Metal Substitution with Improved PA

Special Polyamides 6 Match the Properties of Polyamide 66

Replacing metal with polyamides (PA) in components can not only reduce weight and costs, but also offers developers greater design freedom. However, this requires materials with improved mechanical properties. A new PA6 series with greater stiffness and strength meets these requirements, not only as a substitute for metals but also replacing PA66 in components.

With their very good mechanical properties and cost efficiency, polyamides (PA) 6 and 66 are widely used in the automotive sector and other fields of application. Replacing metals with PA6 and PA66 often results in greater freedom of geometrical design of components. Functional integration becomes feasible, weight savings are possible and costs can be reduced. With regard to downsizing and progressive electrification of the drive train, PA also offers other advantages, such as improved noise-vibration-harshness (NVH).

The further replacement of metal components and the technical realization of future innovations, however, requires PAs with greater strength and stiffness. Such materials have been developed by BASF SE, Ludwigshafen, Germany, under the trade name Ultramid XP. They are based on PA6 and are destined for higher quality structural components. For the same glass fiber content, the materials have a property profile that is virtually identical to the corresponding glass fiber-reinforced PA66.

The PA6 reinforced with 35% glass fibers (PA6-GF35) B3WG6 XP, compared, for example to a standard PA6-GF35, has greater stiffness over the entire temperature range, irrespective of whether it is in a dry or conditioned state. Compared with a standard PA66-GF35, both products show a similar property level over wide sections of the temperature range (**Fig. 1**). The improved properties of the material can also be seen in the tensile strength over the entire temperature range. It is significantly higher than that of the standard PA6-GF35 and is approximately at the level of a PA66-GF35. In tensile tests, the curve profiles were almost congruent over the entire temperature range (**Fig. 2**).

Combining the Advantages of PA6 and PA66

In a direct comparison, glass fiber-reinforced PA6 do have lower strength and stiffness values than corresponding PA66-GF grades with the same glass-fiber content, however they are the materials of choice as soon as a higher toughness is required. The Ultramid-XP grades combine these properties. They reach the mechanical level of PA66 GF products with the same glass fiber content and have higher impact strength than these. Due to the higher impact strength, they offer an alternative to impact-modified PA compounds for various applications (**Fig. 3**).

In component tests, it was possible to demonstrate other very good mechanical properties of the Ultramid XP grades. To evaluate the component properties, a 3-point bending test was performed on a ribbed component developed for this purpose. When this test is performed, the sample is laid on the apparatus at its outer edges and a plunger is pressed onto its midpoint until it fractures, while the displacement of the plunger and the applied force are measured (**Fig. 4**).

It was found that the maximum applied work of fracture for the Ultramid B3WG10 XP BK23346 exceeds both the values of the corresponding standard »

