Improving Efficiency and Specific Energy Consumption in Injection Molding

Material Modified, Cycle Time Reduced

Cycle time is an important factor in injection molding. Reducing it boosts productivity, reduces specific energy consumption and improves flexibility, while the overall cost per component drops. Cycle time can be reduced not only through technical advances but also by using appropriate compounds, as demonstrated by the collaboration between BASF, Engel and TE Connectivity.

The reduction of cycle time during the production of injection-molded parts presents a complex challenge. Progress in tooling technology and machine equipment plays a crucial role in this. Another limiting but optimizable factor is the plastic compound used, as the time it takes to eject a strong and high-quality part depends on it.

TE Connectivity, a manufacturer of connector and sensor solutions, is constantly striving to optimize its production processes, particularly in the production of connectors. The shortest possible cycle time has a significant impact on increasing productivity. The plastic compound used is a decisive factor for overall cycle time, so the further development of the material is crucial in order to optimize cycle time. In a joint development project, TE and BASF have investigated the desired material optimization. The two companies have been working closely together for years. BASF supplies TE with such technical plastics as polybutylene terephthalate (PBT), polyamide (PA) and polyphthalamide (PPA).

More than ten years ago, BASF developed its "High Speed" product line and successfully established it in the market. These compounds are noted for their excellent flow behavior, especially for thin-walled parts, enabling processing with shorter injection times and lower injection pressures.

An alternative approach is to lower the melt temperature compared to conventional products while maintaining the same flowability (**Fig. 1**).

This enables shorter cooling times and thus further reduced cycle times. The use of high-speed compounds thus offers huge potential for cycle time optimization and boosting efficiency in the injection molding process. For the joint development project, these compounds served as the basis.

Improving of the high speed compounds with accelerated crystallization and, in some cases, higher heat deflection temperature enables significantly earlier removal from the injection mold (**Fig. 2**).

Initially, comparative tests were carried out under production conditions at the TE site in Dinkelsbühl, Germany. A specially compounded PBT-GF15 was processed for the initial mold trials. Based on the experience gained, BASF developed a dedicated product line called High Productivity Plus (HPP). For the tests, parts were selected that had already reached the limit of the minimum achievable cycle time using conventional optimization methods.

Quality Is Maintained

Even in the first test settings, it became clear that the time it takes for the component to be ejected can be significantly reduced while maintaining the

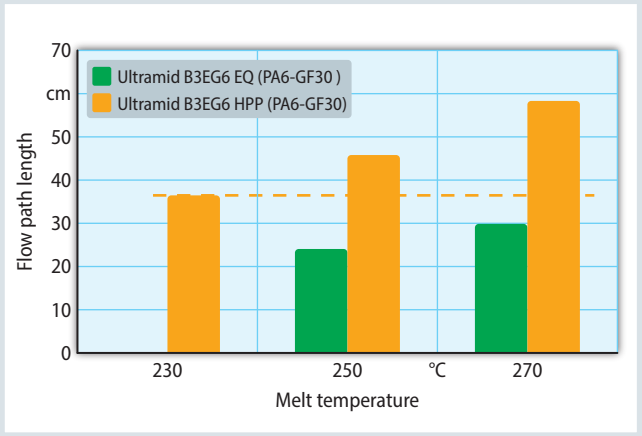

Fig. 1. Studies on flow spirals show the excellent flowability of PA6-GF30 HPP. Even at low melt temperatures of up to 230 °C, the flow path length surpasses that of unmodified PA6-GF30 at 270 °C.

Source: BASF; graphic: © Hanser

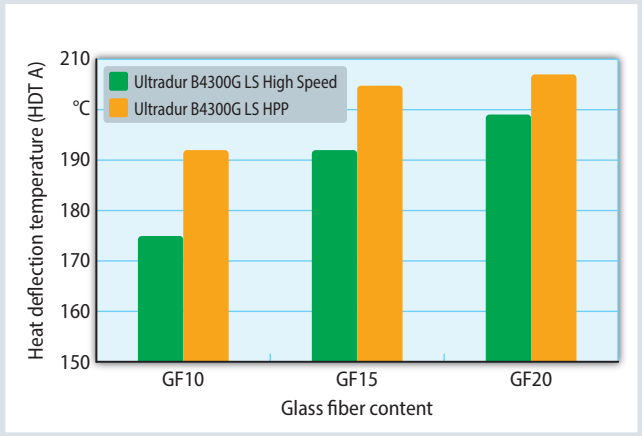

Fig. 2. The measurement shows the significantly higher heat deflection temperatures of the optimized PBT HPP. This property enables parts to be demolded at higher temperatures and correspondingly shorter cooling times. Source: BASF; graphic: © Hanser

same quality. However, it was found that the injection molding machine and the metering process prevent a further reduction in cycle time. This limiting factor can be compensated for by increasing the screw speed. However, this makes the processing recommendations impossible to adhere to, and increased shearing introduces additional heat into the compound.

