Producing Intricate Parts Economically

Steering angle sensor produced from flow-enhanced PBT

Car Electronics. By adding a specially developed nanoparticle system the flow properties of polybutylene terephthalate (PBT) can be distinctly improved. In processing by injection moulding the product considerably reduces injection pressures and cycle times and in this way affords marked cost advantages. These come to the fore especially in the production of components for motor car electronics.

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Polybutylene terephthalate (PBT) in its conventional form is already an engineering thermoplastic suitable for widespread applications. The material is semi-crystalline, has high heat resistance, low water absorption, high dimensional stability and is very resistant to numerous chemicals. As with most thermoplastics a decisive factor in its processing is its melt viscosity. Accordingly, any improvement in this property should shorten cycle times, reduce processing costs and hence make a contribution to ensuring the competitiveness of both manufacturers and processors.

With the aid of a specially developed nanoparticle system BASF achieved a significant reduction in the melt viscosity of PBT (Fig. 1). Depending on the glass-fibre content the new PBT compound, Ultradur High Speed, flows at least twice as far as comparable standard types of Ultradur. The mechanical properties of rigidity and strength, shrinkage characteristics and heat resistance are not affected by the modification so that the newly developed product is able to meet the steadily rising demands imposed in the field of engineering thermoplastics. This greater scope for processing affords processors and designers a great deal of design freedom when working with PBT.

Nanotechnology is the Key

The research field of nanotechnology is concerned with structures and applications of the order of magnitude of billionths of a metre (nanometres), corresponding to a diameter of up to 10 atoms. In applications in polymers the term nanocomposites is also used, this referring to minute particles dispersed in the polymer which can have a major effect on the properties of the material. The key to the innovation in flow-enhanced PBT lies in the use of additives in the form of finely dispersed nanoparticles. In doing so it was essential not only to determine the optimum particle size, but also to distribute the nanoparticles uniformly in the polymer. The size of the particles in the additive used in the new Ultradur

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varies from 50 to 300 nm. This additive together with the special method of admixing it alter the rheology of the base polymer fundamentally: while the structural, non-Newtonian viscosity remains the same the melt viscosity drops dramatically, by approximately 50 % in the case of a PBT product containing 30 % glass fibres (melt temperature: approx. 260 °C).

Advantages for Processors and Designers

The improved flow properties afford processors a series of advantages. For example, due to the lower melt viscosity lower injection and holding pressures are adequate. In the injection moulding process, by lowering the temperature of the melt the cooling time and hence the total cycle time can be reduced.

New vistas also emerge for thin-walled parts: the less viscous Ultradur High Speed can flow in even thinner moulds and so can be used for producing quite novel structural parts. For this reason it is now possible to use PBT for manufacturing intricate components which up to now could only be made from expensive high-performance plastics. Fig. 2 shows a filling study in which it can be seen that the very thin webs of the small plug weighing 1.5 g are not filled by standard PBT (left-hand side) but are filled very well by the more free-flowing Ultradur High Speed (right-hand side). In this case the customer was persuaded by the outstanding ease of flow which helped him to solve the production problems associated with his complex mould incorporating eight cavities. The volume of waste fell and it was possible to reduce the cycle time by 20 to 25 %.

Flow behaviour

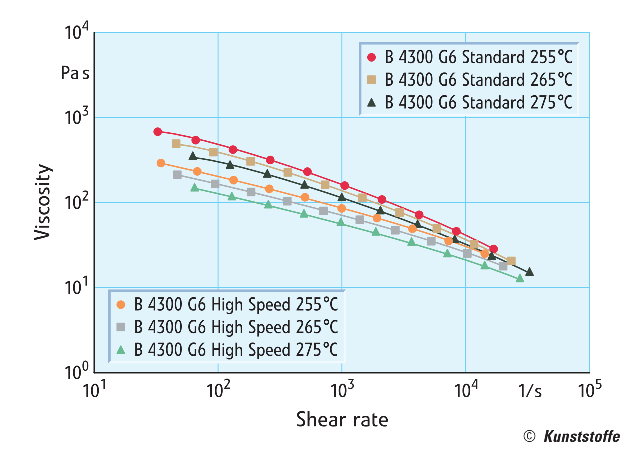

Fig. 1. While shear remains the same, flow-enhanced PBT Ultradur High Speed has a much lower viscosity than conventional PBT

