Co-Extrusion of PVC with Modified PBT Blend Improves Profile Mechanics

Extending the Limits of PVC

Profiles made of rigid PVC have many advantages: they are easily extrudable, inexpensive, and with suitable additives, they exhibit good UV resistance. However, regarding its mechanical and thermal properties, PVC occasionally reaches its limits. This shortcoming can be evaded by co-extrusion with a PBT blend.

PVC is widely used for extruded profiles. Typical applications are the profiles for windows, roller blinds, cable ducts, and other technical products. But in a few cases, the mechanical and thermal properties of PVC are inadequate for certain applications. A possible solution is to stiffen the profiles with metal. However, it would be preferable to find a material that combines the positive properties of PVC in terms of extrudability, UV resistance, weldability, flexibility in profile design, and costs with the outstanding mechanical properties of a highly reinforced technical plastic.

This can be achieved by co-extruding PVC with technical plastics. Previously, this was not possible, because the processing temperatures of technical plastics are significantly higher than those of PVC. Consequently, both polymers could not be guided simultaneously through a mold as a melt.

Therefore, BASF developed a new material: Ultradur B4040 G11 HMG HP. Ultradur is the company's trade name for a partially crystalline thermoplastic polyester based on polybutylene terephthalate (PBT). PBT is an established material for high-grade and highly stressed technical components in numerous industrial fields. Apart from its very good thermal stability, low moisture absorption, and good resistance to many chemicals, PBT features high stiffness. The melting point of PBT is usually 223 °C. However, the melting point of the material developed by BASF is 198 °C and therefore 25 °C lower. This permits co-extrusion with PVC in the classical processing window, thereby opening up a new, very interesting application area.

If the properties of pure PVC profiles are inadequate, PBT co-extruded versions are an option. For example, their thermal expansion and post-shrinkage when heated are lower. © BASF

Customized Melting Point plus High Stiffness

Aim of the development was a product that offers very high stiffness in addition to the customized melting point. A high elastic modulus and a low coefficient of expansion are required to meet the properties necessary for the profile. Thanks to a specific PBT blend plus a 55 % proportion of chopped glass fibers by weight, the required properties were achieved.

Frequently, the mechanical and thermal limits of PVC are as follows:

- Post-shrinkage, as soon as the material is heated once above 60 °C – in case of one-sided heating, this leads to a permanent curvature of the profile.
- High thermal expansion coefficient – with uneven temperature distribution, this also results in curvature.
- Temperature-dependent stiffness (elastic modulus) – even with slightly increased temperatures, the elastic modulus of PVC drops strongly.
- Creep tendency of the material.

The properties of classical rigid PVC and the newly developed Ultradur type are compared in **Table 1**. The values for stiffness and tensile strength were measured on injection-molded samples acc. to ISO 527. Extrusion results in lower values, because the fibers are less aligned in the manufactured product. However, a well-designed mold permits 70 % of the initial value to be achieved.

PBT Bears the Main Load

In the co-extruded product, PVC and PBT with their respective cross sections jointly dissipate the mechanical or thermal loads, whereby PBT frequently dominates. This is illustrated very well by analyses of the remaining post-shrinkage of different profiles. For this, pure PVC profiles, pure PBT profiles, and

co-extruded hybrid profiles were examined. Hereby, the temperature was maintained at 50 °C for 16 hours, and then reduced to 23 °C, and the remaining shrinkage measured. Subsequently, the cycle was repeated with the profiles, but with increasingly higher holding temperatures up to max. 100 °C (**Fig. 1**).

The PVC profile exhibits very strong post-shrinkage of up to 1.2 %. With a value of 0.015 %, post-shrinkage of the pure PBT profile across the entire temperature range is comparatively low. At maximum temperature, the co-extruded profile exhibits a shrinkage of just 0.13 %, which is considerably lower than that of the pure PVC profile. This clearly improved behavior of co-extruded profiles can be used to notably reduce permanent curvatures, for example in dark window frames subjected to intensive solar radiation, without resorting to a metal insert. Similarly, the co-extrusion with PBT also reduces the longitudinal thermal expansion of PVC significantly, as well as a possibly resulting curvature.