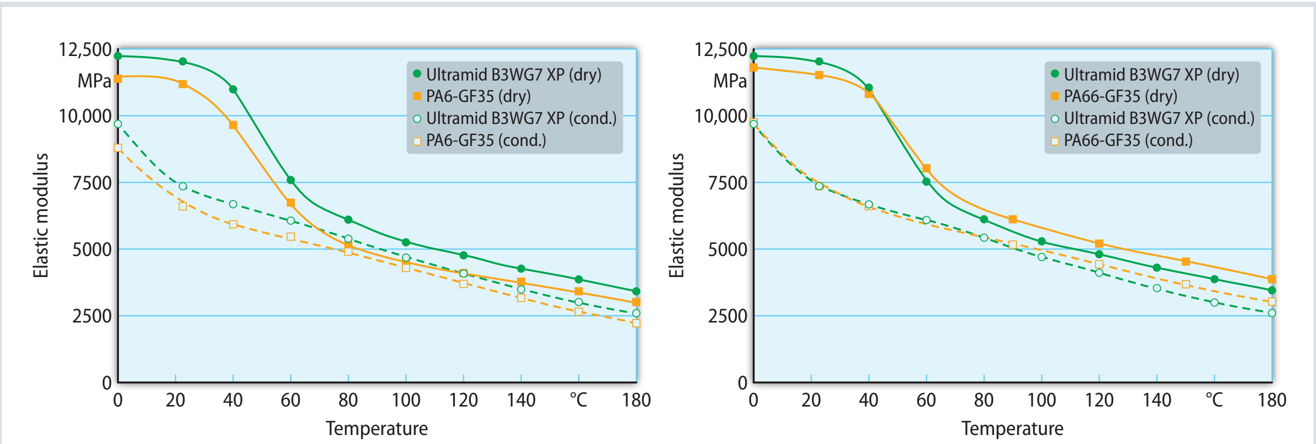

Fig. 1. Profile of elastic modulus against temperature for Ultramid B3WG7 XP BK23346 in comparison with a PA6-GF35 (left) and a PA66-GF35 (right) in the dry and conditioned states: the material has similar values to a PA66 over the entire temperature range Source: BASF; graphic: © Hanser

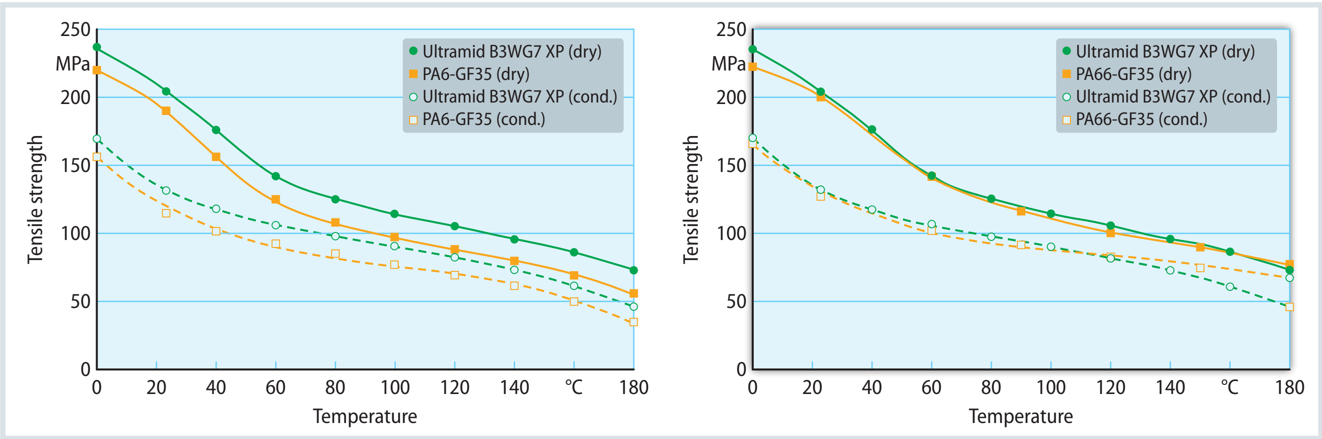

Fig. 2. Tensile strength against temperature for Ultramid B3WG7 XP BK23346 in comparison with a PA6-GF35 (left) and a PA66-GF35 (right) in the dry and conditioned states: the tensile strength is clearly above that of a standard PA6 and is comparable to that of a PA66 Source: BASF; graphic: © Hanser

