A Comparison of PA66 and PPA for Electric Vehicles

Higher Performance in Water

With the change from internal combustion engines to hybrid and electric vehicles, peak operating temperatures have dropped from 135 °C to 110 °C. At the same time, the number of operating hours compared to combustion engines has increased nine-fold. This has an influence on material selection. Whether high-performance polymers can be replaced by cheaper alternatives in future was evaluated by EMS using a PA66 and a polyphthalamide as examples.

The goal of nearly every research project is to find, among all possible solutions, the one solution with the greatest technical and economic significance. Technical significance is determined by the degree of fulfilment of the fixed, minimum and, in some cases, additional preferred requirements. These can be, for example, economic savings, higher effectiveness or longer working life. Manufacturing costs, i.e. material and processing costs, are taken as the main factor for economic significance.

Possible key technical factors are, for example, limited installation space, demand for a reduction in installation space, due to miniaturization for instance, or limited wall thicknesses as, for example, in sensor technology. In addition, increasing requirements, e.g. longer working life, reliability under unknown conditions and minimization of risks, are limiting any technical alternatives. Automotive manufacturers and suppliers are also facing major challenges due to the changeover from internal combustion engines to electric motors as the material properties required for the two technologies differ greatly in some cases (**see Table**). Among other things, the question arises of whether previously used high-performance materials can be replaced with less expensive alternatives. The polymer manufacturer EMS-Grivory has evaluated this, taking a hydrolysis-stabilized polyamide 66 (PA66) and a high hydrolysis-resistant polyphthalamide (PPA) as examples. Currently typical representative materials were chosen; for PA66 a grade with 30 % glass-fiber content (PA66-GF30) and for PPA, a grade with 40 % glass-fiber content (PPA-GF40).

PPA: Lower Water Absorption than PA66

The most important physical differentiating features of the PPA used (product name: Grivory HT1VA-4 HY; manufacturer: EMS-Grivory) compared to the PA66 are a 55 °C higher glass transition temperature as well as significantly lower and slower water absorption (**Fig. 1**). In many cases, the lower moisture absorption and correspondingly better dimensional stability, is already sufficient reason to prefer the PPA over the PA66. In addition, HT1VA-4 HY exhibits clearly higher stiffness, strength and resistance to creep over a wide temperature range which, in contrast to PA66, is largely independent of the moisture content. Furthermore, PPA exhibits superior resistance to chemicals and hydrolysis.

For processing of the PPA, higher processing temperatures in the injection-molding unit and mold (oil tempering) are required compared to PA66. Shrinkage behavior of the materials differs, which can have an influence on dimensional tolerances. A direct transfer from PA66 to PPA in an existing mold is therefore generally not possible without modifica-

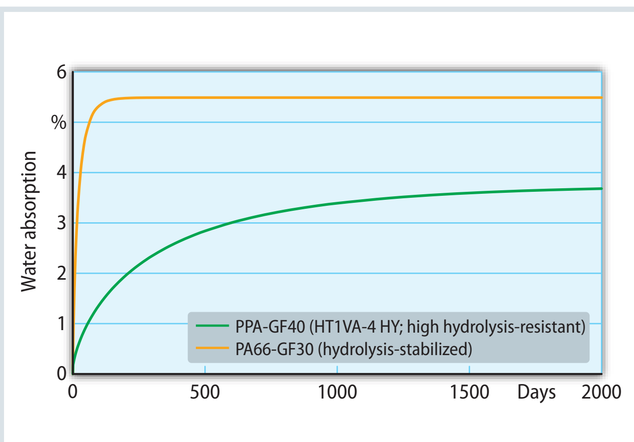

Fig. 1. Compared to the PPA Grivory HT1VA-4 HY, even hydrolysis-stabilized PA66 absorbs significantly more water and more quickly (results measured on plates 100 x 100 x 3 mm according to ISO 62 at 23 °C. Source: EMS-Grivory; graphic: © Hanser

