Reinforced Polyamides. Glass fibers in different lengths and structures can be used to reinforce partially aromatic polyamides, so enabling them to replace light metal alloys. For example, a three-dimensional fiber network gives polyamide strength properties that are even superior to most pressure diecasting alloys.

Superseding Metals

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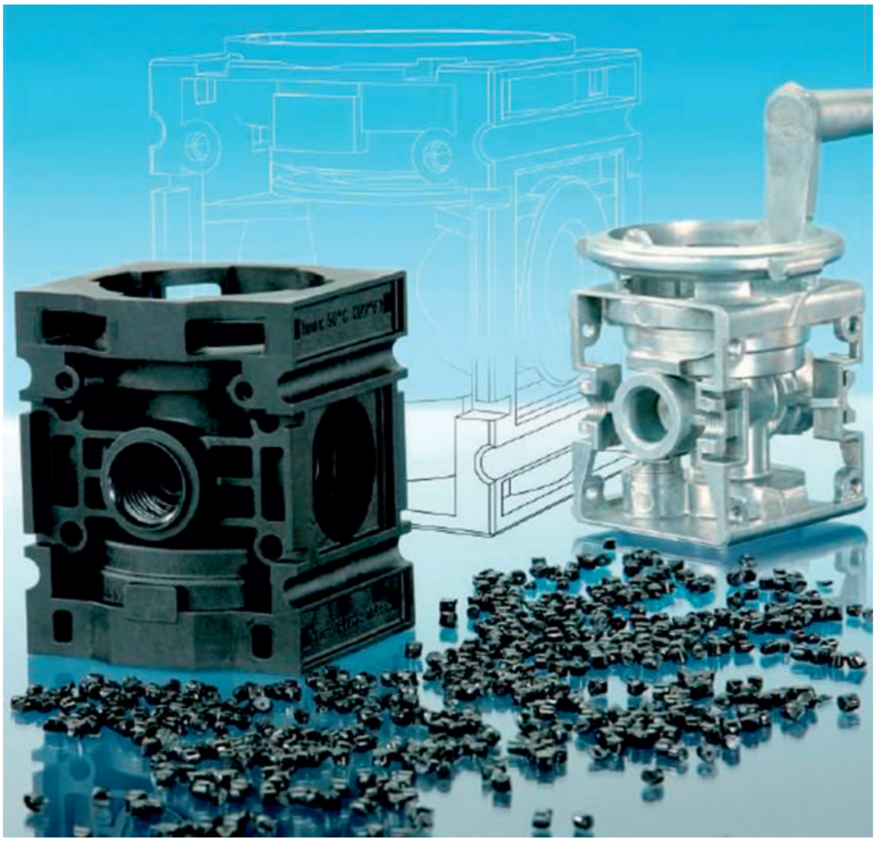
Semi-crystalline polyamides based on aromatic components (Grivory G) fill the property gap between engineering thermoplastics and high-performance plastics. They are particularly suitable for replacing light metal alloys because their properties show minimal change, even after moisture uptake. Two new product families have now been developed for metal applications requiring an even more sophisticated property profile.



Reinforced partially aromatic polyamides are also increasingly replacing sophisticated metals

Three-dimensionally Matted Fiber Network

The newly developed Grivory GVL product family combines the advantages of partially aromatic Grivory G products with those of long-fiber-reinforced polymers. In comparison with G products, much longer glass fibers are retained in components produced from Grivory GVL after injection molding. This is achieved by using 10-mm-long pellets, each containing between 4,000 and 16,000 long reinforcing fibers in parallel alignment. These individual fibers are separated in a special process and impregnated with a PA 66/aromatic polyamide melt. The pellets can be processed on standard commercially available injection molding machines and form a three-dimensionally matted fiber network in the component. The fiber content is normally between 40 and 60 wt.-%.

This structure gives Grivory long-fiber grades many different high-performance properties. Load transmission within the component takes place directly from fiber to fiber (like in a wool yarn). Moisture-resistant Grivory G protects this fiber structure and guarantees exact component dimensions. Ultimately, even without polymer, the component retains its loadbearing structure (Fig. 1).

The fiber network also alters thermomechanical characteristics in the direction of higher temperatures. This is reflected in the heat deflection temperature, which is some 50 % higher than that of a standard product. So the intertwining of the reinforcing fibers significantly reduces stress yield. A comparison of tensile stiffness values as a function of temperature also indicates this. The longer, intertwined glass fibers increase stiffness values by up to 30 % above the glass transi-

Fig. 1. A three-dimensional fiber network (right) gives semi-crystalline polyamide high-performance properties that are even superior to those of most pressure diecasting alloys