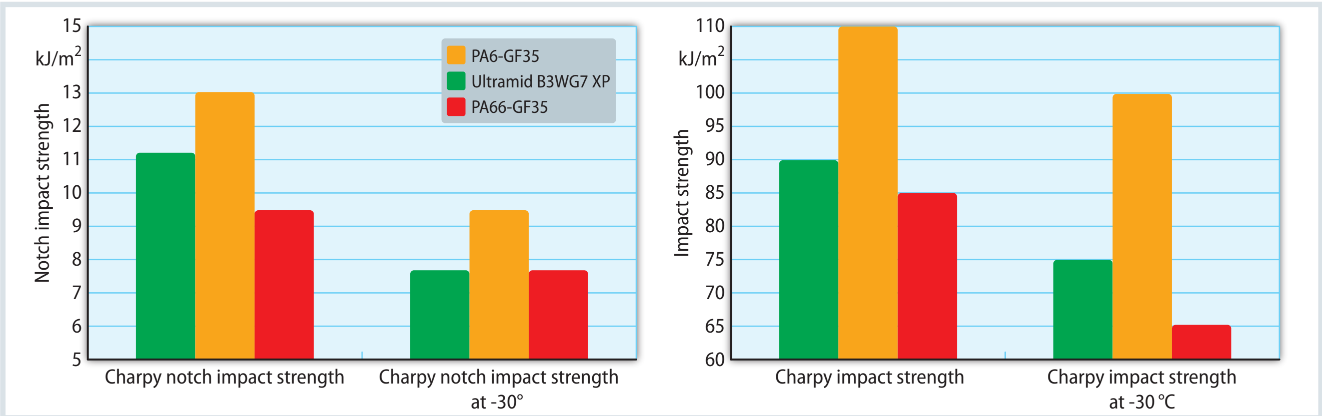

Fig. 3. Comparison of notch impact strength (left) and impact strength (right) at room temperature and at –30 °C between Ultramid B3WG7 XP BK23346 and a PA6-GF35 and PA66-GF35 respectively: in both cases, the material surpasses the comparison materials Source: BASF; graphic: © Hanser

PA6 and PA66 compounds, with 50 wt.% glass fiber-reinforcement in each case, as well as that of a more highly filled PA6-GF60 (**Table 1**). The latter material is in some cases considered as an alternative to a PA66-GF50, and is available from various manufacturers, including BASF. As regards the mechanical characteristic data, it is almost equal to a PA66-GF50. However, the high glass-fiber content leads to disadvantages in the part weight, the elongation at break, the weld-line strength and the fatigue resistance. That can also be demonstrated with the above-described three-point bending test. The maximum deflection of the component as a measure of the elasticity is significantly reduced here.

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Alternative to PA66-GF50

These disadvantages do not occur with Ultramid B3WG10 XP. It is thus a suitable alternative to a PA66-GF50 product. In a direct comparison with a PA6-GF60, it offers significantly better processing by injection molding and better component properties thanks to its lower glass fiber content. Tool abrasion during injection molding has been found to increase significantly at degrees of reinforcement above 50 wt.%, while the flowability and weld-line strength in the part decrease

	PA6-GF50	Ultramid B3WG10 XP	PA66-GF50	PA6-GF60
Deflection [%]	5.4	5.8	5.2	4.7
Max. force [kN]	9.5	9.8	9.2	9.8
Total work [J]	28.8	32.0	25.8	25.8
Component weight [g]	138	139	138	152

Table 1. Characteristic values of the 3-point bending test on the part Source: BASF

Fig. 4. A 3-point bending test showed that the maximum necessary work of fracture for Ultramid XP grades which exceeds that of comparable PA6 and PA66 grades © BASF

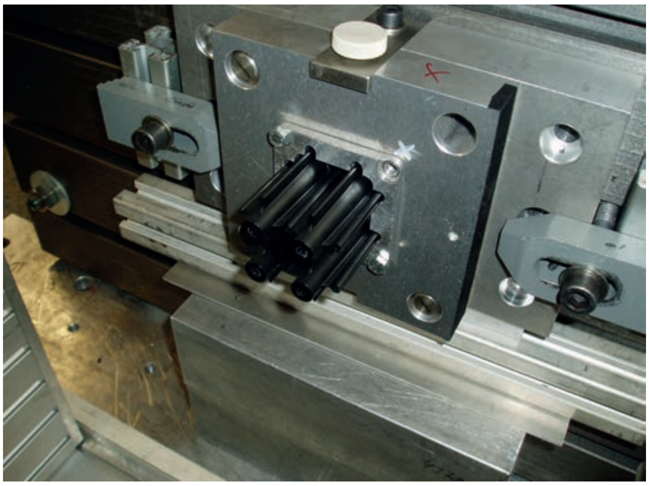

Fig. 5. For crash tests, so-called "crash domes" were driven against a metal wall at 8.5 m/s. The domes made of Ultramid XP achieved high energy absorption values © BASF

significantly. Ultramid B3WG10 XP can therefore also offer advantages in the overall cost consideration of a part compared to PA6-GF60 and PA66-GF50.

