New thermoplastic composite solutions for automotive lightweighting

Carbon emissions reduction is one of the key drivers for new developments in the automotive industry. Manufacturers and their development partners are working on multiple solutions to realize improvements – reducing aerodynamic drag, enabling electrification or using alternative fuels. In addition, most automakers say that models coming to the market after 2021 will need to be significantly lighter, up to a few hundred kilograms per car.

The inclination on the part of most in the industry is to consider use of high strength steels and aluminium instead of composite materials because the latter are much too expensive. Put differently, the penalty paid for weight savings (expressed in Euros per kilogram of weight saved) is too high. The cost would typically be about 15 to 20 €/kg for a carbon composite part, which is significantly higher than the maximum increase a manufacturer would be willing to pay (e.g., a solution in aluminium).

Recognizing this challenge, SABIC has developed new affordable material forms for use in an overmoulding process, which significantly reduces the amount of composite material, as shown in figure 1. Under this approach, selective use of high performance multi-axial UD tape-based laminates takes place along the main load axis. At the same time, functional details can be integrated, eliminating separate production steps.

The material form developed for this, most suitable for automotive applications, would be multi-axial laminates with constant thickness, as shown in figure 2. SABIC has developed UD tapes, using various resins and fibres, and multi-axial or uni-directional laminates and can offer a wide range of fully compatible overmoulding products. A first UD tape offering is called UDMAX™ GPP 45-70 TAPE, based on glass fibre reinforced polypropylene. In addition, SABIC can provide moulding and application development support, which includes the expertise and capability needed to predict a part’s mechanical behaviour. Note that SABIC is also evaluating fabric-based materials, which may go into specific applications, not further discussed here.

Materials

Depending on the application, a clear load path may go in only one direction. In this...
The part was redesign for a composite overmoulding process, as a one-shot moulded component, as shown in figure 7. Although it may look a bit different, the same equipment can still be mounted. The blue parts indicate the use of multi-directional composite laminates, while the yellow parts represent the overmoulding material, in this case a 30 percent-by-weight long glass PP material. The main design driver for this part is the Eigen-frequency driven by the vibrations of the steering wheel column. The composite part was optimized for equal performance at 65°C. Although this temperature hardly influences the continuous fibre composite material, it does have some effect on the overmoulding material.

Other components may see loadings in multiple directions. Studies on a number of beam-like hang-on components has shown that a typical weight-optimized laminate would have a combination of 0° and ±45° directional layers. In such a case, UD material offers higher weight savings than traditional fabric-based materials, as the 90° orientations in a traditional 0/90° fabric simply add weight without any structural contribution. As an example, figure 5 shows calculated laminate properties based on measured ply data.

For equal stiffness performance, the UD-tape based solution would be 26 percent lighter. Of course, in between solutions are possible, such as the use of non-crimp fabrics to mimic the UD tape solution. However, these types of materials need stitching/weaving and are more difficult to impregnate, which adds some cost without the benefit of improved performance from use of the pure UD material.

Component examples

Design optimization studies on various components can help assess the competitiveness of various materials. For a particular component, within the same design space, using the same fixations, and with the same stiffness/strength/impact requirements, the design was optimized separately using steel, aluminium, magnesium (if applicable) and glass and carbon fibre composites.

As an example, consider the cross car beam, shown in figure 6, carrying the dashboard, steering wheel and a number of components. For the existing C-class car model, this application was an aluminium-welded assembly. Most cars in the same class would be made out of steel.

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Figure 8 shows results of the various weight optimizations.
In figure 8, the blue segments indicate the amount of overmoulding material; the red segments show the amount of continuous fibre material. Clearly, the majority of material is long fiber thermoplastic (LFT) overmoulding material, which dilutes the cost for this component significantly. Compared to the steel solution, four to five kg of weight savings is possible, depending on the choice of carbon or glass fibre. Looking at the €/kg weight saved value, glass fibre is the more favourable alternative and compares very well against weight saving alternatives such as magnesium or aluminium. In this case, one could even consider use of carbon fibre because the amount of material needed is very small.

Consider a similar study on a car side door, where requirements are more severe. A primary design driver for this application is Euro NCAP side crash requirements, which was checked at different temperatures and positions and higher impact loads to obtain a robust safe solution in composites. The reference door was a state-of-the-art steel door for a small B-class car. The composite solution consists of a two-part structural solution (welded together), while the Class A surface outer door panel remains in steel, as show in figure 8. The red areas represent the use of multidirectional UD laminate, while the grey areas show overmoulding material. The actual ribbing of the final optimized design is different, but this picture shows the main concept. Further functional integration options for the inner door panel were not yet taken into account.

These results are similar to those of the cross car beam. The one exception is the difference between the carbon and glass solution is no longer as large. This is the case because the part design calls for and is designed more for strength (crash impact) than stiffness. So high failure elongations are beneficial to keep the impact beams intact during the crash.

As a result, the glass solution would be an attractive alternative compared to aluminium as a lightweight solution and would offer greater weight savings overall. Consider a similar and much more extensive design study for a C-class vehicle body in white (BIW). In this case, the main drivers are torsional stiffness and many crash cases acting from different directions. Figure 11 shows the resulting design. In this case, it turns out that the only sensible material would be carbon fibre material. Weight savings would be significant – more than 150 kg from a BIW of about 300 kg. The use of thermoplastic composite would allow lightweight joining solutions involving welding. However, with current carbon fibre prices, obtaining acceptable lightweight costs for large volume production cars would still be a challenge. Likely, thermoplastic composites would be introduced part by part, based on

**Conclusion**

Thermoplastic composite solutions are a viable option to meet lightweight targets for automotive mass production. Success factors for implementing this strategy include:

- Do not do a one-to-one replacement of simple sheet metal parts; instead, select complex components to take advantage of the part integration potential given by plastic overmoulding.
- Design components to maximize the percentage of overmoulding material to minimize costs.
- When possible, use UD-based material forms to maximize the mechanical performance and minimize €/kg weight saved.

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