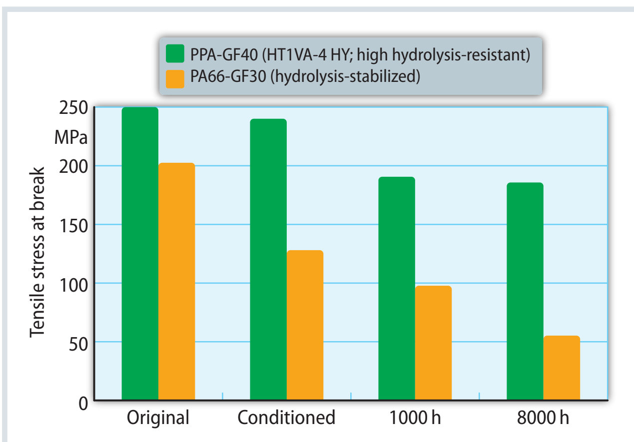

Fig. 2. After storage for 8000 hours at 110 °C in a 1:1 water-glycol mixture, the tensile stress at break value for hydrolysis-stabilized PA66-GF30 dropped from 202 to 55 MPa (-73 %). PPA (Grivory HT1VA-4 HY) showed a drop from 249 to only 186 MPa (-25 %). Source: EMS-Grivory; graphic: © Hanser

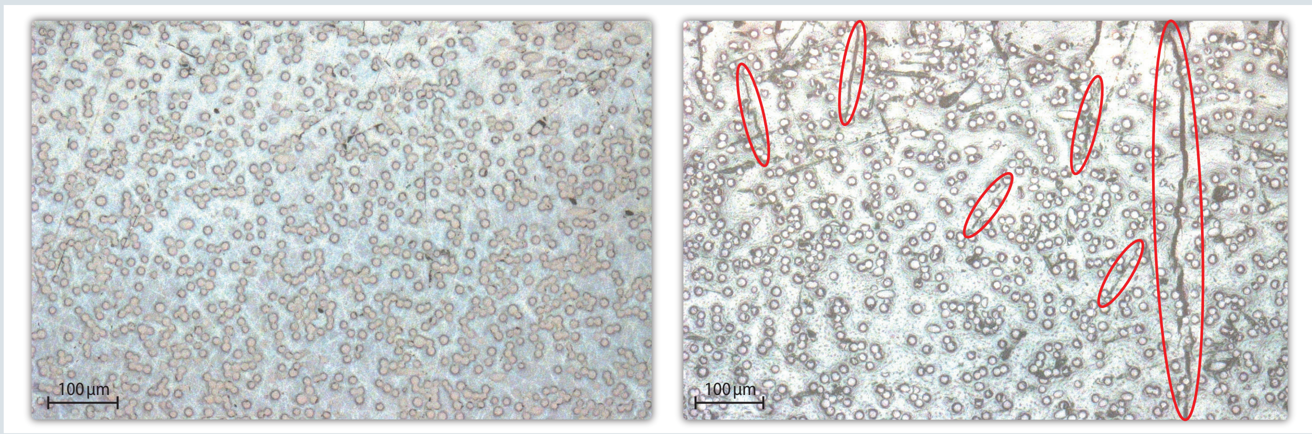

Fig. 3. Micrographs after 8000 hours storage in a water-glycol mixture (based on ethylene glycol, mixing ratio 1:1) at 110 °C. Grivory HT1VA-4 HY (at left) shows no damage. The PA66-GF30 (at right) however, shows various surface microcracks (marked in red). These indicate significant damage to the material. © EMS-Grivory

tions being necessary. For suitability tests of PA66 compared to PPA in cooling systems of electric vehicles, DIN tensile bars with a wall thickness of 4 mm were stored in a water-glycol mixture based on ethylene glycol with a mixing ratio of 1:1 at 110 °C in an autoclave for a period of 8000 hours.

After conditioning under the above mentioned conditions, the tensile stress at break value for PA66-GF30 dropped by more than 40 % to 127 MPa (**Fig. 2**). After 8000 hours, the value was 55 MPa, which corresponds to a reduction of 73 % of the original value in a dry state. For the PPA-GF40, the tensile stress at break value after conditioning was 240 MPa (-4 %) and after 8000 hours, 186 MPa (-25 %). After storage for 8000 hours in a water-glycol mixture at 110 °C, the PPA-GF40 shows more than three times higher tensile stress at break values than the PA66-GF30 examined. This corresponds to a performance increase of 240 % when using PPA.

In the case of PA66-GF30, micrographs of the tensile bars showed micro-cracks on the surface after conditioning for 8000 hours (**Fig. 3**). This is a clear indication of damage to the material after less than half the required minimum operating period of 20,000 hours. Designs with higher wall thicknesses can reduce the risk of failure due to the influence of temperature or media, although this makes the components heavier and requires longer cooling times in the injection-molding process, which has a negative effect on part costs. Micrographs of Grivory HT1VA-4 HY, on the other hand, show a perfect surface finish. Consequently, parts with lower wall thicknesses and therefore, lower weight, can be realized using this material. Thanks to its high strength and stiffness at high temperatures, PPA is particularly well suited for light-weight construction. Using this material, component wall thicknesses can be reduced to a minimum and savings achieved not only for part weight, but also for cycle times and, thereby, manufacturing costs.

