Easier to Reach the Destination

PP Compounds for Automotive Lightweight Construction

Weight reduction is one of the major requirements of automotive components. Regardless of the vehicles in which they are used. One of the lightest materials that can be considered is polypropylene (PP). With the right reinforcements, it is also suitable for demanding vehicle components. This is demonstrated by its use in vehicles such as the NIO ES8.

The Chinese manufacturer NIO uses carbon fiber-reinforced PP compounds for the center console support of the ES8 electric SUV (© NIO)

The industry is undergoing transformation on a scale not seen for decades. Trends such as connected vehicles, autonomous vehicles, powertrain electrification, and car sharing are causing manufacturers and OEMs to rethink their existing business models and develop innovative mobility solutions. While each of these trends calls for its own unique set of solutions and novel technologies, they all have something in common: the need to reduce weight for better energy efficiency.

In conventional petrol or diesel-powered vehicles, a weight reduction of 100 kg can in theory reduce fuel consumption by 0.2 to 0.3 l/100 km, the equivalent of up to 8 g CO_2 per km. In practice, however, driving style plays an important role in fuel efficiency. Vehicle weight plays a subordinate role to aerodynamic drag when maintaining consistent speeds over longer distances, as for example on the motorway. But the opposite holds true for driving patterns with frequent braking

Fig. 1. PP compound Daplen EE001AI has good scratch resistance and surface quality despite its low material density of 0.95 g/cm³. Skoda therefore relies on this material for the door trim of its Scaa (© Skoda)

and accelerating. Here, weight is crucial. These same principles apply to electric vehicles (EVs): while some braking energy can be recuperated and transformed back into electric energy, this regenerative process cannot avoid all losses.

Today's typical EV is heavier than a comparable vehicle powered by a combustion engine. When directly comparing models within a given platform, the weight of an electric-only vehicle is more than 15% higher than the same model with a combustion engine. Even though EVs no longer require many components of a powertrain, their heavy batteries inevitably increase their overall weight. And while the energy density of batteries continues to rise, the range of modern EVs still lags behind that of conventional vehicles with combustion engines. This makes more efficient and lighter construction as well as improved functional integration more essential than ever for EVs.

To this end, automakers are increasingly turning to polypropylene, or PP. With a density of 0.9 g/cm³, PP is lighter than water; in fact, it is one of the lightest materials that can be used in a vehicle. However, the heavy demands placed on automotive materials normally do not allow for the use of pure PP; instead, in most cases, PP compounds are employed. Reinforcement materials such as talc, glass fiber, and carbon fiber may increase the density of PP compounds, yet values remain low, ranging from 1.05 g/cm³ ± (0.1).

In recent years, much progress has been made in reducing the levels of reinforcement materials used in mineral-filled PP compounds. Targeted polymer design optimization has made it possible to maintain the desired mechanical properties while improving compound processability and reducing density. PP compounds of the past often contained up to 20% or more filler, yet today's materials may contain 10% or less. »