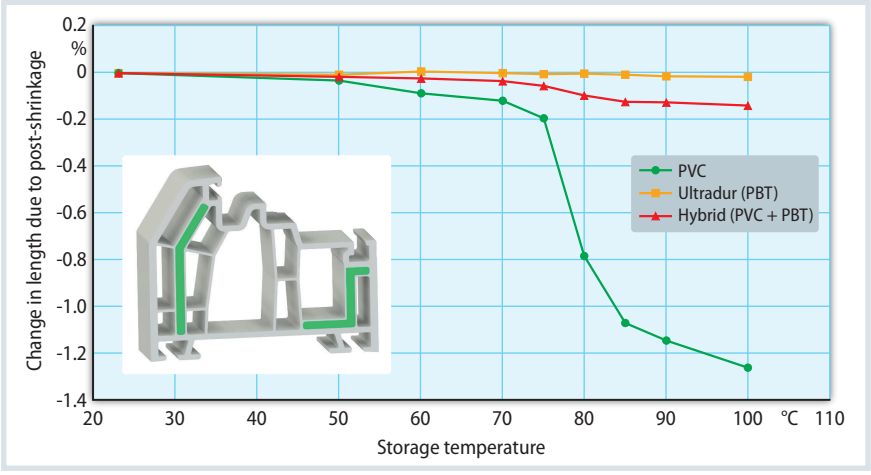

Fig. 1. Permanent post-shrinkage of profiles made of rigid PVC and the PBT Ultradur from BASF, as well as hybrid profiles of PVC and PBT after heating to a certain temperature: shrinkage of hybrid profiles is significantly lower than with pure PVC profiles. On average, the measured hybrid profiles contain about 18 % PBT. Source: BASF; graphic: © Hanser

Processing with Single-Screw or Twin-Screw Extruders?

The PBT developed by BASF for this purpose can be processed in both mono and co-extrusion. Important for processing is a low moisture content, which should lie below 0.03 %. If the value is higher, e.g. with open containers, pre-drying of the material is recommended. Among the different drying systems, the dry-air drier has proved to be superior, both technically and economically. Typical drying times are two to four hours at 80 to 120 °C.

Single-screw extruders as well as counter-rotating twin-screw extruders can be used for processing Ultradur. With single-screw extruders, single-flight, three-zone shallow screws with a length of 22 to 25 D should preferably be used. Hereby, a compression ratio between 2.5 and 3 is recommended. The compression zone length should be about 4 to 5 D. Barrier screws and shearing/mixing devices are less advisable, because they can damage the glass fibers. Single-screw extruders should be of the flat-bore type without a grooved bush. A melt temperature range of 210 to 220 °C should be aimed for, with a moderate screw speed as far as possible.

Important Processing Parameters

Counter-rotating twin-screw extruders, both parallel and conical, are the preferred choice in the PVC industry. They are also suitable for processing PBT. Disadvantageous is the higher purchasing price compared with single-screw extruders. But the frequently present degassing and pressure build-up (chamber feeding) can be advantageous. Suitable wear protection (barrel and screw) should be observed with single as well as twin-screw extruders. As with all glass fiber-reinforced polymers, processing of Ultradur requires that shear is kept as low as possible to prevent the glass fibers being damaged or shortened. The challenge hereby is to ensure complete melting of the material at the lowest possible temperature, so that the PVC is not affected negatively during convergence. The temperatures in the co-extrusion mold must be selected so that the PBT can flow without freezing, while preventing damage to the PVC at the same time.

Fast and Safe Way to a Good Mold

A good mold, combined with a functioning extrusion process, must ensure the following properties: »

	Tested acc. to standard	Unit	Rigid PVC	Ultradur B4040G11 HMG HP
Polymer	-	-	PVC	PBT blend
Chopped glass fiber portion	-	%	0	55
Melting point	ISO 11357	°C		198
Vicat softening temperature VST/B/50	ISO 306	°C	81	134
Elastic modulus (at 23 °C)	ISO 527	MPa	2800	20,000
Elastic modulus (at 80 °C)	ISO 527	MPa	180	4800
Tensile strength (at 23 °C)	ISO 527	MPa	45	160
Tensile strength (at 80 °C)	ISO 527	MPa	11	41
Expansion coefficient: lengthwise/crosswise (at 23 °C)	ISO 11359	10^{-6}/K	70	15/65
Post-shrinkage	BASF method	%	0.9	0.03

Table 1. Properties of a classical rigid PVC and an Ultradur PBT type. Source: BASF

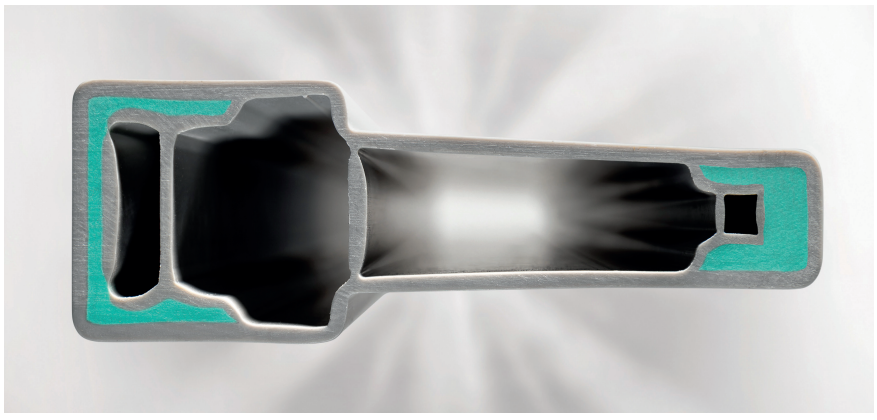

Fig. 2. This co-extruded profile replaces a steel profile in certain window frames. The lower thermal conductance increases the energy efficiency. © Profine

