Fiber-reinforced composites made of polyurethane systems
Dwindling resources, rising carbon emissions, population growth and the growing global desire for mobility are the biggest challenges facing the automotive industry in the coming years. The EU is calling on European vehicle manufacturers to cut their average fleet emissions to 95g CO₂/km by 2020 – which amounts to a reduction of about a third within the next 7 years. In addition to refining classical and alternative drive technologies and improving rolling resistance and drag, lightweight construction is one of the levers for achieving this goal. Just 100kg less weight translates into 0.4l less fuel consumed per 100km or about 10kg less emitted carbon.

By using fiber-reinforced plastics, significant weight reductions are already being achieved today in vehicle engineering. Their simple and flexible processing and exceptional functional integration also permit a degree of design freedom and individuality unattainable with conventional materials. The mechanical properties of composites and hence their weight-saving potential depend on their specific design and basically improve with increasing fiber length, content and orientation. Short- and long-fiber-reinforced plastics are already established in many car and commercial vehicle applications, with a weight-saving potential of up to 40 percent per component. To replace metals in load-bearing applications, oriented continuous-fiber reinforcement is required. Carbon-fiber-reinforced composites in particular yield high-strength, stiff and crash-resistant structures. Multi-material systems can reduce weight by up to 65 percent.

Polyurethane systems represent a unique way of exploiting the benefits of such fiber-reinforced composites. Whatever the reinforcement system – with short fibers, long fibers or continuous fibers – BASF Polyurethanes has the solution to match the application.
Typical components:
High-grade, readily paintable components for small car series and commercial vehicles

Process:
The RRIM process makes it possible to cost-effectively produce short-fiber-reinforced components with typical fiber weight content of 15 to 25 percent. The PU primary components filled with short fibers (glass, mineral or carbon fibers, length < 200µm) are thoroughly mixed in a mixhead. The reaction mix is then injected in a matter of seconds at low pressure into a mould and, after a short time for curing, the finished component is demoulded.

PU performance:
Owing to their outstanding flowability, the Elastolit® systems developed for the RRIM process permit the realization of even the most challenging designs. The components are distinguished by their superlative quality combined with low weight and can be readily painted thanks to their Class A surface. Their excellent price/performance ratio contributes significantly to the success of small-series components in cars and commercial vehicles.
CROSSLINKED RRIM

Typical components:
Roof and rear spoilers, technical housings in the engine compartment, trim components in the interior and carrier components

PU performance:
Elastolit K is a high-strength short-fiber-reinforced RIM system whose high crosslinking density lends itself well to the production of highly stiff components.

- Feasibility of the most complex component geometries
- Facilitation of wall thickness transitions from 2 to 15mm
- High dimensional stability thanks to low thermal expansion
- Possibility of integrating inserts and fasteners

HIGH-SPEED RRIM

Typical components:
Front, rear and side skirts, commercial vehicle fenders and trim components for trucks, buses and tractors

PU performance:
Elastolit R 8 is a short-fiber-reinforced, tough, hard and elastic HS-RRIM (High Speed Reaction Injection Moulding) system. It is ideal for exterior parts with a high-grade, readily paintable but also extremely hard-wearing surface with very high impact resistance.

- Exceptional flowability for large-area components
- Very high elasticity and cold impact resistance
- Compliance with crash safety requirements
- Very short component demoulding time of 30sec

HIGH-TEMPERATURE RRIM

Typical components:
Fenders, side panels, outside rear-view mirror housings

PU performance:
Like Elastolit R 8, Elastolit R 8-HT is a short-fiber-reinforced HS-RRIM system. However, thanks to its special fiber matrix composition, it has a higher modulus and is thus ideal for thin-walled, tough and hard add-on body parts with extra-high stiffness requirements.

- Pronounced stiffness with low wall thickness
- Extremely low coefficient of longitudinal thermal expansion of 30x10^-6/K
- Excellent heat distortion temperature of up to 190°C
- Low component weight due to the use of milled carbon fibers
**Semi-structural composite solutions with surface films**

**LFI | Long Fiber Injection**

**Typical components:**
Lightweight composite structures such as hoods, covers, flaps, lids and front, rear and roof modules for commercial vehicles and caravans

**Process:**
The LFI process facilitates the production of long-fiber-reinforced components with typical fiber lengths of up to 25 mm in the closed mould. To this end, glass rovings are chopped with a chopper at the mixhead into fiber of defined length and wetted in the mixhead with the pre-mixed low-viscosity PU system. The PU-fiber mix (15 to 35 weight percent fibers) is transferred by a robot into the open mould; the part then gains its shape in the closed mould through expansion of the PU system. A Class A surface is usually achieved by back-foaming a pigmented thermoplastic film. This eliminates subsequent painting.

