Hard Shell, Lightweight Core

Rapid and Cost-Effective Sandwich Parts with PU Resin and PET Core Foam

The combination of fiber-reinforced face layers with a lightweight foam core combines high strength and stiffness with low part weight. However, when processing, it is anything but easy to combine anisotropic FRP materials with lightweight, cost-effective foams. A tailored material system now makes processing by high-pressure resin transfer molding possible at low temperatures and pressures, with short cycle times.

The automotive industry must reduce the pollutant emissions of its vehicles and satisfy requirements regarding economy, electromobility and vehicle performance. Both these aims can be satisfied by new, lightweight materials and processes. With their high specific strength, and broad freedom of design regarding shape and material construction, fiber-reinforced composites (FRP) are appropriate lightweight construction materials, especially in sandwich construction with foam core layers. In cost-sensitive automotive engineering, in particular, a major role is played not only by the mechanical properties of the part but also by the cycle time and resulting manufacturing costs.

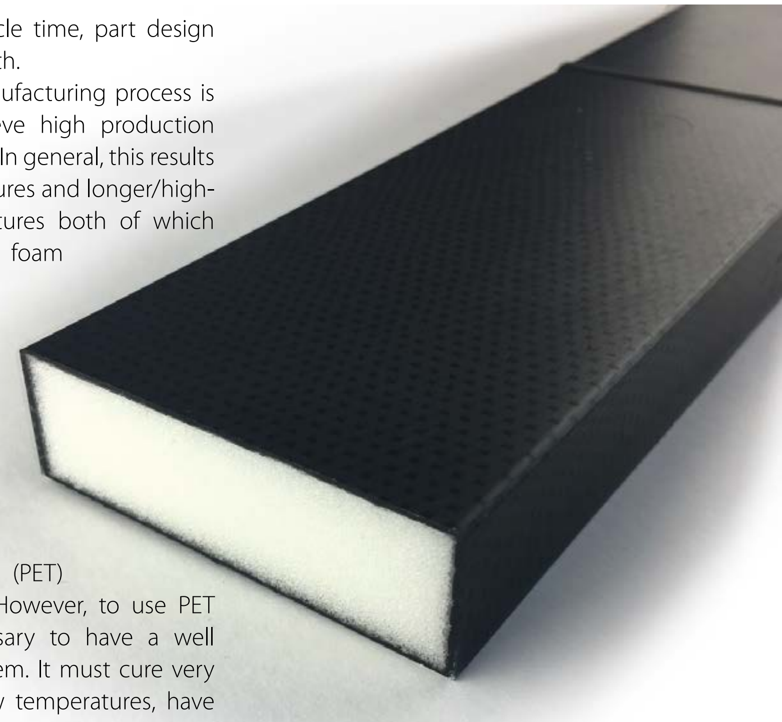
A structural sandwich part with oriented endless fibers as scrims or mats in the face layers and a lightweight, stiff core foam is a very efficient lightweight construction alternative. High-pressure resin transfer molding (HP-RTM) permits the production of sandwich parts with cycle times of below 3 min with low cavity pressures of less than 5 bar. This ensures the necessary productivity together with low investment costs, and is therefore an attractive overall solution for large-series production in automotive engineering.

Good Connection between the Facing and Core Layers

The sandwich construction with FRP facing layers does indeed significantly reduce the weight of parts and components. However, processing them poses severe challenges to the process control, resin system and the lightweight foam core as regards cycle time, part design and material strength.

A very fast manufacturing process is necessary to achieve high production rates and low costs. In general, this results in high cavity pressures and longer/higher curing temperatures both of which severely stress the foam core. The aim is therefore not to use high-performance plastics or cores with a high density of 400 to 500 g/dm^3, but cost effective core materials of polyethylene terephthalate (PET) with low density. However, to use PET foams, it is necessary to have a well matched resin system. It must cure very rapidly even at low temperatures, have low exothermic reaction and efficiently wet the reinforcing fibers, even at low cavity pressures, as well as provide good surface quality.

The use of a specialized polyurethane (PU) resin in combination with an advanced PET foam core and a modified HP-RTM process led to successful attainment of the goals: the highly reactive resin system Loctite Max 2 from Henkel AG & Co. KGaA, Düsseldorf, Germany, has a very low viscosity from temperatures as low as 60 °C. Even at low cavity pressures of 3 to 5 bar, this permits complete infiltration and rapid curing. This process window permits the use of PET rigid foam cores with densities in the range from 100 to 200 g/dm^3.



Good surface quality, pristine foam core: a cross-section through an HP-RTM part with carbon-fiber reinforcement of Airex T10.110 core and Henkel Loctite Max 2 PU resin (© Henkel)

Evaluating the Process Window

In a joint study, suitable process windows for processing the PET foam Airex T10 from 3A Composites Holding AG, Steinhausen, Switzerland, with the polyurethane resin system Loctite Max 2 from Henkel by the HP-RTM process were worked out and validated at the Henkel Composite Lab in Heidelberg, Germany. Sandwich parts with the dimensions

800 x 80 x 25 mm³, with three facing layers, unidirectional carbon fiber mat with an areal weight of 300 g/m² and a foam core with a volume weight of 110 and 170 g/dm³ are used. Three pressure sensors integrated into the mold cavity were used to record the pressure profile during injection of the resin. To determine the maximum compressive strength of the foams, the cavity was deliberately overfilled so as to compress the foam.

