Easier Said than Done

In the Audi R8 Spyder 4.2 FSI quattro, selected body parts are made from carbon fiber composites

CFRP Composite Construction. Everyone is talking about fiber-reinforced composites – their potential for lightweight construction is well known. But their use in high-volume automotive production has expanded far less than expected. The example of the Audi R8 Spyder is featured to show the kind of hurdles that have to be overcome. In this convertible, the side panels and cover for the droptop storage compartment are made from carbon-fiber-reinforced plastics (CFRP).

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When Thomas Edison carbonized first cotton and then bamboo fibers in 1879, no one had mechanically loadbearing fibers in mind. At that time, the focus was on increasing the burn time of incandescent lamps. Not until some 75 years later were carbon fibers produced with oriented molecular structures, which are a prerequisite for high mechanical property values. But the filaments were produced on a laboratory scale and the costs were astronomically high. In the early 1970s, Japanese companies established fiber types that offered not only good mechanical properties and ready availability but also suitable industrial production processes and therefore lower costs.

Since then, the use of carbon fibers has expanded from niche astronautical and military applications to motor racing and then leisure sports. The next step is automotive manufacture. And here, this new lightweight construction material is urgently required. Lightweight construction has always been an important theme in vehicle engineering but, in recent years, efforts in this area have been considerably stepped up. Sustainable mobility, which relies on economical use of resources and alternative drive concepts, requires bold, innovative lightweight construction solutions. Carbon-fiber-reinforced plastics (CFRP) offer the potential here to achieve further vehicle weight reductions as compared with conventional metal auto body construction materials. In addition, fiber composites enhance customer benefit because the greater design freedom they offer makes it easier to produce technically challenging designs successfully. At the same time, the surface finishes obtainable with CFRP also allow emotional values such as “high-tech“ and “sporty“ to be con-

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veyed. This raises the question, however, as to why, in view of these advantages, the use of carbon-fiber-reinforced plastics in high-volume automotive production is still, relatively speaking, not very widespread. The answer lies in the number of hurdles that have to be overcome in the development chain from the initial product idea to production-line manufacture.

Challenging Requirements

This development chain can be followed with the example of the Audi R8 Spyder **(Title picture)**. In this vehicle, the side panels and cover for the droptop storage compartment are produced from fiber composites **(Fig. 1)**. Besides potential for lightweight construction, the primary criterion for material selection here was the component design aspect. The side panels have a challenging geometry that could not have been reproduced in sheet metal construction because of the high draw ratio and narrow radii involved. Since the component design also includes undercuts, the geometry is even more complex. This is where a special property of fiber composites comes into play, namely that the material only takes on its final form during component manufacture. This allows greater freedom of component design than is possible with sheet metal semi-finished products. Only this design flexibility afforded by the use of fiber composites enables the special component design to be precisely reproduced.

Development of the cover for the droptop storage compartment was constrained by the extremely tight installation space. The outer contours of the component were determined by the very sleek, sporty design. Underneath the storage compartment cover are the stowed droptop and the engine. Despite optimized component positioning in the rear of the car, there is still very little installation room. Normally this is no problem with thin-walled body shell components. But in the R8 Spyder, high mechanical properties in this area are crucially important. The cover for the droptop storage compartment is attached by two hinges and locks but must tightly seal the storage compartment all round and withstand the forces this involves. This, combined with challengingly low deformation tolerances, dictates the need for exceptionally high component stiffness. Since the installation space and hence the resulting moment of inertia are significantly restricted, the requirements for this application could only be met with carbon-fiber-reinforced plastic.

Another example of the excellent performance of the droptop storage compartment cover is the fact that it can be operated while the car is in motion. The cover can be opened and closed at vehicle speeds of up to 50 km/h. This function increases the vehicle's suitability for everyday use and enhances customer benefit significantly. If there is a head wind, the wind load on the opened cover could double. The cover operating system for the R8 Spyder was tested with these high wind loads in the Audi wind tunnel center and requirements were considerably over-fulfilled. Here once again, the outstanding mechanical properties of fiber composites are essential for production of a weight-optimized component.

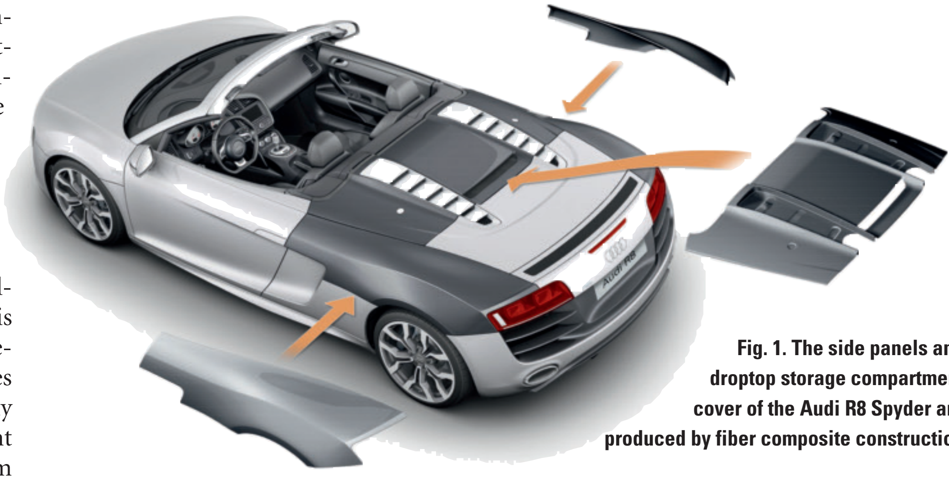

Fig. 1. The side panels and droptop storage compartment cover of the Audi R8 Spyder are produced by fiber composite construction