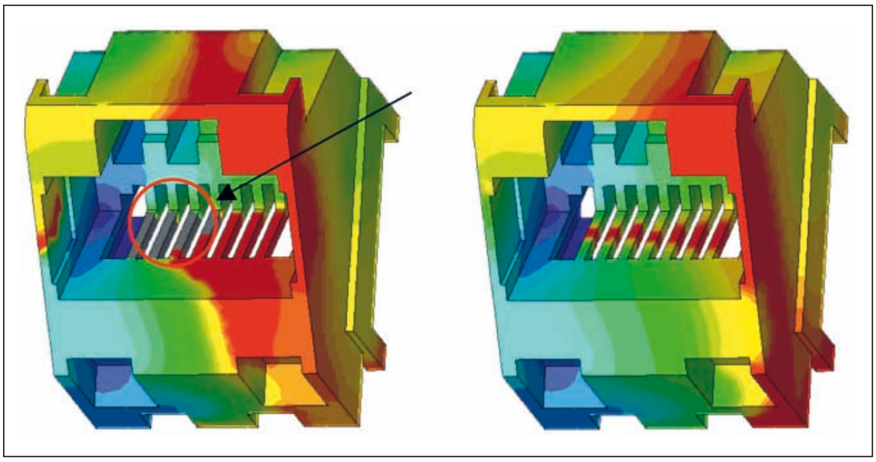

Fig. 2. While standard PBT (left) does not fill the part completely it was possible using flow-enhanced PBT to fill the intricate webs without leaving voids (right)

Even thin-walled articles containing a relatively high proportion of reinforcing materials, such as glass fibres or mineral fillers, are possible with this new, free-flowing PBT. At the same time better mechanical properties can be achieved while wall thickness is reduced. The overall machine configuration can be trimmed down: smaller injection moulding units and moulds with fewer gates – and hence fewer costly hot runner nozzles – are possible and the number of critical weld lines falls.

Fig. 3. Nine-pin plug for a car made by Tyco from flow-enhanced PBT

Preferred Applications: Motor Car Electronics

Following the first mass-produced part (Fig. 2) for the telecommunications sector, the new PBT has in the meantime been chosen for numerous interesting applications in car electronics. These include, for example, the nine-pin plug developed by Tyco, Bensheim/Germany, for the engine compartment (Fig. 3) and the steering angle sensor for which Bosch, Abstadt/Germany, specifically employs Ultradur High Speed. The sensor, which is seated on the steering column, passes on the current position of the steering wheel directly to the electronic stability program (ESP). In this application high-contrast laser etching has proved to be a further advantage of the material (title picture). The 16-pin plug

Fig. 4. 16-pin hybrid plug made from flow-enhanced PBT by Molex for fuse and relay boxes in the interior of vehicles

for fuse and relay boxes developed by Molex, Ettlingen/Germany, is also used in car interiors. In the case of the so-called Sicma hybrid plug, due to the excellent flowability of the material it was possible to fill this under such mild conditions that the balanced mechanical properties of the plastic are retained. Thus, the elasticity of the component is high enough to accommodate even cables having large cross-sections (Fig. 4).

Some electronics-related components in the car, e.g. ABS housings, are produced by encapsulating metallic conductor tracks in plastic by injection moulding. The higher the pressure acting on the conductor tracks while this is being done the greater is the risk of them being deformed or crushed and losing their ability to function. Due to its enhanced flowability Ultradur High Speed reduces the pressure acting on the conductor tracks during injection moulding and reduces any deformation (Fig. 5).

Ease of Colouring and Improved Adhesion

Uniformly dispersed nanoparticles also account for the fact that flow-enhanced PBT can be uniformly pigmented with less colour batch. As Figure 6 makes clear homogeneous pigmentation is achieved with as little as 0.1 % of a blue PE-based masterbatch. When switching from conventional PBT to Ultradur High Speed up to 50 % of masterbatch can be saved to achieve the same depth of colour. Pigments are better dispersed and the colour distribution is more uniform. As a result total costs of in-house pigmenting for the processor are distinctly lower.

Advantages of in-plant pigmenting which come to the fore especially with Ultradur High Speed are reduced complexity in logistics and more flexible changes in colour. Investments in the metering unit, test equipment and mixing elements are amortised even if consumption amounts to only 5 t PBT per annum after about three years.

In order to investigate adhesion between the new PBT and metal layers standard tensile test pieces made from a conventional product (Ultradur B4300 G6) and from the analogous flow-enhanced PBT were electroplated with copper and then the adhesion of the metal to the plastic was tested. The peel resistance (specified in N/mm) was determined at the Institut für neue Materialien (Institute for New Materials) in Fürth/Germany in accordance with DIN 53494 using a stripping test (Fig. 7). In the case of Ultradur High Speed it was found that adhesion between metal and plastic was improved by almost 50 %.

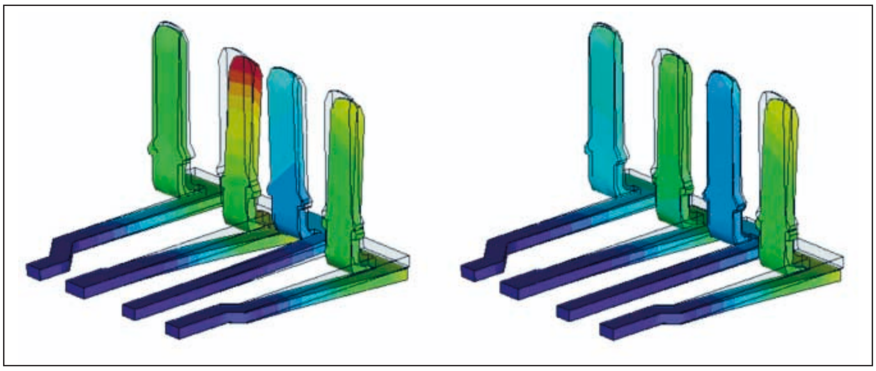

Fig. 5. Even in the case of conductor tracks encapsulated by injection moulding a free-flowing material has advantages: due to the reduced injection pressure unwanted deformation of the conductor tracks is largely prevented (on the left: conventional PBT with 30 % glass fibres; right: High Speed variant)