- effective implementation of the PBT's mechanical properties (suitable positions and cross sections),
- high forward orientation of the glass fibers in the PBT – this leads to a high elastic modulus, higher strength, a lower expansion coefficient, and even lower creep behavior,
- specified wall thicknesses in all areas of the geometry,
- no curvature of the extruded profile,
- high haul-off speed,
- permanent serviceability, and
- plannable time from ordering to delivery of the molds.

However, the development requires more expertise than for classical co-extrusion molds, which are mostly used to process materials with comparable properties.

In the present case, the flow channels in the mold must be designed for two materials with different flow behaviors (PVC: wall slippage, PBT: wall adherence). The two materials also differ in viscosity and velocity profile in the channel.

Moreover, it is advantageous if the glass fibers are shortened as little as possible, and have a maximum forward orientation. After all, the PBT should freeze in a suitable position.

During mold design, it must be taken into account that PVC tends to swell considerably. If possible, the thickness of the Ultradur profile should not be less than 1.5 mm, to minimize glass fiber damage.

Several molds for this material combination have already been developed and are in series production. Greiner Extrusion, an Austrian mold maker, has already built several successful molds.

Weldability of Co-Extruded Profiles Ensured

In some applications, e.g. for PVC widow frames, the profiles are cut at a 45° angle and then welded. Simultaneous welding is also possible with co-extruded profiles made of PVC and Ultradur, because both materials can be processed in the same temperature window. To obtain high strength, it must be ensured that PVC butts against PVC, i.e. there is no PBT melt in between. Due to the glass fibers in Ultradur, a higher wear of welding foil has been observed during butt welding. However, the cycle time remains practically the same.

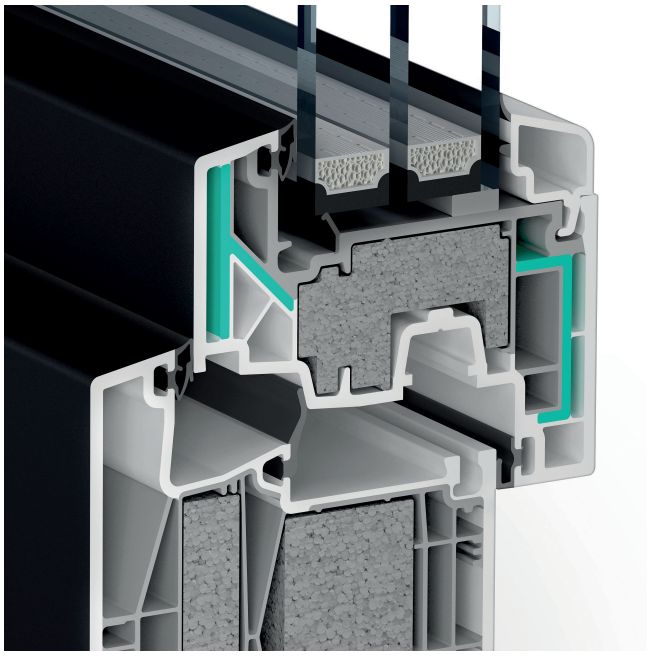

Fig. 3. Ultradur B4040 G11 HMG HP can be used instead of steel to stiffen rigid PVC profiles. The result is a lower permanent deflection after one-sided heating. Moreover, thermal conductance is reduced. This permits large, energy-saving windows, also with dark-colored profiles.
© Profine

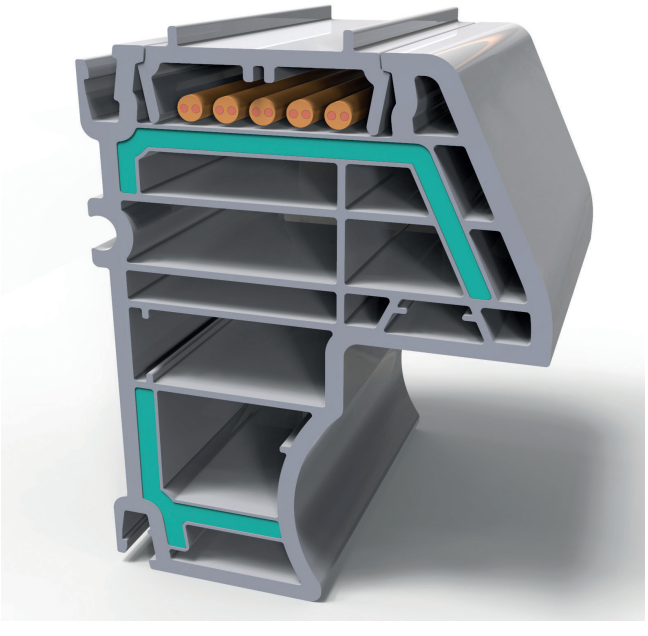

Fig. 4. Door profile of a chest freezer: hereby, Ultradur replaces a metal stiffener, which eliminates the need for an electrical heater in the profile to prevent condensate formation on the outer surface. This improves the freezer's energy efficiency.
© Greiner Extrusion

