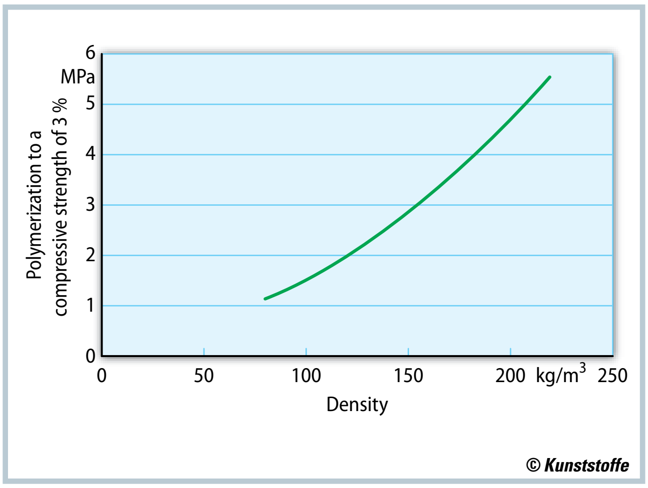

Fig. 2. Compressive strength of the PMI foam, Rohacell Triple F, with different densities

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References & Digital Version

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ter, the new particle foam based on PMI has highly homogeneous density over the entire component thickness and therefore uniform mechanical properties as well. As a result, any surface flaws no longer lead to collapse of the foam core during resin injection under high pressure.

Foam cores made from Rohacell Triple F are particularly envisaged for applications involving production volumes from about 1,000 up to 50,000 units per annum. These could be in the automotive sector, e.g. sports cars and premium vehicles, where CFRP accessory, vehicle body or chassis parts are used (**Title figure**). But they could also be in the aerospace sector, where cost-efficient carry over parts are increasingly required in quite large numbers. Finally, in the sports equipment market, too, lightweight sandwich cores are of ever growing interest for systematic lightweight design.

Combined Expertise

Rohacell Triple F foam cores are produced by LiteCon GmbH, Hönigsberg, Austria, a joint venture founded in 2014 between the specialty chemicals manufacturer Evonik Industries and Secar Technologie GmbH, Hönigsberg, a company with expertise in the manufacture of CFRP products for the automotive, aerospace and medical technology sectors. In a modular production center, LiteCon is already manufacturing the first serial automotive parts. The company is optimistic that, with particle foams, further process steps can be integrated in the future, such as back foaming of thermoplastic covering layers (organosheets) or the application of coatings to the core surface to achieve the required finish or special properties. But continuous production of profiles or sheets is also being considered. ■