Lightweight Material with Class A Surface

Rear Apron Made from Polyurethane with Extremely Low Density

Construction with lightweight materials offers great potential for reducing vehicle weight. This is demonstrated by the example of the rear apron on the new Porsche 911 GT3 RS sports car. It is made from polyurethane (PU) elastomer with an extremely low density and is around 23 % lighter than its predecessor model, while providing the same mechanical performance and surface quality.

The performance dates of the new Porsche 911 GT3 RS are on the threshold of that required for professional motorsport. The rear apron is produced from the lightweight material, Bayflex Lightweight, and is one of the largest exterior automotive parts of its type made from polyurethane (© Dr. Ing. h.c. F. Porsche)

Lightweight design is becoming increasingly important in automotive construction. It makes cars more environment-friendly and cuts fuel consumption and CO_2 emissions. In the case of electric vehicles, every saving in weight extends the battery range. In addition, some of the weight saved can be used to design larger batteries. There is also a benefit in terms of driving dynamics. The lighter a vehicle is, the lower its roll and acceleration resistance, which means higher final speeds.

With their lower density than steel and aluminum and wide variety of shaping options, plastics are playing an increasingly important role in lightweight automotive construction. This is particularly true for vehicles whose performance is on the threshold of that required for professional motorsport. So, for example, intelligent lightweight design solutions in plastic play a key part in the sportiest version of the present 911 generation of cars manufactured by Dr. Ing. h.c. F. Porsche AG, Stuttgart, Germany (**Title figure**).

Lighter than Water

In the Porsche 911 GT3 RS sports car, a PU elastomer system with a density lower than that of water (less than 0.9 g/cm^3) is used for the first time in serial production. For comparison, the density values of steel and aluminum are around 8 and 3 g/cm^3 respectively. The lightweight material, Bayflex Lightweight, has been developed by Covestro Deutschland AG, Leverkusen, Germany, formerly Bayer MaterialScience, in close collaboration with

3M Deutschland GmbH, Neuss, Germany, and the processor, Polytec Car Styling, Hörsching, Austria (**Fig. 1**). The rear apron of the sports car is produced from this material. It is about 1.2 kg lighter than the corresponding component in the predecessor model. This weight saving of around 23 % is the result of close cooperation between auto manufacturer Porsche, the two material producers, and the processor.

One of Polytec's core competencies is to develop materials and processes that enable plastic components to be made even lighter and more stable. The company adapted the PU-reinforced reaction injection molding process (RRIM) to this lightweight material and optimized cost-effective serial production of the required components. It developed a suitable method for mixing the PU starting materials isocyanate and polyol with the special fillers and reinforcing materials. Polytec's expertise encompasses selection of the right processing parameters for the RRIM machine (including air nucleation and material and mold temperatures), as well as mold and component design and further processing of the components to deliver premium paintability.

Fig. 1. The design freedom offered by the polyurethane system is not only exploited to advantage in the size and complex shape of the rear apron but also permits a high degree of functional integration (© Polytec Group)

Density Reduction with Lightweight Filler

The previous rear apron design was produced with Bayflex 180, also a tough-elastic PU elastomer system made by Covestro. This material has a much higher density (1.26 g/cm^3) than Bayflex Lightweight, which is due mainly to the 17 % content of mineral fibers with a relatively high density of 2.85 g/cm^3, which are added to increase strength and stiffness. The material producer therefore looked for alternative fillers and reinforcing materials to reduce density and obtain an even more lightweight PU elastomer. The solution finally adopted was to use 3M glass bubbles instead of mineral fibers in combination with lightweight, ground carbon fibers.

The glass bubbles are a functional lightweight filler. They consist of hollow microspheres made from borosilicate glass, which combine very low density with high compressive strength. The glass bubbles are chemically inert, water-insoluble, and finely dispersed in the PU reaction system. 3M is currently expanding this bubble range for use in a wide variety of different applications. At the present time, it covers average nominal densities from 0.125 to 0.60 g/cm^3. To extend its spectrum of use, 3M is continually adding new product variants with modified properties to the range. Among such products are glass bubbles which, compared to the PU material described above, give rise to more impact-resistant foams with a slightly lower flexural modulus and minimally higher density. Such foams are intended for applications involving exposure to very high impact stress. These hollow glass microspheres are suitable for various other types of polymer besides PU systems. For example, 3M has also developed highly crush-resistant variants for injection molding of thermoplastic lightweight components.

Carbon Fibers from Scrap

The function of the ground carbon fibers is to impart good strength and stiffness to the PU system. Their short length of only 500 µm and the shape of the glass bubbles mean that, in contrast to mineral-reinforced Bayflex 180, the PU material produces components with virtually isotropic mechanical properties, so facilitating design simulation of the components for various load cases. Because of the short fiber length required, the carbon fibers can be collected from the fiber mat residues occurring during manufacture of carbon fiber-reinforced plastic parts. These recyclates impart »

Fig. 2. View of rear apron production in Hörsching, Austria. The components are not only produced here but also receive a class A paint finish. The site specializes in short-run production of automotive exterior parts (© Polytec Group)

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the same mechanical properties to the PU materials but cost considerably less. In addition, the use of scrap closes the material loop and is therefore very sustainable.

PU Elastomer Lighter than Polypropylene

The rear apron of the Porsche 911 GT3 RS is one of the largest car body parts made from PU. It extends 1.80 m across the entire vehicle width and is 0.9 m deep and 0.7 m high. Thanks to the low density of this newly developed PU material, the apron is the same weight as comparable trim parts made from polypropylene. With older PU elastomer systems, on the other hand, the component solutions were always heavier. The wall thickness (3 mm) is only slightly more than the 2.8 mm or so typical of equivalent polypropylene components. The development aim for future trim of this type is further localized reduction of wall thickness to make the parts lighter than polypropylene trim.

The component weight and low wall thickness achievable with the new PU system make it suitable for the production of other large car trim parts such as bumpers, fenders, side member and door sill trim or large panels. This lightweight PU material could benefit from the fact that many auto manufacturers are now making minor changes to the design of their models in ever shorter cycles, resulting in only medium-length to longish production runs.

In this case, PU elastomer molded by RRIM is a more cost-effective solution than polypropylene. It can be processed on less costly aluminum molds with low clamping forces and simple mold parting design. On the other hand, production with polypropylene only pays off for very long component runs because of the high cost for the injection mold made from special steel.

Class A Surface and Functional Integration Possible

Despite its lower density, the lightweight PU material has the same properties as its predecessor material. So it enables class A surfaces with good paint adhesion to be obtained. Important mechanical properties such as stiffness, strength, elasticity, and elongation at break remain at the same high level. The low coefficient of linear thermal expansion (CLTE) makes it possible to have narrow gaps between adjacent assemblies (zero joint optics). The good flowability of the low-viscosity PU reaction components diisocyanate and polyol allows long flow paths so that, even with large components, complex geometries can be precisely reproduced and thin walls achieved. Besides affording wide design freedom, the new PU material also permits functional integration (**Fig. 2**). For example, the rear apron for the 911 GT3 RS also incorporates air inlets and outlets with mountings for the expanded metal grille as well as mountings for closures, reflectors, the license plate, the lower rear skirt, and the wheel arch extensions.

Outlook

The development partners are presently concentrating on increasing the performance limits of the material and the associated RRIM technology. One aim, for example, is to raise the level of mechanical properties so that wall thickness and hence component weight can be further reduced. Another important focus of development is to cut production costs to the point where, even in quite long runs, they are at least on a par with those typical for injection molded polypropylene. ■