Recycling: Easy Separation of PVC and PBT

Recycling is gaining in importance, and has become firmly established in the PVC window frame industry for years. Also co-extruded profiles made of PVC and PBT can be recycled easily. Hereby, the coloring of the plastics is helpful during treatment. Ultradur B4040 G11 HMG HP is available in a non-colored and in a green-tinted version, which simplifies sorting of the window frame profiles in the recycling procedure at the end of their service life.

After the profile has been disintegrated into small particles in a mill, Ultradur can be separated from the PVC using different methods. This works most effectively with color sorters, because other green-colored plastics are not used in the window making business. In case of similar coloration of PVC and Ultradur, use of an NIR sorter or an electrostatic sorter is possible. Should traces of Ultradur remain in the PVC, these can be removed by means of a melt filtration. Subsequently, the recycled PVC and Ultradur fractions can be reused. Their recyclability has been confirmed in plants that are customary in the industry.

Summary

If a PVC profile does not meet the mechanical requirements, co-extrusion with Ultradur B4040 G11 HMG HP can be an intelligent alternative. This is shown by various application examples developed jointly with BASF (**Figs. 2, 3, and 4**). Other possible applications are folding shutters, roller blinds and their housings, gutters, fence and balcony profiles, house cladding panels, and rods for agricultural use. ■

Info

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Glass Fiber-Reinforcement Made of 100 % Recycled Material

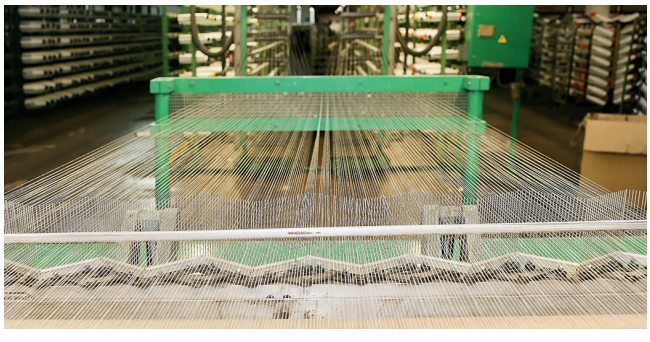
PBT Compounds for a Lower Carbon Footprint

The plastics manufacturer **Sabic** has presented two glass fiber-reinforced compounds based on polybutylene terephthalate (PBT). LNP Elcrin WF006XXPiQ compound and LNP Elcrin WF0061XPiQ compound, the first two grades in a new portfolio of materials that incorporate pre-consumer recycled glass fiber diverted from the waste stream of industrial processes. These compounds are reinforced with 30 % pre-consumer recycled short glass fiber. According to the company, they offer mechanical properties and color equivalency of Elcrin iQ grades that use virgin glass fiber-reinforcement.

The short glass fiber used in these compounds contains 100 % recycled content as stated in a press release. Compared to virgin PBT reinforced with virgin glass fiber, LNP Elcrin WF006XXPiQ compound contains 67 % recycled content and lowers carbon footprint by 29 %, while LNP Elcrin WF0061XPiQ compound contains 55 % recycled content and reduces carbon footprint by 24 %.

In addition to their improved sustainability profile, these materials deliver good structural performance (stiffness and strength), chemical resistance and colorability. Furthermore, the new LNP Elcrin WF0061XPiQ compound offers non-halogenated flame retardance.

As a drop-in replacement for incumbent virgin PBT and Elcrin iQ grades, the two new compounds enable customers to increase application sustainability without the need for design or tooling changes, e.g. for applications in the consumer electronics, automotive and electrical & electronics industries. Sabic plans to extend the use of pre-consumer recycled glass fiber to reinforced compounds based on other resins.



The glass fibers for the compounds come from treated industrial waste. © Sabic

"These two next-generation materials create new possibilities for customers to advance their carbon neutrality strategy by further increasing the amount of recycled content they use and lowering the carbon emissions of their applications, all while maintaining equivalent properties and processability," said Darpan Parikh, Global Product Management Leader, LNP Portfolio, Sabic's Specialties business.

www.sabic.com