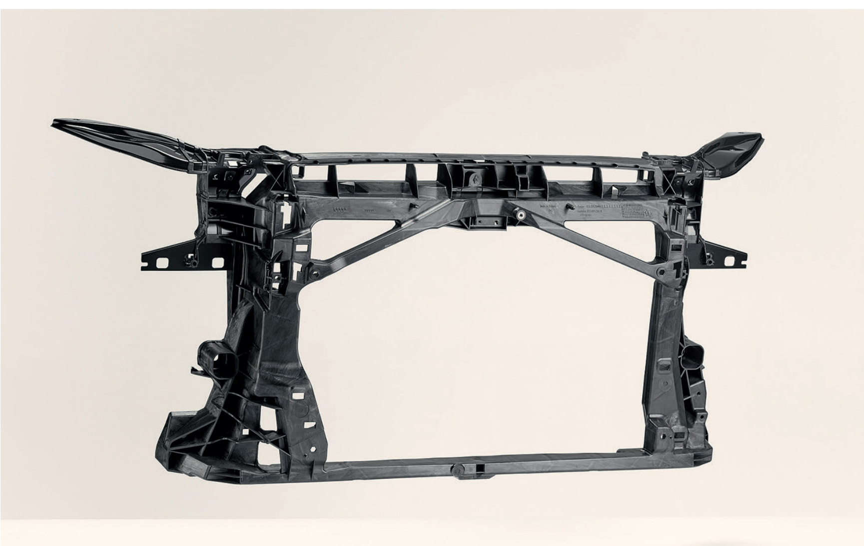

Fig. 2. Glass fiber-reinforced PP is suitable as a PA replacement. For example, the front end module of Borealis is made of the material (© Borealis)

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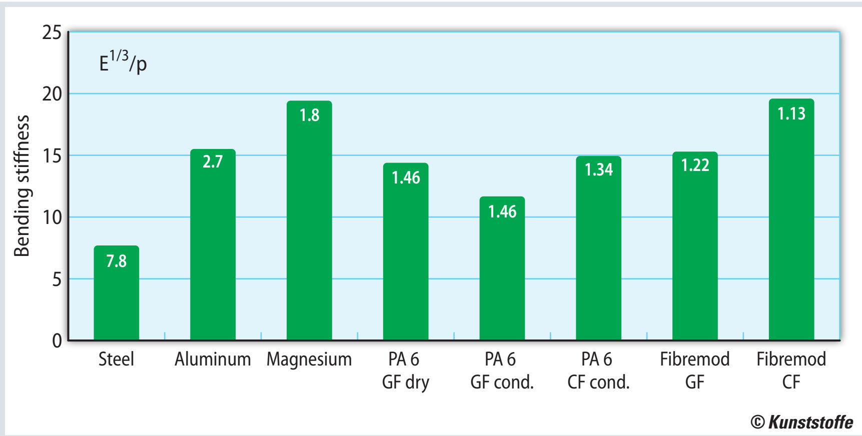

Fig. 3. Comparison of the bending stiffness ($E^{1/3}/p$) of different lightweight materials (number in the bars indicates the density in g/cm^3): the filler content of all plastics is 40 % (source: Borealis)

To use the example of door cladding materials, which nowadays can boast densities lower than 1 g/cm^3. One material solution used to achieve this is Daplen EE001AI, a highly impact-resistant PP compound providing very good surface aesthetics and scratch resistance – and a density of only 0.95 g/cm^3. Above and beyond its pleasing aesthetics, Daplen EE001A1 also fulfils other demands placed on interior materials. It meets the highest OEM standards in accordance with the German Association of the Automotive Industry's VDA 278 (thermodesorption) and VDA 270 (odor test). In comparison to conventional PP compounds, Daplen EE001A1 also enables component weight reductions of up to 6 %. Its proven benefits have led to its incorporation in models made by various automotive marques, for example the Skoda Scala (**Fig. 1**). It will play an important role in future EV manufacture.

Need for Weight Reduction Drives Innovation in Automotive Exteriors and Structural Parts

A focal point when it comes to modern vehicle exteriors is the integration of sensors and various measurement technologies required for advanced driver assistance systems (Adas) and for self-driving vehicles. Yet there should be no need to compromise when it comes to very good optics, or drag coefficient (cd value). Functional and full integration requires materials with known properties, yet with enhanced flowability and minimal linear thermal expansion coefficient.

In addition to traditional polyolefin applications such as bumpers, sills, and spoilers, entire tailgates can be produced using PP. While these may be based on different concepts – such as a 3-shell solution with cladding elements, or a 2-shell one with visible frame – metal is normally replaced by frames composed of fiber-reinforced PP.

If strength in combination with especially robust mechanical properties and low weight is required, for example for tailgates, the gold standard is fiber reinforced PP. The Borealis Fibremod range contains short glass, long glass, and carbon fiber-reinforced PP compounds with varying strengths. For instance, Fibremod GB477HP: a 40 % short glass fiber compound offering very good stiffness, impact performance, dimensional stability and long-term heat aging resistance. It is ideal for use in under-the-bonnet applications. Currently, it is being used in the front-end module (**Fig. 2**).

