The battery module in the Opel Ampera consists of a large number of plastic battery frames (figure: Mann+Hummel)

Mobility of the Future

Lightweight Construction. The demands on future mobility will remain unfulfilled without more widespread use of polymer materials. This was the unanimous view of almost 1,500 experts who met at the beginning of March at the "Rosengarten" in Mannheim, Germany, for the VDI Congress "Plastics in the Automobile".

WOLFGANG KIRCHER

For the future of plastics in the automobile it makes no difference whether the vehicles are electrically powered or continue to be fuel-powered. What is important is the saving of every single gram of weight – either to increase the range or to reduce the emissions. And of course the focus must also be on the manufacturing processes, otherwise the savings that can be laboriously achieved in use are wasted during production.

Know-how and Simple Processes

Lean production has been a buzz word for decades. Fabian Seidemann from BMW AG, Munich, Germany, allowed us to take a look at how his company deals with the subject. The main innovation is that the larger companies no longer send their older employees into early retirement, but keep them fit through special programs – at BMW, for example, "Health Management 2020" or "Today for Tomorrow". That is all linked to the demographic change, the changes in legislation on the retirement age and the aging workforce. The average age of all BMW employees is today 43. The know-how of the older employees is also finally being recognized – and utilized.

Production facilities are designed to be flexible in order to bring new developments or improvements into series production as quickly and as easily as possible. Automation is employed only where it is necessitated by the complexity. Great importance is attached to the "fun of improvement". Important is also the "fun of flow". The transport facilities are built in-house and employ a gravity concept for part transport.

Supplier workshops are also very popular. Fifty such events were staged in 2012. Suppliers are frequently surprised to see what simple processes are used at BMW. But the success is plain to see. The errors in delivery have been reduced by over 90 % since 2007. Furthermore, the Landshut works was commended by an international jury as the best factory in 2012.

The Steel of the 21st Century ...

... is light, strong and just 5 to 8 µm thick. We are talking about the carbon fiber that was presented by Dr. Hubert Jäger from the SGL Group with headquarters in Meitingen, Swabia. A first driving force for the material was space travel with prices of around 500 EUR/kg. This was followed by applications in sport and motor racing. From 1995, lightweight construction found its way into aircraft thanks to the carbon fibers. Some ten years later the product spread to wind generators. And today the leading market

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is the automotive industry. A worldwide volume of 47,000 t at a price of 10 to 20 EUR/kg is forecast for 2015. Around half of this volume will be used in the automotive industry and in wind power generation. The speaker recommended that carbon fibers should be produced where energy is cheap, because the transport of the fibers costs very little. They should also be used only in structures subject to high loads. A major challenge is still the process of knitting, weaving and laying of the fibers and the associated cycle times.

Dr. Arnim Kraatz from Evonik Industries AG, Essen, Germany, presented an application example of this with a study of a CFRP tailgate. For a middle-class station wagon, a component of this kind weights approx. 20 kg. If a weight saving can be achieved, this also has a positive influence on related components such as the gas struts can also be made smaller. The window with a weight of over 9 kg also offers a starting point for weight reduction. The conventional sheet metal structures are designed in line with the admissible forming. They also have the disadvantage of the "tinny" acoustics during closing. A CFRP sandwich solution with PMMA window still offers more than sufficient strength, and attention has to be paid to the forming. In a two-shell CFRP variant, the wall thickness is 2 mm. The laminate structure consists of four layers. The CFRP structure has to compensate the lower rigidity of the PMMA or Perspex window compared with glass. The potential of the concept lies in a weight reduction of 50 % or 10 kg.

In a motor vehicle, different components and materials have to be combined with one another. Welding and bonding methods have been used for this to date. Andreas Retzlaff (VW, Wolfsburg) reported on studies in which, for example, locking catches and joining clips were injection molded onto a natural fiber-reinforced non-woven cover. The most important criterion here is naturally the bonding strength. It is not surprising that very good adhesion is achieved when the two partners are made from the same material mix **(Table 1)**. An important factor for optimum wetting and hence optimum adhesion strength is the contact angle **(Fig 1)** that has to be as small as possible in order to create a large contact surface area. The temperature also has a crucial influence. If the substrate placed into the injection mold is preheated, a more durable bond is achieved due to the better fusion between the contact surfaces.