**PU performance:**
With the Elastoflex® E and Elastolit D foam systems specially adapted to the LFI process, lightweight composite structures can be cost-effectively produced with colored Class A surfaces. Thanks to its low coefficient of thermal expansion in all directions of stressing, the material is particularly suitable for the production of large-format visible components. As the glass fibers are embedded well in the PU foam matrix, higher strength and stiffness are achieved than with short-fiber-reinforced materials. The PU composite’s high pull-out resistance also permits the integration of fasteners and inserts.

- Significant weight reduction over metal and SMC due to low PU composite density
- Short process times due to PU foam’s high reactivity
- Very high composite impact resistance for highly stressed exterior components
- Remarkable temperature stability for applications close to the engine
- Thermal insulation due to PU’s low thermal conductivity
COMPOSITE SPRAY TECHNOLOGY

**Typical components:**
Exterior parts for commercial vehicles in small production runs, engine hoods, covers, and reinforced metal or plastic panels

**Process:**
With the composite spray process, it is possible to produce glass-fiber-reinforced composite and sandwich structures in the open mould. To this end, a succession of compact or expanded layers of PU are sprayed into a mould. Some layers can be optionally reinforced with up to 20 weight percent chopped glass fibers. The low-viscosity PU system is sprayed as it emerges from the mixhead and wets the glass fibers drawn off a roving and chopped to a defined length of usually 12 mm as they enter the PU jet from the side. Moulding takes place with the polyurethane curing in the heated open mould without subsequent pressure application.

**PU performance:**
The compact Elastocoat® C systems developed for the composite spray process are renowned for their high processing-friendliness and can be combined as desired with an expanded, low-density Elastolit D system for the production of lightweight and torsionally stiff sandwich structures to suit the component's requirements in terms of shape and function. The PU system and the process permit a high degree of surface design freedom – be it in-mould coating, subsequent painting or back-foaming of a pigmented thermoplastic film inserted in the mould. The PU composite also makes it possible to reinforce metal panels or plastic films in order to enhance their resistance to denting and twisting.

- Elastocoat C is the emission-free alternative to solvent-based GFRP systems
- Feasibility of even large-format and complex 3-D components
- Excellent characteristics of the composite material
- Compatible with different surface layers

REINFORCEMENT OF FILMS AND METAL PANELS/COMPOSITE STRUCTURES

**Typical components:**
Instrument panel, door lining, and panel of front panels and doors of commercial vehicles

**Process:**
Ready-cut semi-finished fiber products and in most cases glass or natural fiber mats (hemp, flax, sisal) are laid as reinforcement in the mould and are impregnated with a PU foam system. The typical fiber content ranges here from 15 to 35 weight percent. Moulding takes place with the polyurethane foaming and curing in the closed mould. Decorative surface films can be back-foamed with PU in the mould.

**PU performance:**
So that the fiber mats are effectively impregnated, the foam has to flow well. The tailor-made Elastolit D systems can be applied by casting, injection or spraying. Even with low foam densities, the finished mouldings display fine mechanical properties in all directions of stressing. The low internal mould pressure during the foaming process permits the production of high-quality components in simple moulds, which is an advantage particularly for short production series.

- Low component weight due to the use of low-density PU foam
- PU foam systems highly compatible with decorative films
- Suitable for the production of natural fiber components

SEMI-STRUCTURAL COMPOSITE SOLUTIONS WITH SURFACE FILMS

**SRIM | STRUCTURAL REACTION INJECTION MOULDING**

**Typical components:**
Lining and carrier components for cars and commercial vehicles

**Process:**
Ready-cut semi-finished fiber products and in most cases glass or natural fiber mats (hemp, flax, sisal) are laid as reinforcement in the mould and are impregnated with a PU foam system. The typical fiber content ranges here from 15 to 35 weight percent. Moulding takes place with the polyurethane foaming and curing in the closed mould. Decorative surface films can be back-foamed with PU in the mould.
HONEYCOMB TECHNOLOGY

**Typical components:**
Trunk floors, rear parcel shelves, sunroofs, headliners, trays, semi-structural components in cars and commercial vehicles

**Process:**
With the PU spray impregnation process, very light and stiff sandwich structures consisting of a paper honeycomb as the core material and a long-fiber-reinforced surface layer, e.g., using a random fiber mat of glass or natural fibers, can be produced on the large commercial scale. In an automated process, a semi-finished sandwich element consisting of a honeycomb and fiber mat is thinly sprayed on both sides with a PU system designed for thermal activation. The component is shaped by pressing and curing the impregnated semi-finished element in a heated mould. The PU system readily expands in the peripheral zone of the sandwich to create a solid composite material. Hinges and inserts can be firmly integrated in the same process step. This technology also facilitates the use of alternative surface layers and core materials as well as metal honeycombs or foams.