Figure 1 shows the compressive strength of the foam cores dependent on the mold temperature. With the low viscosity of the PU resin, it is possible to neatly infiltrate the parts with maximum cavity pressures of below 5 bar and achieve high fiber volume ratios and good surface quality. At the same time, the very rapid infiltration and curing processes prevent greater heating of the highly insulating foam, and therefore also greater softening. In addition, demo parts were produced in which the core is completely enclosed in multiple layers of carbon-fiber mat as well as scrim of visible carbon fiber, in order to be able to validate the process parameters and evaluate the parts in all spatial directions as regards the surface quality. The **Title figure** shows as example a demo part produced in this way, with a foam core density of 110 g/dm³.

The reactivity of the PU resin was adjusted by varying the catalyst content. Thus, curing could be achieved within 2 min., even at mold temperatures below the glass transition temperature of the PET foam, of 75 °C and at cavity pressures below 5 bar. Due to the low exothermic reaction, the foam here remains intact and ensures that the sandwich structure has very good mechanical properties. **Figure 2** shows, as example, the measured ion viscosity of the resin mixture depending on the catalyst content at a mold temperature of 70 °C.

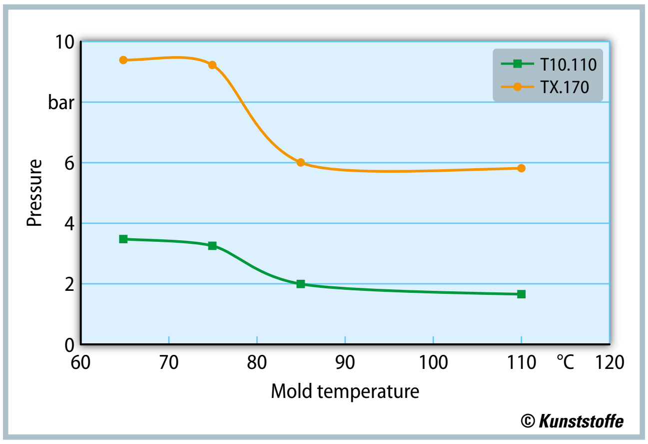


Fig. 1. Compressive strength of the foam cores Airex T10.110 and Airex TX.170 dependent on the mold temperature in the HP-RTM process (source: 3A Composites, Henkel)

Summary

The combination of PET foam and PU resin matched to one another allows high-stiffness sandwich FRP parts to be produced at high quality by the HP-RTM process. Thanks to the short cycle times of the PU resin and the low densities together with low costs of the PET foam, sandwich parts can be manufactured cost effectively in large series. In addition, good surface qualities and high fiber volume ratios are obtained, which forms a very good basis for other near-series developments.

The HP-RTM sandwich manufacturing process described above can be used in very diverse applications. Typical examples are seat elements, bulkheads or rear walls, gear tunnels, floor elements, battery housings, stiffening elements and many others. As part of the cooperation between Henkel and 3A Composites, a 3D part will soon be developed and manufactured, and is to be unveiled at the JEC Composites show in Paris, France, in mid-March. Subsequently the expertise developed will also be made available to other partners who want to develop with similar technology. ■

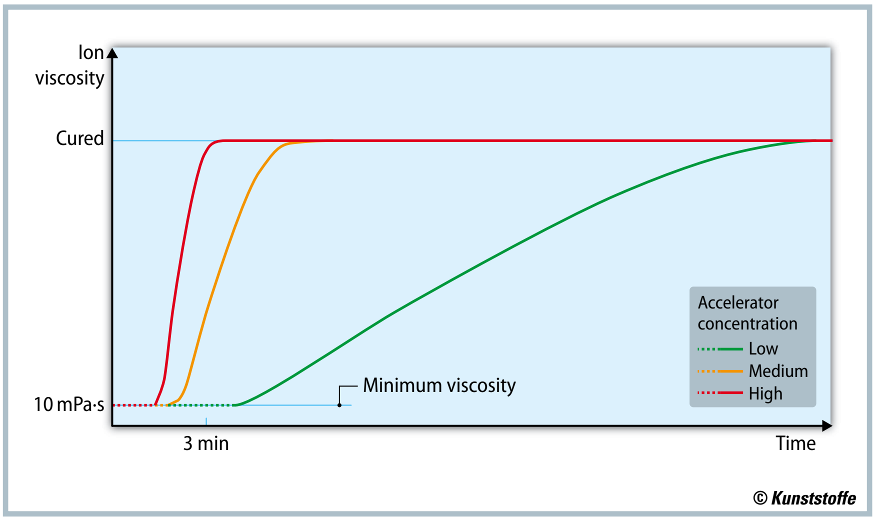


Fig. 2. Schematic curing behavior (DEA measurement) of Loctite Max 2 at 70 °C mold temperature. The characteristically low viscosity at the start of the reaction is represented as a dotted line. Due to the freely selectable concentration of accelerator, a very rapid curing of below 3 min can be achieved even at very low mold temperatures in the range from 60 to 70 °C (source: Henkel)

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