Carbon Fiber-Reinforced PP: When Stiffness Matters Most

If the highest possible stiffness is the aim, then carbon fiber-reinforced PP can deliver (**Fig. 3**). With a stability nearly as high as glass fiber-reinforced PP, this material class is characterized by very low density, good processability, and very low thermal expansion and warpage.

Borealis offers materials that are up to 40 % carbon fiber-reinforced. The ultra-lightweight Borealis Fibremod CB201SY, a 20 % carbon fiber PP compound, achieves a stiffness of around 10,000 MPa at a density of 1 g/cm^3. Used for example in the center console bracket of the all-electric, premium SUV NIO ES8 (**Fig. 4**), CB201SY offers a 20 % reduction in part weight (when compared to conventional PP long glass fiber 40), and offers good dimensional stability for a large part of these dimensions.

Yet manufacturers should keep in mind that in some instances, simply substituting one material for another is not productive. In order to implement complex structural parts, fundamental expert-

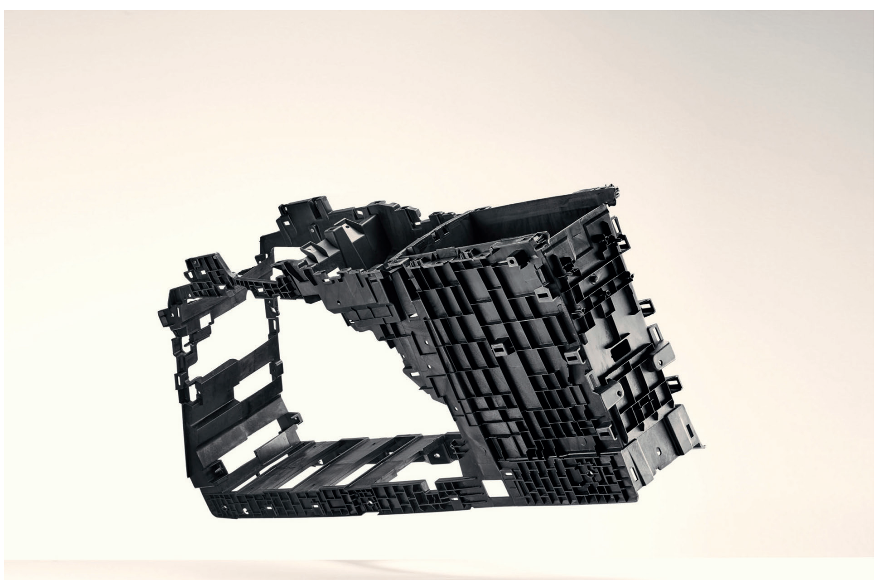

Fig. 4. The center console of the NIO ES8 electric vehicle consists of a 20 wt. % carbon fiber-reinforced PP. The complex geometry can be easily implemented in the carbon fiber as with glass fibers (© Borealis)

ise in simulation and modelling is necessary to make calculations and predictions. Extensive material know-how is also essential to the process. Developing increasingly precise simulation and measurement tools helps identify the most suitable materials for the respective part while at the same time offering opportunities for weight and cost savings. The provider of materials must also develop comprehensive models for testing purposes. In order to master complex loading conditions, including crash simulations, material characterization must be rigorous and ongoing (**Fig. 5**). Materials are constantly tested for wear and tear, longevity, and durability under a wide range of temperature conditions. Processing factors such as orientation, weld lines and more must always be heeded in material testing.