For further tests, machines with larger plasticizing units or tools with needle shut-off systems were selected. This enabled cycle time savings of up to 30 %. These results show the potential for significant cycle time improvements and the need for machine and tool adjustments to achieve these savings. The findings of the study help to improve efficiency and productivity further in the injection molding process.

The manufactured parts were subjected to internal release and series testing at TE under defined conditions. To identify deviations from the series material, wet-chemical, thermal and physical material analyses, as well as component-specific test series, were conducted. No application-relevant differences between the developed materials and the series material were found.

Product name	Polymer	Available colors	Special features
Ultradur B4300G2 HPP	PBT-GF10	black, laser markable	optimized for cycle time reduction
Ultradur B4300G3 HPP	PBT-GF15		
Ultradur B4300G4 HPP	PBT-GF20		
Ultramid B3EG6 HPP	PA6-GF30	black and uncolored, laser markable	optimized for cycle time reduction and CTI 600

Table. BASF HPP product portfolio (High Productivity Plus) Source: BASF

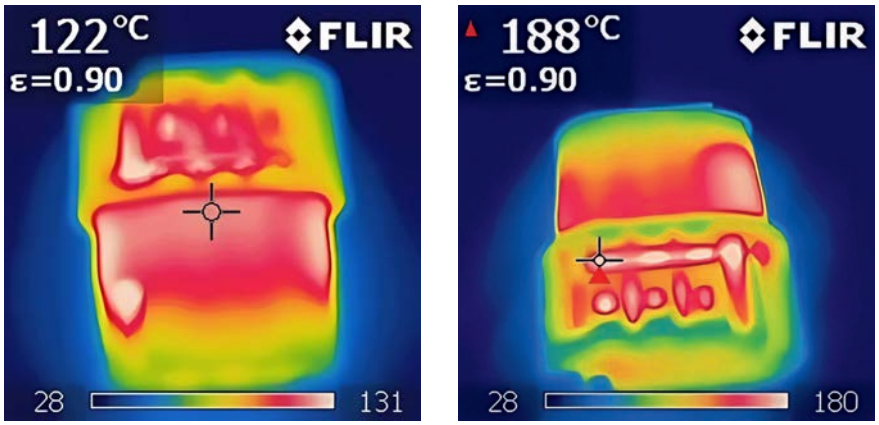

Fig. 3. Thermographic images of the parts immediately after demolding (left: standard PBT, right: optimized PBT HPP): Parts using HPP can be demolded at significantly higher temperatures without damage. © TE Connectivity

Demolding at Higher Temperatures

During the DSC analyses, the developed material showed a higher crystallization peak (median 202 °C) than the flow-modified variant (median 195 °C). The difference between the onset and endset temperatures, marking the beginning and end of the crystallization process, were comparable. This allows the parts to be demolded at higher temperatures (**Fig. 3**), thus helping to reduce cycle time.

No Dimensional Deviations

Computed tomography (CT) scans showed no relevant dimensional deviations between the components produced with the experimental material in reduced cycle time and the series-produced components (**Fig. 4**). The overall development process and the conducted studies were documented in a bachelor's thesis [1]. This project provides detailed insight into the process of cycle time reduction and shows the successful implementation of the developed material in practice. »

Fig. 4. In the evaluation of CT scans of the part, standard PBT versus HPP material, no dimensional deviation is observed despite the significantly reduced cycle time.

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The investigations in the co-creation project were initially conducted at the BASF technical center and at TE's production facility. It was important here to generate representative results on the latest-generation machines in a neutral test environment. To ensure optimal testing conditions, the injection molding machine manufacturer Engel Austria was brought in as a reliable partner. Thanks to Engel's expertise and technological skills, the studies were conducted at the highest level and the desired results achieved. Additionally, the collaboration ensured that the project results are realistic and industry-relevant.