As product development continued, XP technology was extended to PA66, with the aim of transferring the improved production properties. Ultramid A3WG10 XP BK23346 represents an alternative to the already available PA66-GF50 and PA66-GF60. Compared to a PA66-GF50, it offers increased mechanical properties in all areas and, compared to a PA66-GF60, better weld-line strength, easier and gentler processing, lower part weight, and a higher fatigue resistance. It is thus a good option for metal replacement if the requirements on the part are so high that they cannot be met with a conventional glass fiber-reinforced PA66.

20 Percent Higher Energy Absorption in a Crash

Since the Ultramid XP products have very high impact strength values, the behavior of these materials was also investigated under the high dynamic loading of a crash situation. For internal tests at BASF, an own-developed crash dome was produced and mounted on a slide. To perform this crash, this dome was driven against a metal wall at a speed of 8.5 m/s (**Fig. 5**).

On impact, the energy absorbed in each case was plotted against the path length. For evaluation of the crash tests, it was found that the very high impact strength of the materials leads to a significantly higher energy absorption during the crash. Compared with corresponding standard products, the PA6 and PA66 grades showed about 20 % higher energy absorption (**Fig. 6**). It was confirmed that, at temperatures below the glass transition temperature of the polymer matrix, a PA6 grade has slightly higher energy absorption than a comparable PA66 grade.

Improved Property Profile with Good Aging Resistance

Because of their properties, Ultramid XP products are ideal for applications at which standard PA6 and PA66 reach their performance limits. They have a generally improved property profile in terms of strength, stiffness and impact resistance. At the same time, they feature the good aging resistance of the Ultramid series and have slightly improved creep and fatigue properties. They are therefore very highly suited for replacing metals in various applications.

The Ultramid XP series has a myriad of possible fields of application. Since the PA6-based XP products reach the mechanical property level of reinforced PA66 grades for the same glass fiber content, they represent a good alternative to these. In addition, the highly reinforced Ultramid XP products can be used as metal substitutes that would have previously been inconceivable with commercially available compounds given their poor mechanical properties. With the design and development of new crash-relevant components, too, the series offers additional application potential due to the significantly higher energy absorption under dynamic loading. For the design of the corresponding components, BASF offers support with the Ultrasim simulation software if required. ■

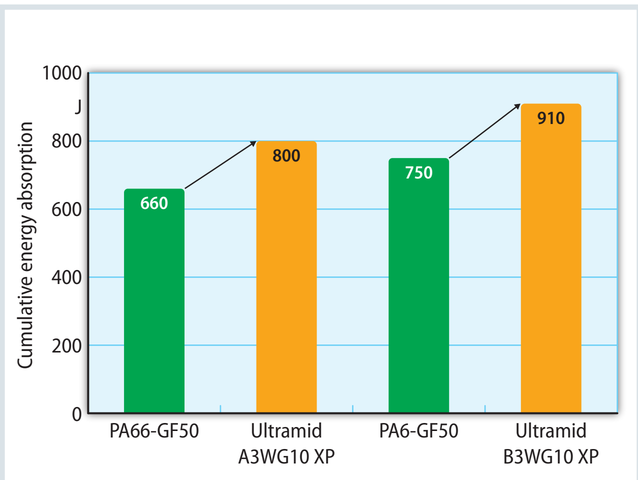

Fig. 6. In the crash tests, the Ultramid XP products show an approximately 20 % higher energy absorption in each case compared with the corresponding standard products Source: BASF; graphic: © Hanser