**PU performance:**
The low-density Elastofoam E and Elastolith D foam systems specially developed for sandwich technology are distinguished by their high processing-friendliness. They ensure not only the thorough wetting of the fiber surface layers but also a firm bond with the core. The systems are activated by heat, which facilitates long spraying times and short curing times. The use of internal release agents makes for easy demoulding and subsequent bonding with decorative materials.

- Long spraying times of >100 seconds for large-format components combined with rapid demoulding
- Low process energy consumption due to low mould temperature
- Direct lamination and the back-foaming of decorative materials in the mould
- Low material input thanks to viscosity-optimized wetting

**LONG-FIBER-REINFORCED COMPOSITES**
In the RTM process, fabrics (woven or nonwoven) or preforms of glass or carbon fibers are laid in a heated mould. The mould is then closed, a vacuum is possibly applied, and a defined quantity of the reactive resin system is mixed and injected into the mould. Polymerization is initiated when, ideally, the fibers have been fully wetted by the low-viscosity resin. The component can be demoulded after the reaction.

This process is best for complex three-dimensional components. Owing to the oriented continuous fiber reinforcement in high concentrations (typically 50 volume percent), these components display extreme mechanical properties (stiffness and strength) and are capable of replacing metals in load-bearing applications (structural components, chassis). Depending on the fiber layup employed, weight savings of up to 60 percent can be achieved over metals.
Sandwich technology

Sandwich systems consist of tailored, highly stiff foam cores and surface layers. Such systems are possible by integrating a moulded foam in an RTM or spray process or, alternatively, by subsequently back-foaming metal profiles or fiber-composite surface layers.

To demonstrate the potential of sandwich components, a concept study of a three-part convertible roof module in a sandwich design has been carried out (BASF and EDAG). The central layer serving as the spacer between the carbon-fiber-reinforced laminate surface layers is a closed-cell PU foam that ensures high component stiffness, while also contributing good insulation properties.

This prefabricated moulded foam is faced on both sides with the selected carbon-fiber textile structure and the sandwich is manufactured in an RTM injection process. Its high weight-saving potential is revealed by a comparison of the weights of the same component made from different materials: Steel 8.3 kg, aluminum 4.55 kg and CFRP sandwich 2.9 kg. This amounts to a 40 percent weight reduction over aluminum and 65 percent over steel.

**PU performance:**
- Customized PU foams (Elastolit D) are obtainable by choosing the appropriate sandwich process: closed-cell, compression-resistant foams of low density or modified systems for the back-foaming of surface layers.
- Exceptionally high weight-saving potential
- Very good adhesion to a wide range of surface layers
- Possible integration of functions (NVH)

**PU performance:**
- The compact PU reactive resin systems are noted for their extremely broad processing window and are easily demoulded with the aid of suitably adapted internal release agents. In addition, they are also compatible with all conceivable process variants (vacuum-assisted RTM, variothermal RTM, gap impregnation, liquid impregnation in the open mould).
- Long infusion time coupled with rapid demoulding thanks to customized catalysis
- Low energy consumption due to low component and mould temperatures
- Excellent compatibility with conventional fiber types and fiber sizings
- Very good mechanical properties, and above all high fatigue strength and excellent damage tolerance

**Process:**
Sandwich systems consist of tailored, highly stiff foam cores and surface layers. Such systems are possible by integrating a moulded foam in an RTM or spray process or, alternatively, by subsequently back-foaming metal profiles or fiber-composite surface layers.
POLYURETHANE SYSTEMS ALREADY REPRESENT A UNIQUE WAY OF EXPLOITING THE BENEFITS OF FIBER COMPOSITE MATERIALS:

Whatever the reinforcement system – short fibers, long fibers or continuous fibers – BASF Polyurethanes has the solution to match the application.

We look forward to joining forces with you in developing successful lightweight construction solutions optimized in terms of cost, performance and sustainability.
Note
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Request of brochures:
PM/K, F204
Fax: +49 621 60-49497

If you have technical questions on the products, please contact the Infopoints:

**Elastollan® Infopoint**
+49 5443 12-3456
elastollan-infopoint@basf.com

**PU Infopoint**
+49 5443 12-3579
pu-infopoint@basf.com