Edited by ***Ryan Gehm***

Bionics delivers new material option

Plastics are an increasingly important option in automotive engineering. During an international congress held by the plastics division of the German institution of engineers, **VDI**, industry experts in attendance were introduced to the potential of bionics as a plastic development tool in the near future.

Professor Thomas Speck of the **University of Freiburg**, Germany, gave an example of a new gradient material that is now in the transition process from the lab to automotive applications. The new hollow fiber-reinforced structure with integrated functional ducts was patented in November 2006 as "Technical Plant Stem," or "Technischer Pflanzenhalm" in German.

Following a typical bottom-up development process of bionics, Speck and his team—the university's plant biomechanics group—developed a compound material that is said to combine very high stiffness with excellent damping qualities. Speck is convinced that in material design there is a lesson to be learned from nature: "Typically, nature has only very few materials available," the scientist explained. "Yet, in structure and design, nature always optimizes on a number of levels at the same time, which results in plants with quite outstanding mechanical properties."

When looking for a new lightweight material with high stiffness, it was Giant Reed (Arundo donax) and Scouring Rush (Equisetum hyemale) that grabbed the experts' attention. "The stalks of Giant Reed simply never break, whatever the wind strength. Scouring Rush, on the other hand, achieves a high strength with a minimum of material weight," Speck said.

Analyzing the stalk designs, the bionics group came up with six different elements of structural optimization. Gradients in the material transition from lignified, very stiff fibers to the more flexible substrate were one important observation. Together with the **German Institute for Textile and Process Technology** (ITV) at Denkendorf, the bionics experts transferred the findings into a hollow fiber manufactured by a modified pultrusion braiding process. The resulting technical plant stem is braided from several hundred fibers in a precisely defined 3-D pattern, and the fibers are embedded in expanded polyurethane foam.

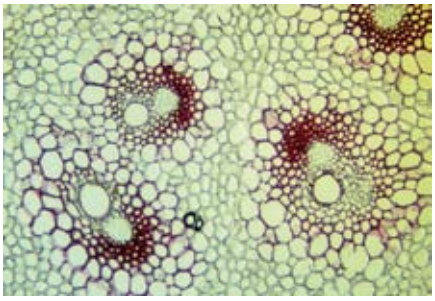
The resulting structure is not only very stiff and very light, it also shows advantageous failure mechanics that Speck characterizes as "good-natured." In contrast to existing fiber-reinforced materials that have step transitions between brittle but strong fibers embedded in a softer substrate, the Technical Plant Stem is not prone to delamination. Instead, the mode of failure is a continuous process that only gradually lowers the load-bearing capability of the material.

"That is probably as important as the other material properties because the mechanics of the failure mode make it possible to screen the remaining material strength after an overload or impact," Speck said. "Ultrasonic measurement can tell whether it is actually necessary to replace a part manufactured from Technical Plant Stem."

Another property of the patented fibrous compound material is the hollow ducts that offer the possibility to integrate additional functions such as media transport, cabling, or others within the structure. "We are currently in contact with vehicle manufacturers to transfer this material into an actual product," Speck said. This last step from the laboratory to product is the result of a long development process. "For this type of bionics bottom-up development, anything between three to seven years duration is reasonable," he noted.

Jörg Christoffel

Learning from nature: The patented Technical Plant Stem (center) is a lightweight result of bionics material engineering.



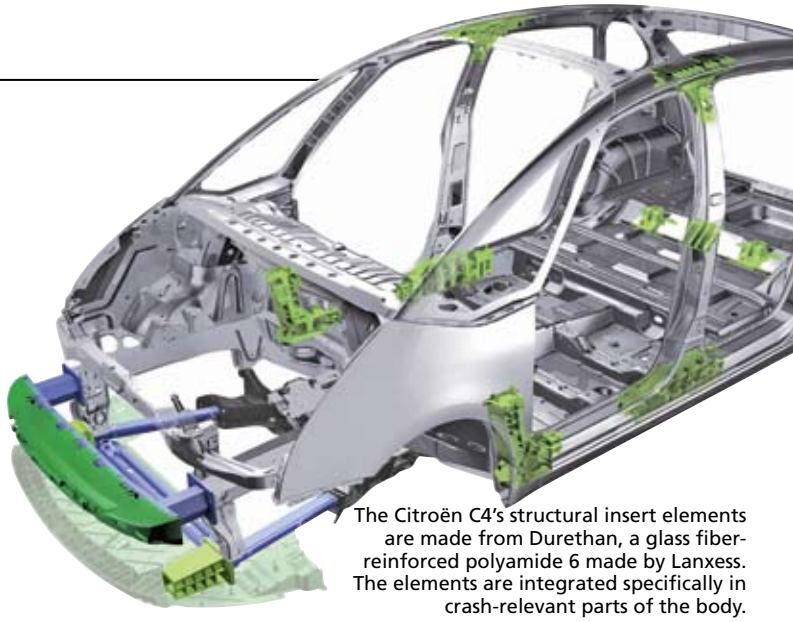
The gradient transition from high-strength, lignified bundle sheaths (stained red) of Arundo donax to the more flexible surrounding tissue (green) was one role model for the Technical Plant Stem's high strength and good damping qualities.