Additional Expertise from Engel

At Engel's customer technical centers, 20 different injection molding machines are constantly available for material trials, as well as for tool and machine tests. The machines cover a wide range of clamping forces from 500 to 55,000 kN, thus accommodating a very large range of materials and shot weights. Over 40 experienced application engineers are on hand for the technical support of tests and daily customer support regarding process management and optimization.

All BASF products from the HPP portfolio were processed at Engel's technical center using fully electric injection molding machines. Two different-sized connectors were chosen for the test series: A smaller part with a shot weight of 37 g was produced on a fully electric Engel E-mac 465/130 with a clamping force of 1300 kN, while a larger connector, with a shot weight of 185 g, was produced on a fully electric Engel E-motion 940/220 with a clamping force of 2200 kN (**Fig. 5**). The injection molding tools used by TE are state-of-the-art.

To achieve comparable results, the following procedure was adopted for all material-part combinations:

1. **Reference setting:** Stable production cycle with standard material.
2. **HPP base setting:** Material switch to HPP material with identical process parameters.
3. **Optimized HPP:** Reduction of cycle times to the absolute minimum.
4. **Termination criteria:** Inspection for warping, ejector marks, material build-up, stress whitening, voids and other typical injection molding defects.

Up to 36 Percent Shorter Cycle Time

The present studies confirm previous results and show that significant cycle time savings of up to 36 % are possible (**Fig. 6**). However, it is important to note that this setting should be regarded as

Advantages at a Glance

- Reduction of cycle time with comparable material performance
- Significant cost savings and easy material changeover
- Significant increase in material throughput by an average of 30 %
- Lower specific energy consumption due to increased output by an average of over 15 %
- Contribution to reduced carbon emissions

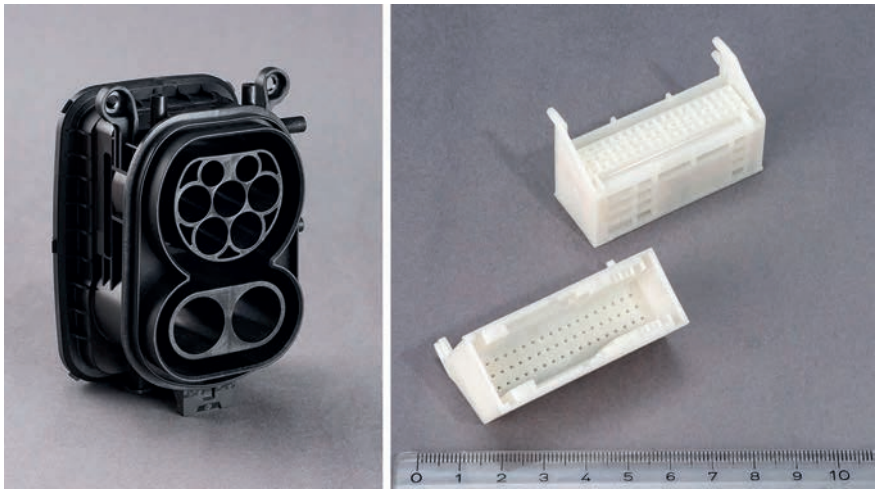

Fig. 5. For the tests, standard charging inlets (left) and connectors (right) were produced on two different injection molding machines. © TE, BASF