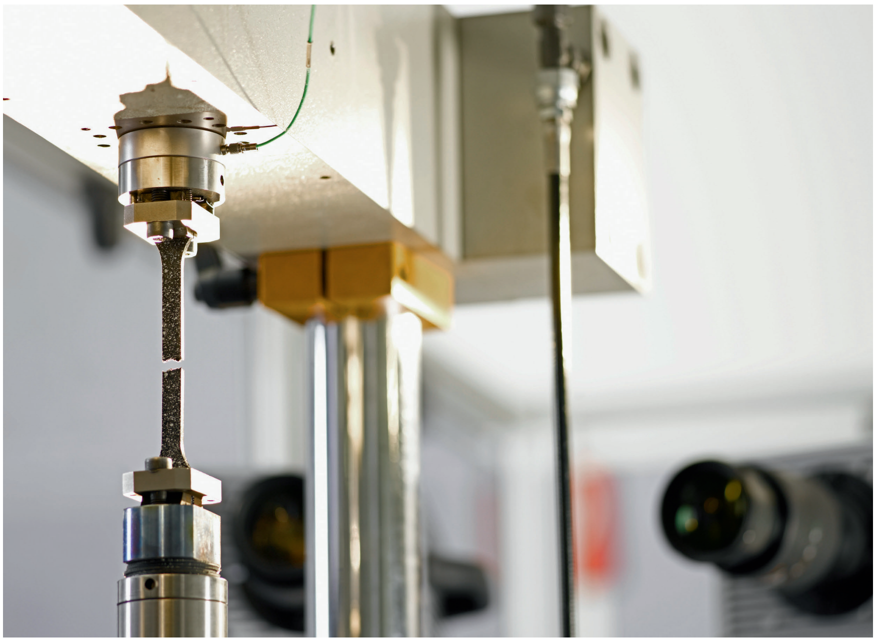

Fig. 5. In order to be able to simulate components in a meaningful way, comprehensive material characterization by the manufacturer is necessary. This requires material tests such as tensile tests (© Borealis)

PP Foams: Keeping Cool without Draining the Battery

Air-conditioning poses an additional challenge to increasing EV energy efficiency. Recent studies have shown that more than one third of battery power is used for air-conditioning. Improved temperature management is thus crucial to achieving greater range.

Borealis Daploy high melt strength polypropylene (HMS PP) products are used to replace rigid plastic materials in numerous automotive applications, including roof liners, moisture barriers in door modules, and lightweight air ducts. HMS PP products combine both high melt strength and extensibility in the melt phase. They open up the possibility of bringing the numerous property benefits of PP into the world of low-density polymeric foams. These benefits include lower weight, a wide mechanical property range, high heat stability, good chemical resistance, and easy recyclability.

A conceptual study (**Fig. 6**) on PP and the extrusion foamed blow molding process demonstrates that component weight and energy consumption can be reduced by combining innovative materials with equally innovative production processes. Automotive air ducts manufactured in this way boast weight savings of 20 to 60% in comparison to conventional solid ducts; they also offer greatly improved thermal and acoustic insulation qualities.

Fig. 6. Foamed components reduce the weight and thus also the energy consumption of the vehicles. Foaming is therefore an interesting option, especially for electric vehicles (© Borealis, Trexler)

Sustainability: Higher on the Agenda than ever before

PP compounds offer a wide range of opportunities to enhance the energy efficiency of modern vehicles. Yet reducing the vehicle's carbon emissions is no longer sufficient: the total energy footprint of a vehicle must be considered, from raw material extraction to production, from period of actual use, to end-of-life recovery or recycling of materials. Focus must lie on the total CO_2 footprint when assessing sustainable mobility. Borealis was one of the first virgin polyolefin suppliers to launch a range of dedicated PP compound solutions that include post-consumer recyclate (PCR) and which can be used in automotive applications. The Daplen compounds originally launched in 2014 have in the meantime been rebranded as Borcycle. The current portfolio includes three proven high-quality compounds containing between 25% and 50% PCR: Borcycle ME2220SY, MD2550SY and MD3230SY. PP compounds can help to create a more efficient mobility. Low density, easy processing, small CO_2-footprint and comparable easy recyclability make them also in the future the materials of choice when it comes to provide sustainable mobility solutions. ■