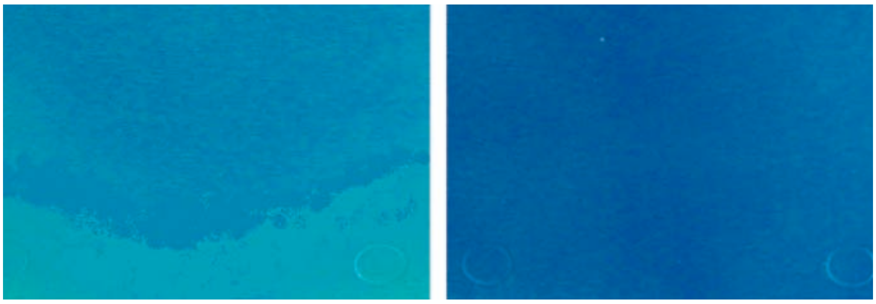

Fig. 6. Colouring PBT: When Ultradur High Speed is used the pigments are dispersed much more uniformly to yield a better colour distribution (on the left: 0.1 % blue colour batch (Eupolen) in standard PBT; right: in Ultradur High Speed)

Fig. 7. Metallised tensile test piece after peel test in accordance with DIN 53494

Application development technicians determined its adhesion to flexible components by two-component injection moulding of parts made from standard Ultradur B4300 G6 and Ultradur B4300 G6 High Speed with Elastollan C65A and C85A. The latter are two thermoplastic polyurethane elastomers (TPU) produced by BASF's subsidiary Elastogran with a hardness of 65 and 85 Shore A respectively. Adhesion in N/mm for the Ultradur High Speed/TPU combination of materials is almost twice as high as the ▶

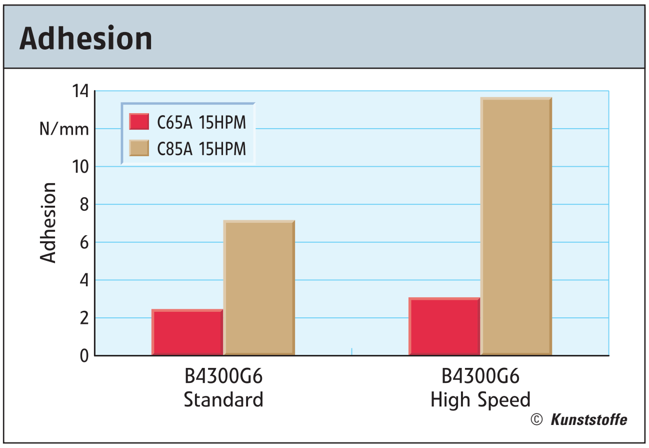

Fig. 8. Adhesion of standard (left) and High Speed PBT (right) to TPU having hardnesses of 65 and 85 Shore A

combination using conventional PBT (Fig. 8).

Ecological and Economic Advantages

The technical university ETH in Zurich has now quantified not only the economic but also the associated ecological advantages of the new material. Due to the material's good flowability the production of injection moulded parts is not only less costly but at the same time helps to save energy and hence to conserve the environment. With the aid of an ecoefficiency analysis different alternative products or processes having the same objective can be subjected to a life cycle review – that is to say their impact is quantified from cradle to grave. In this way energy, material and cost savings arising from the use of Ultradur High Speed can be determined for each customer or application (Fig. 9).

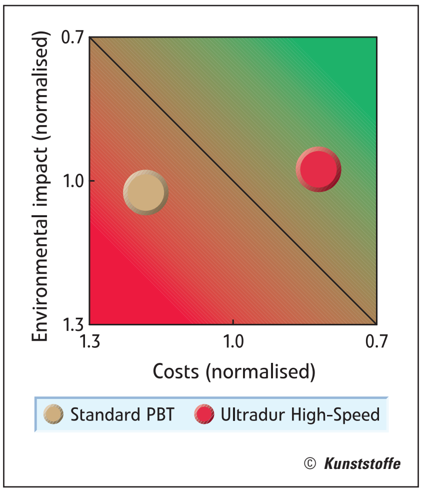

Fig. 9. Ecoefficiency analysis of Ultradur High Speed and standard PBT compares ecological and economic advantages of two alternatives offering the same benefits to customers

Today most products in BASF's PBT range are also available in a High Speed variant. This applies to the classic injection moulding types, the particularly low-warpage (PBT+ASA) blends and the B4040 versions having optimised surface properties. These will soon be joined by a halogen-free, flame-retardant Ultradur High Speed. All High Speed types pigmented in black are, moreover, laser-etchable. At present, interest in Ultradur High Speed is growing in particular in Asia and America because it helps bring the enormous cost pressures under control. ■

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