PPA Reduces Manufacturing Costs by 44 %

As an example, a U-profile made of PA66-GF30 and one made of PPA-GF40, both with diagonal ribbing, were compared under bending stress. After storage in a water-glycol mixture at 110 °C, PPA has 3.4 times higher tensile stress at break values (**Fig. 2**) providing a performance increase of 240 %. The higher strength of PPA-GF40 compared to PA66-GF30 in this example allows wall thicknesses to be reduced from 5 mm to 2.5 mm with a simultaneous reduction in assembly height of 36 %, resulting in a volume reduction of 62 % (**Fig. 4**). This reduction in wall thickness is however, limited by the flowability of the material. In this way, the theoretically calculated cycle time is shortened by 66 % resulting in overall manufacturing cost savings of 44 %. Calculation of these cost savings was made taking an average machine rate of 150 EUR per hour. Due to the lower »

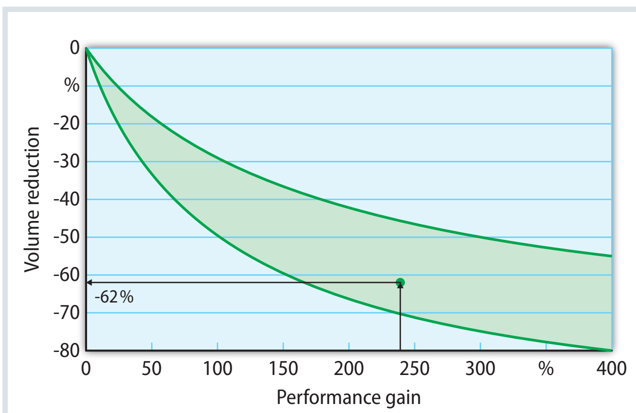

Fig. 4. Selection of a PPA instead of PA66 makes a significant reduction in component volume possible. The flowability of the material sets definite limits for a reduction in wall-thickness however. Source: EMS-Grivory; graphic: © Hanser

	Internal combustion engine (ICE)	Plug-in hybrid (PHEV)	Electric vehicle (BEV)
Peak temperature [°C]	135	120–125	95–110
Operating time [h]	3000–5000	8000–20,000	20,000–45,000

Table. Requirements on the operating temperatures and duration of operating time for different types of vehicle. Source: EMS-Grivory density of PA66-GF30 compared to Grivory HT1VA-4 HY, use of PPA compared to PA66 results in weight savings of 58 % and cost savings of 38 %. The overall cost saving from lower volume and shorter cycle time amounts to 44 % (**Fig. 4**).

The performance increase using PPA compared to materials with lower strength, such as PA66, is dependent on the type of loading involved and the part geometry. PPA polymers provide design engineers with the possibility of designing components with optimal technical and economic significance. Using PPA materials such as the high hydrolysis-resistant Grivory HT1VA-4 HY, technical and economic improvements can be achieved for components requiring a combination of high strength with extreme resistance to hydrolysis.

The Answer to the Question

The EMS product portfolio includes products for applications in automotive construction as well as for components in contact with food or drinking water and with between 30 % and 60 % glass-fiber reinforcement. The assortment is rounded off by grades for designs involving difficult demolding such as those with complex geometries or undercutting, as well as laser transparency with optical black pigmentation.

High-performance polymers such as PPA will continue to be in demand not only for applications in hybrid and electrical vehicles, but everywhere where maximum performance with a simultaneous reduction in part weight is required. Using products from the Grivory HT1VA series, robust, lightweight, long-lasting and reliable components are possible. ■

Info

Text

Albert Flepp is global product manager Grivory HT at EMS-Grivory.

Contact

EMS Grivory
www.emsgrivory.com

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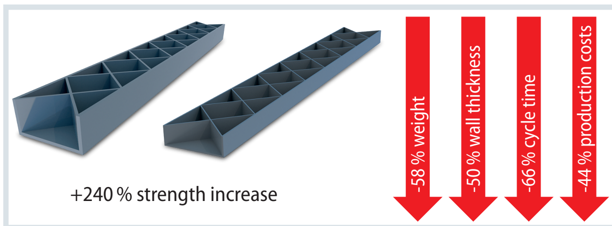

Fig. 5. PPA-GF40 offers a large number of advantages compared to PA66-GF30.
Source: EMS-Grivory; graphic: © Hanser