Plastics inside and out

On average, around 12% of a passenger car is made up of plastics, according to German engineering organization **VDI**. While there would practically be no automotive interior without plastics, exterior applications are now coming at a growing pace. The same applies to structurally and mechanically loaded parts designed from plastics. Both application fields are growth areas in plastics engineering.

DaimlerChrysler is using film technology for plastic add-on exterior parts. As plasma coating and liquid painting of plastic parts are cost-intensive processes, the OEM started looking for an alternative as early as 2000. An analysis showed that film coating would be the best option, "but there was just no ready system on the market that met our specifications," said Walter Aichholzer, Project Manager, Film Coating Technology,

Lustran Polymers' Triax DP 3157, a mineral-reinforced, online-coatable polyamide and ABS (acrylonitrile butadiene styrene) blend, is used for the side panels of the BMW 3 Series Coupe.



The Citroën C4's structural insert elements are made from Durethan, a glass fiber-reinforced polyamide 6 made by Lanxess. The elements are integrated specifically in crash-relevant parts of the body.

DaimlerChrysler Group R&D. The highest hurdles were the matching of metallic colors and defining a stable process to ensure high-end surface qualities. By the end of 2004, a new process, which involves 3-D UV film hardening technology, was approved. The first products stemming from this process are the **Mercedes-Benz** C-Class's license plate frame and the R-Class's antenna cover.

The antenna cover provides a good example of the many detail challenges plastics engineering can trigger. As the film-coated plastic part has a greater thickness, the SDARS (Satellite Digital Audio Radio Service) antenna had to be redesigned to a lower height. In early December of 2006, the first R-Class vehicles were fitted with the new antenna cover at the DaimlerChrysler Tuscaloosa, AL, site. By 2008, all R- and M-Class vehicles will be fitted with the film-coated part.

The **Skoda** Roomster provides examples of both interior and exterior plastic parts. The dashboard consists of three modules, each of which is designed with individual materials to meet the application needs. The upper carrier consists of polypropylene/polyethylene (PP/PE) T20. Reinforcing the plastic with talcum powder ensures the material's required heat performance for temperatures of up to nearly 100°C (212°F) in bright sunshine. As the driver rarely touches this area, the reduced scratch resistance does not matter.

The middle carrier of the dashboard is manufactured in two versions. The carrier for the vehicle's basic equipment level is made from PP/PE 15, which has high scratch resistance and torsional stiffness. The more expensive Roomster version has a dashboard middle carrier made from PP/PE T20 covered with a thermoplastic olefin film.

A new hybrid tailgate, meanwhile, is replacing the Roomster's original steel tailgate that was fitted when the car was first introduced to the market. While the new tailgate is actually more expensive than the steel version, Skoda has gained a lot of technological insight from this pilot project. The hybrid tailgate consists of a leather-grained PP T20 interior part, a steel tube frame, glass, and an exterior plastic part made from PP. All exterior parts are clipped on individually to make repair work easier. The interior part, steel frame, and glass are fitted by adhesive bonding.

BMW's strategy for exterior thermoplastic components in its 3 Series sports coupe and convertible spells out an additional angle of plastics engineering: factory investment. Presently, the OEM uses practically every available process to manufacture side

wall parts: steel, aluminum, and online, inline, and offline coated plastics. "'Why is that so?' we are often asked," said Robert Killermann, Project Manager of Exterior Plastics Technology at BMW. One has to take into account the plastic specific investment, he answered. "If you manufacture a model at three sites, like we do with the 3 Series sedan, it may be pointless to invest three times." That explains why the convertible and sports coupe have plastic side wall components, while the sedan does not.

Large series thermoplastic (polyamide/polyphenylene oxide) side wall parts were first introduced at BMW in the 6 Series in 2003, saving 4 kg (9 lb) of mass per vehicle while increasing freedom of design. The new 3 Series sports coupe introduced last year was the first BMW to be fitted with injection-molded plastic side wall components within an online paint process that exposes the parts to temperatures of up to 195°C (383°F).

"The fully automated process is very stable and has an output of 500 units a day," said Killermann. To further lower gap widths, the BMW expert hopes the plastics industry will be able to come up with material solutions that show lower longitudinal expansion when exposed to heat and are less hygroscopic.

Charles Buehler, Technical Integration Engineer for Materials Engineering at **General Motors**, looks back on many years of GM experience with thermoforming parts, which started in 1984. Currently, the car maker is manufacturing Class "A" finish exterior parts from painted film. GM has developed a five-layer laminated sheet (consisting of substrate, three paint and primer coats, and a masking film) to achieve the optimum color match, *e.g.*, for stone shields (**Chevrolet** SSR and HHR), skid plates (**Saab** 9-7X), fascia (**GMC** Denali), and rocker panels (2006 **Buick** Lucerne and **Cadillac** STS-V).