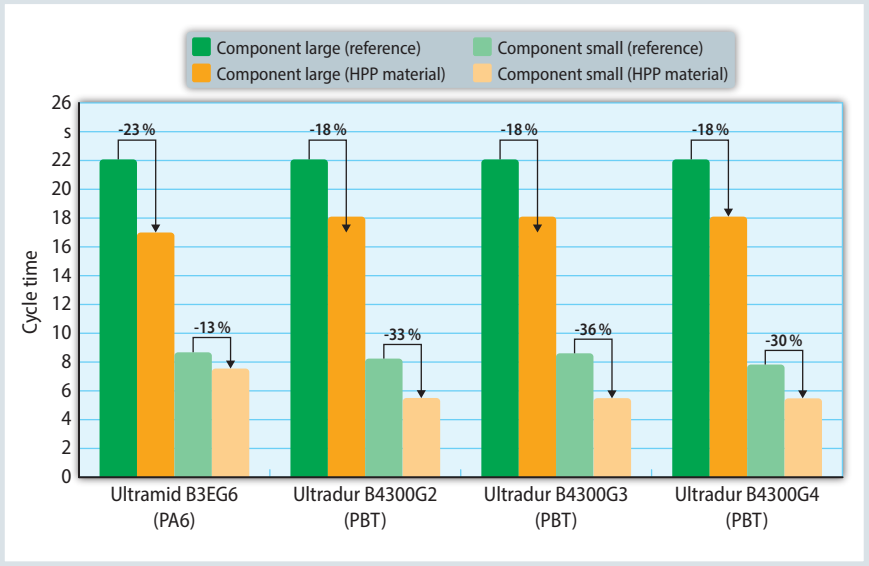

Fig. 6. Results of the joint studies to determine the minimal cycle time at Engel's technical center: Depending on part size, glass fiber content and polymer type, HPP optimization can achieve up to 36 % cycle time savings. Source: Engel; graphic: © Hanser

an absolute limit case. To ensure a robust production process and exclude potential disruptions, buffer times should be considered. Such times allow a degree of flexibility and ensure compliance with production standards and quality. Meticulous planning and weighing up the optimal cycle time are essential to ensure smooth production.

During the test series, the energy consumption of the two Engel injection molding machines was also measured. It was shown that the significantly higher material throughput resulted in a much lower specific energy consumption. A reduction of up to 19 % was possible for the larger connector produced on the E-motion, and over 22 % for the smaller one produced on the E-mac.

Conclusion

The development of HPP materials thus enables processing companies to reduce cycle times while maintaining comparable material performance. Significant savings can be achieved through a simple material switch. The mechanical properties show only minor differences over established standard materials. However, switching materials should always be carefully evaluated.

The studies show that, by reducing cycle times, material throughput can be significantly increased, on average by 30 %. This has direct implications for the machines and tools required. Another advantage of reduced cycle time is lower power consumption per cycle. Energy consumption in relation to material throughput can be reduced by over 15 % on average (**Fig. 7**). Given specific energy consumption of 500 Wh/kg, the economic aspect is not decisive, although carbon emissions can still be reduced.

Thanks to the positive test findings, BASF's HPP technology has been extended to other glass fiber contents and also to PA6 (**Table**). This permits broader application of HPP technology and opens up new scope for cycle time reduction and efficiency improvement in a variety of application areas. ■

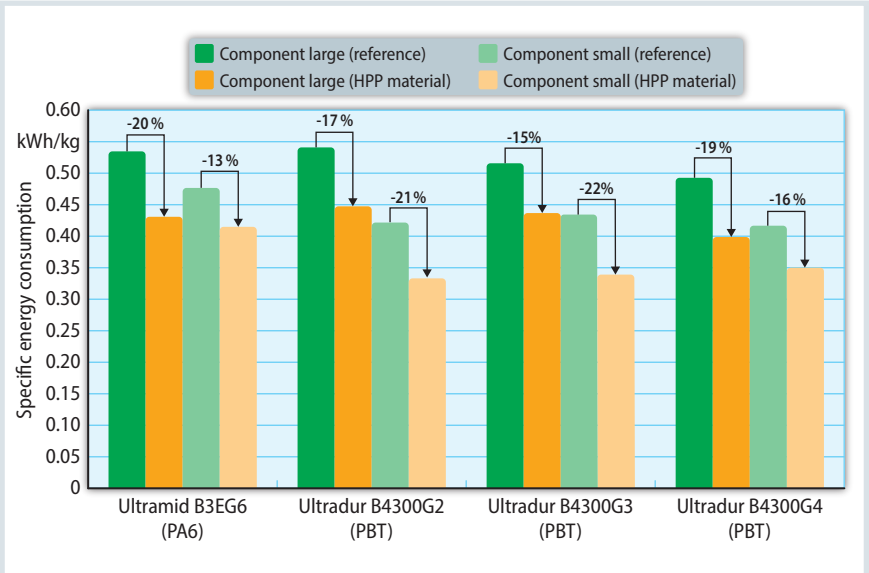

Fig. 7. Specific energy consumption of the injection molding machine in relation to material throughput: The use of HPP material, combined with increased material throughput, reduces the specific energy consumption of the injection molding machine by an average of around 15 %.

Source: Engel; graphic: © Hanser

Info

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References

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