Besides mechanical functional requirements, other hurdles have to be overcome. Vehicles manufactured by Audi AG, Ingolstadt, Germany, are marketed in all regions of the world, which means that widely varying climatic conditions are encountered: from –40 to +80 °C, from dry to humid. In addition, extreme solar radiation can lead to temperatures of up to 100 °C. Add to this, the heat generated by the engine and exhaust system and even these values can be exceeded. It goes without saying that the components must meet Audi AG's high quality specifications in all situations throughout the lifespan of the car **(Fig. 2)**. This means, on the one hand, perfect satisfaction of functional requirements and, on the other, ensuring that properties are maintained over the long term. Corrosion resistance is a good example here. With the combination of metal force transmission elements and carbon fibers, corrosive effects can be expected because of the potential difference in the galvanic series. It is essential here to prevent the possibility of an electrically conducting connection, due either to direct contact or through electrolytes such as salt water. In practice, this is ensured through →

Fig. 2. Quality control in final assembly of the Audi R8 Spyder

insulating fiber layers or special sealing materials.

Another important consideration in the development of these CFRP components for the Audi R8 Spyder was the need to meet Audi AG's high requirements in respect of surface quality and optimum appearance throughout the lifetime of the vehicle. This is a particular challenge for the side panels and droptop storage compartment cover, since these components are situated within the range of exposure to heat-generating vehicle units and also solar radiation. Through the combination of a specially tailored laminate structure and optimized matrix system, the components are able to fulfill these high requirements. This was demonstrated in comprehensive alternating climate and climate vibration tests, outdoor weathering trials and corrosion tests.

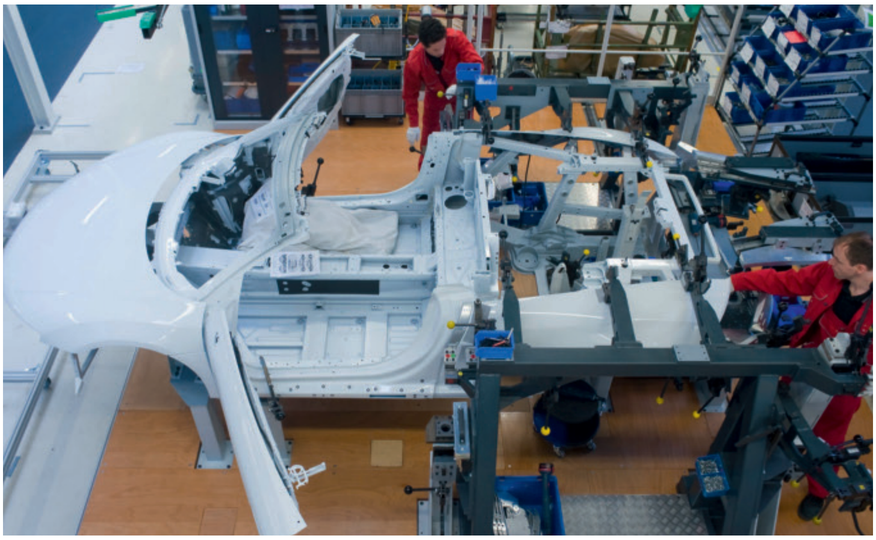

Fig. 3. The side panels of the Audi R8 Spyder are joint-determining body shell components that are only fixed to the vehicle during the final assembly stage

Challenges in Production

The hurdles for fiber composite components do not just lie in the area of development. Various challenges also have to be overcome in production processes, where it is necessary to look for potential ways of achieving significant cost reductions. The fiber composites used as standard materials in Formula 1 are mainly obtained by manual production steps. But it would not be feasible to manufacture production-line cars with such cost structures. The key here is to develop industrialized processes, characterized by identifiable, efficient material flows and automated production steps. A good example of this is the stitching of reinforcing layers in the direction of stress lines in the tailored-fiber placement (TFP) process. In this process, carbon fibers are automatically stitched in the stress direction onto a thin carrier textile and inserted into the final preform. This ensures that the reinforcing fibers are integrated into the component in the ideal orientation, at the optimum point in the right quantity. Wastage is very low and no unnecessary material is used. This technology is used to produce the reinforcing layers of the droptop storage compartment cover. It enables both costs and weight to be minimized.

In assembly of the Audi R8 Spyder **(Fig. 3)**, the side panels are another special case. These joint-determining body shell components are only fixed to the vehicle during the final assembly stage, whereas this normally happens before painting. But since it was necessary to keep thermal stresses as low as possible, a change in the production sequence was tested and implemented. This prevented the CFRP components being thermally stressed in the conventional vehicle painting operation. So the lid, light and door joints are not produced until the final vehicle assembly stage. Various solutions for technical details were required to obtain the required joint pattern in this production sequence.

Fig. 4. The Audi R8 GT is around 100 kg lighter than the Audi R8 Coupé

Conclusion

In summary, it is clear that there are challenges to overcome in developing fiber composite components from the initial idea to final implementation. The topics that need addressing range from mechanical, thermal and optical requirements to processing issues and component production and assembly. The positive aspects of fiber composite construction, such as reduced component weight, greater design freedom, increased functionality and low initial investment costs, have usually been outweighed by the higher overall cost. But in an increasing number of cases, fiber composite concepts can further optimize metal lightweight structures. This is impressively demonstrated in ultra-lightweight construction concepts, such as the Audi R8 GT **(Fig. 4)**, where it was possible to reduce vehicle weight by about 100 kg as compared with the Audi R8 Coupé.

Modern fiber composite materials have been and continue to be part of Audi's lightweight construction strategy. In a number of different vehicles, they are already helping to reduce weight and, as a direct consequence, increase efficiency. ■

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