The composite sheet system has a wall stock variation that is only a little higher than with injection molding but shows excellent color match and is highly chip-resistant: Stone impingement is better by a factor of 10 when compared to an injection-molded part. To keep the wall stock variation down, GM uses an articulated frame during the fascia molding process.

Thermoforming Class "A" exterior parts has advantages over injection molding, says GM's Charles Buehler.

"Currently, the inside of the fascia is contacting the mold, but in the next step we will switch over to a process where the 'A' side contacts the mold to achieve even more pristine, sharply defined edges," said Buehler.

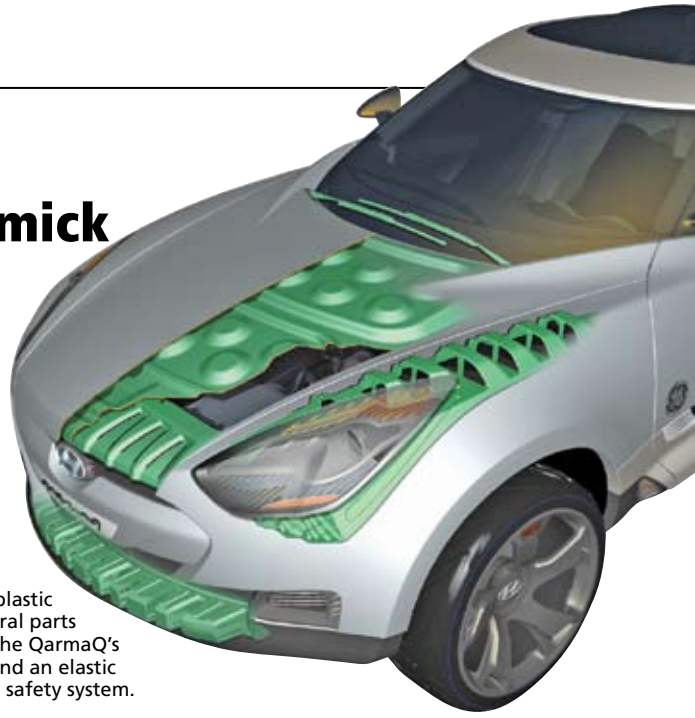
Jörg Christoffel

QarmaQ's use of plastic no gimmick

Plastics can and will break more application boundaries—if they make sense economically and help OEMs to achieve development targets. That is the bottom line of a show car exhibited at the Geneva Auto Show and an international congress on plastics engineering.

GE Plastics used existing but innovative materials to help develop and build a demonstrator vehicle together with **Hyundai**'s European Design and Technical Center in Rüsselsheim, Germany. The QarmaQ crossover coupe (the name comes from an Inuit word) was developed within 13 months in total. The vehicle is not truly a concept car, though usually referred to as such. It is fully functional right through to a diesel engine that is compliant with Euro 5 emissions regulations.

By using both conventional and high-tech plastics in innovative ways, the whole vehicle is around 60 kg (132 lb) lighter than a comparable vehicle. While some might consider it a bit of gimmick that the equivalent of almost 900 polyethylene terephthalate (PET) bottles was used for large parts of the skin and structure, most of the plastics engineering is indeed high-end. The glazing is made from GE's Lexan polycarbonate resin plus Exatec coating, applied for IR heat reflection.



Three plastic structural parts make the QarmaQ's front end an elastic passive safety system.

Using a thermoplastic material for a large horizontal part like the hood is one of the innovations shown in the Hyundai QarmaQ.

Certainly the dual-wall hood is no gimmick. It is a big step to use a thermoplastic for a horizontal exterior part, and a large one at that: The hood measures roughly 1.7 m (5.6 ft) in width by 1.6 m (5.2 ft) in length. "That is about the biggest size of material that we could obtain at all. Nobody seems to be able to manufacture larger plates," said Gerhard Kunkel, Managing Director of GE Polymer Design Associates Europe.

"The QarmaQ's hood alone would weigh 19 kg if made from steel," Kunkel continued. "The thermoplastic composite hood just weighs 11 kg." Normally, one would expect a horizontal exterior part this big to be made from an expensive compound of epoxy and carbon fiber to achieve the desired strength, particularly under the thermal conditions of a large hood spanning a hot engine compartment.

The QarmaQ hood consists of a high-tech material manufactured from a glass fiber and polymer mix substrate that is wrapped twice by endless fibers drawn through a polymer bath, so that the second fiber wrapping overlaps the first wrapping layer at a 90° angle. The resulting material is then heat-formed to shape and has the strength needed.

GE Plastics used the material properties to transform the complete front end of the vehicle into an elastic safety system that consists of three energy-absorbing structures. The deformable hood, for instance, was optimized for pedestrian safety, which resulted in a Head Injury Criteria (HIC) value of 280 at some points of the hood during testing.

"In many cases we were able to reproduce these results even when impacting the same spot twice. The results were within a 10% tolerance of the previous first impact, which illustrates the material strength," said Kunkel. Asked about the time frame for using this thermoplastic technology for a production vehicle, he said that he is confident that "no part of the plastic chassis solution is not ready to go into the next generation of series vehicle."

Jörg Christoffel