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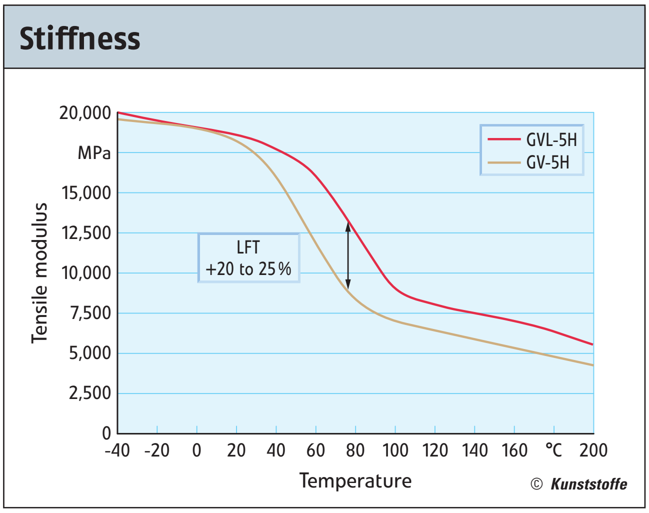

Fig. 2. With long-fiber reinforcement, the aromatic polyamide GVL attains up to 30 % higher stiffness values than short-glass-fiber-reinforced polyamide (LFT = long fiber-reinforced thermoplastics, GVL = long glass-fiber-reinforced, GV = glass fiber-reinforced)

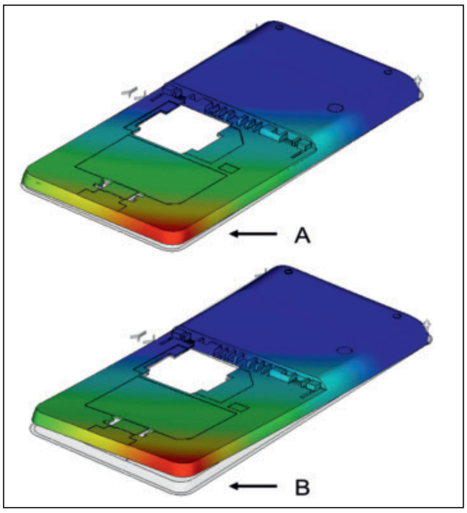

Fig. 3. Moldflow analysis clearly shows the different warpage of strength-optimized polyamide Grivory GVX (A) compared to conventional products with the same glass fiber content (B)

tion temperature in the long-glass-fiber variant of Grivory G (Fig. 2). This allows Grivory GVL to be used at higher temperatures than is possible with Grivory G.

The very good dynamic properties of Grivory GVL are evident from the combination of elastic modulus with very high notched impact strength. The three-dimensional fiber structure effectively prevents crack propagation and makes it possible to produce components with high energy absorption capacity and high stiffness values at the same time. Grivory GVL-6H has a notched impact strength of 40 kJ/m^2 with a stiffness of over 22,000 MPa.

One of the most important properties of long-fiber-reinforced Grivory grades is their very low creep deformation – especially under high load at elevated temperatures. Under a stress of 40 MPa, which corresponds to a load of 160 kg on the cross section of a 10 × 4 mm test bar, Grivory GVL-5H elongates by only 0.3 % at a continuous service temperature of 120 °C over 10,000 h. In comparison with the standard product, the long-fiber grade has higher stiffness with lower elongation at the beginning of the test.

In designing dynamically stressed components, fatigue strength often plays a critical role. Here, once again, it could be demonstrated that long-fiber-reinforced Grivory grades with fatigue strength values of up to 100 MPa are not just equal to but even superior to most pressure diecasting alloys. It is evident that when partially aromatic Grivory G is reinforced with long fibers, it can even outperform metal in some important properties, while allowing significant weight reduction at the same time. In many cases, this can also be achieved at lower cost.

Optimized for Maximum Stiffness

Grivory GVX is a material group in which the matrix and reinforcing material have been optimized for maximum stiffness and strength. This polyamide attains an elastic modulus of nearly 30,000 MPa. Compared with Grivory G, this represents an increase of over 50 %. These values also remain at the highest level when the material is in the conditioned state, whereas conventional polyamides lose up to 35 % of their stiffness.

The transverse stiffness of Grivory GVX can be increased by 26 % compared to the value for Grivory G with the same fiber content. This enhanced performance particularly benefits components under internal pressure stress, where high stresses act across the fibers.

For semi-crystalline plastics, warpage is a problem. With Grivory GVX, warpage has been successfully reduced by up to 50 %. By optimizing the interaction between the matrix and glass fibers, 25 % lower shrinkage can be achieved perpendicular to the fiber direction than with other highly filled products. This low transverse shrinkage leads to components with far lower warpage. Moldflow analysis (Fig. 3) clearly shows the different warpage of Grivory GVX (A) compared to conventional products with the same glass fiber content (B). This lower warpage is not just Moldflow theory. Both test specimens and everyday applications confirm the low warpage.

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Conclusion and Outlook

The two new product families represent an evolutionary step within the Grivory G series in the direction of even more sophisticated metal replacement. The crucial point is to choose the right product for the target application so as to optimally exploit the specific advantages of the grade according to the stress acting on the component. Here again, the technical support offered as backup to the product developments is a critical factor in the success of the concept. ■

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