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Efficient manufacturing of lightweight composite car seats

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A new optimization approach combines the use of fiber-reinforced materials, laying and stacking design methods, as well as integrated forming and injection molding processes.

Fiber-reinforced plastics (FRPs) are composite materials that consist of a polymer matrix (e.g., thermoplastic or thermoset) reinforced with fibers (e.g., made of glass or carbon).[1] It is common for FRPs to find applications in several industries, such as aerospace, automative, construction, and defense. Conventional FRPs, i.e., those made out of thermosets or short-fiber-reinforced thermoplastics, however, are unsuitable (with regard to cost, weight, performance, and cycle times) for some automotive applications (e.g., the manufacturing of car seats).

An ideal alternative to FRPs would be a material with higher mechanical performance and cost-effectiveness (e.g., aluminum). Such a material—like thermoplastics—should also be easy and quick to process in injection molding or thermoforming processes.[2] A typical approach, until now, is to use woven FRPs (so-called organo-sheets) to stiffen manufactured parts.[3] In most cases, however, this process results in too much weight, excessive costs (for materials), and over-fulfillment of requirements (i.e., local stiffness levels that are too high).

Our team at HBW-Gubesch—together with several partners (i.e., EVONIK, Johnson Controls, Toho Tenax)—has developed a new approach with which we can reduce the weight and costs involved with these manufacturing processes. We are able to achieve these savings by following a set of design rules to make composite parts from appropriate materials, in the correct quantity, with suitable processes.[4] For this particular project, we use effective materials (e.g., fiber-reinforced thermoplastic tapes that have high elastic modulus values), design methods (i.e., laying and stacking of thermoplastic tapes, or locally reinforced parts), and processes (i.e., a combination of forming and injection molding). Although these three parts of the project are not in themselves new, our combination and optimization approach is novel and unique. As such, we have designed—using our novel approach—a locally reinforced and load-optimized seat structure (see Figure 1) known as CompoSeat.[5]

To create CompoSeat we have collaborated with EVONIK to develop a new effective carbon fiber unidirectional tape with a polyamide 12 (PA12) matrix. In addition, EVONIK has developed a new carbon fiber non-woven PA12 system that can be used for non-highly stressed areas.[5] The sheets of the tape and the non-woven system are pre-impregnated using in situ polymerization, which provides optimized adhesion to the fiber system. We do not, however, impregnate the fibers into the matrix system within a heated press.

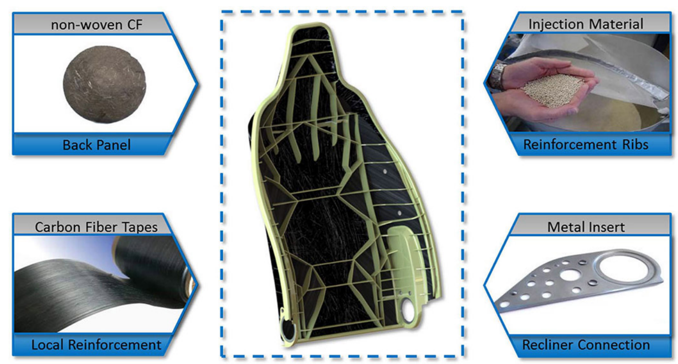

Figure 1. *The configuration of effective materials in a tailored blank for CompoSeat. Areas of the seat that experience low loads (e.g., the back panel) are made from a non-woven carbon fiber (CF) system. Areas that receive high loads, however, can be locally reinforced with specifically designed carbon fiber unidirectional tapes. The same, and therefore compatible, matrix material—polyamide 12 (PA12)—is used for the injection molding of the seat's reinforcement ribs and for the tapes and non-woven systems. This means that there is good adhesion between the different parts.*

For our CompoSeat design, we place our effective PA12 carbon fiber material in areas of the seat that experience high loads, which we also locally reinforce with compatible short-fiber-reinforced material. We stack the tapes in a maximum of seven layers. Each layer has a different orientation so that the load can be transferred and absorbed from several directions. Areas of the seat that experience low loads, however, are made from the PA12 carbon fiber non-woven system. This design means that the highly stressable carbon fiber tapes are located mainly at the side of the seat beam (producing a nearly U-shaped structure

Continued on next page

SPE Plastics Research Online

around the seat), whereas the non-woven system covers all of the space of the seat structure. We use the SpriForm process[3] to form the non-woven and tape sheet within the same mold. In this process, a metal inlay is over-molded and then integrated to fix the seat structure. We also design additional ribs to reinforce and stiffen the seat.

After we completed the design of CompoSeat, we transferred the 3D part results and generated a 2D layup (see Figure 2) of the stacked tapes and the non-woven system. It is then possible to manufacture this layup with the use of an automated tape laying process, and subsequent cutting to achieve the correct shape. The result of this process is a tailored composite blank. The full procedure for manufacturing the final CompoSeat part is therefore an integration and combination of several individual processes.

First, we place the metal insert in the mold on a standard vertical injection molding machine. Meanwhile, we heat the tailored blank in a convection oven. Once this reaches the correct process temperature, we transfer it—with the use of a six-axis robot that is equipped with a needle gripper handling system—to the mold. We then lay the tailored blank on the mold and close the mold to form the sheet. In the next step, we inject the hot melt into the same mold to form the ribs and over-mold the metal insert (i.e., form closure). We use the same material (PA12) for the injection molding and for the tapes and non-woven elements. As such, we can achieve a good level of adhesion (material closure) between the different parts. We finish the whole process by cooling the part. A ready-for-use part can thus be ejected after only 90s.

We have designed and are now manufacturing a new type of seat that is suitable for automotive applications. We use a novel technique in which we combine and optimize lightweight materials, lightweight designs, and suitable processes. We are thus able to achieve weight

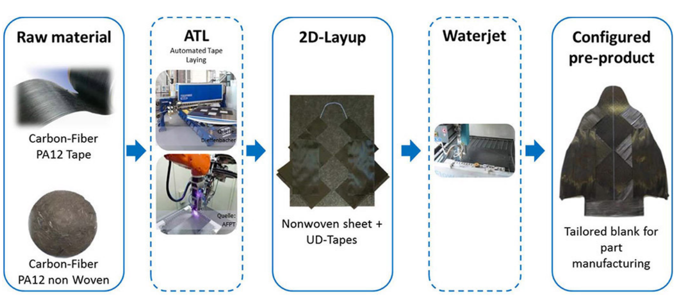

Figure 2. *Schematic illustration of the process by which the effective carbon fiber PA12 materials are configured to produce the tailored blank. First, an automated tape laying (ATL) process is used to produce stacks of the carbon fiber PA12 tape and non-woven sheets. The 3D design is then used to generate a 2D layup. Finally, a waterjet system is used to produce the configured pre-product tailored blank that is used to manufacture the final CompoSeat part.*

savings of more than 40% compared with steel seats. Our use of cost-effective materials also means that we have reached our cost-saving goals (i.e., we are able to save more than €5 per kilogram). Furthermore, our reduced cycle times allow a finished part to be produced in about 90s. We are currently working with several industry partners—including original equipment manufacturers—to bring our CompoSeat technology to the market. We are analyzing the structural and semi-structural parts within a car that fit well with our technology and permit metal parts to be substituted. We also continue to investigate new solutions for joining metal and FRPs.

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