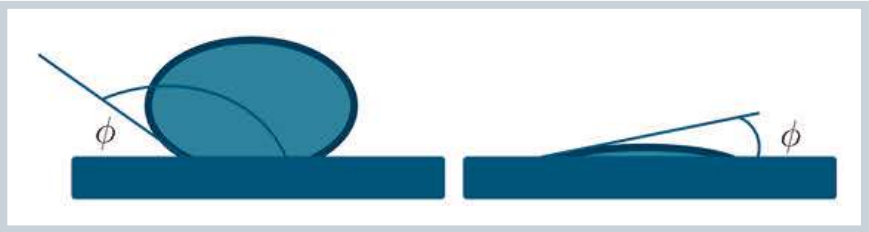

Fig. 1. Poor wetting (left) and good wetting (right) (figure: VW)

No Disturbing Noises

If engine and rolling noises are perceived inside the vehicle as audible or tangible vibrations, then experts speak of noise vibration harshness (NVH). Remedies can be found here in the field of absorption or insulation. Dr. Johannes Dresen-Rausch from the Ford-Werke in Cologne, Germany, presented an insulation system developed jointly with the Pezler Group, Witten, Germany, that is installed between the engine compartment and the passenger cell. It consists of cotton and PET fibers embedded in a PET matrix. The whole package is coated on the driver's side with a perforated PE/PA film. The first series application was in the Ford C-Max. This solution allowed costs and weight to be saved compared with the previous model.

Mercedes has succeeded with a different route to NVH optimization. Dr. Harald Zeizinger (Daimler AG, Stuttgart, Germany) presented a plastic engine mount that was used for the first time worldwide in the GL Class. The relatively rigid aluminum mounts used to date were unable to adequately damp the disturbing engine noises. Aluminum mounts filled with cast resin were also unable to offer the desired improvement. The positive damping properties of plastics were well known, but the demands were high. Both the static and the dynamic loads – the latter particular with poor road conditions – had to be withstood just as much as the temperatures of up to 150 °C. The component has to survive at least 20 million load cycles during the vehicle life as well as the extremely high crash demands. BASF SE, Ludwigshafen, Germany, provided the computation methods and the structural analysis. The fiber orientation had to be optimized such that the fibers lay parallel to the flow of forces in the areas subject to the highest loads. A heat-stabilized, fiberglass-reinforced polyamide that successfully passed all the tests was used here. If the thermal loads increase to over 200 °C and strengths of more than 200 MPa are demanded in future model generations, then long fiber-reinforced heat-setting plastics could be used.

Great Tractors

Until well into the 1980s, plastics were practically unknown in agricultural vehicles according to Andreas Stieglitz (AGCO-Fendt, Marktoberdorf, Germany). That has changed fundamentally in the meantime. The Bulldogs have since become noble vehicles with air conditioning, acoustic insulation, Class →

	PA	PE	POM	PP	PVC
PA	+	#		#	
PE	#	+	#	+	–
POM			+	#	
PP	#			+	#
PVC					+

(+) Very good adhesion, (#) Limited adhesion, (–) No adhesion, ( ) Conditional adhesion

Table 1. Adhesion behavior of plastics to one another (source: VW)

A quality for the visible surfaces, minimum gap sizes and prices of 350,000 EUR for standard models in the upper performance class. This type of tractor then achieves 3,000 operating hours a year. It is therefore hardly surprising that in the meantime some 120 injection and blow moldings and roughly 30 SMC, LFI and RIM parts are used in this type of tractor. Many demands such as quality, innovative design or attractiveness of the interior already match those in the automotive sector. Functional integration is also employed.

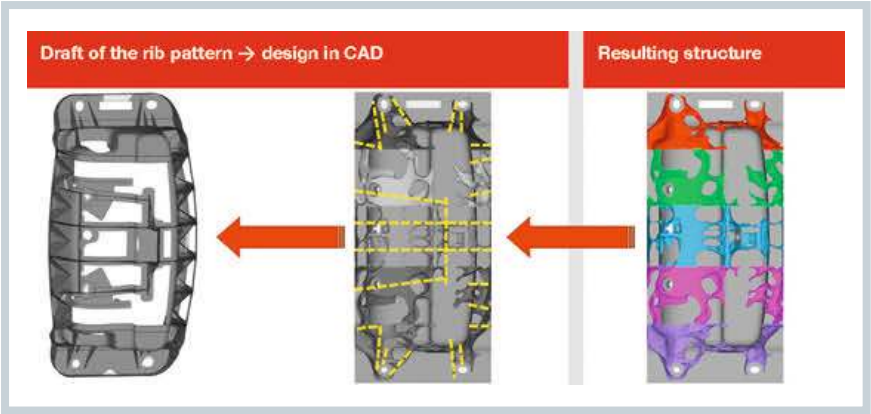

Fig. 2. Result of the topology optimization (each color stands for an area of the part that was investigated (figure: Lanxess)

Faster Than a Blink

A blink takes approx. 80 ms. An airbag has only 5 to 8 ms in which to inflate. After triggering it is stopped abruptly. This results in tensile forces of 2 t. But the search for weight-saving potentials makes no concessions even when it comes to such safety components. Julian Haspel (Lanxess Deutschland GmbH, Dormagen, Germany) and Udo Gaumann (Takata AG, Aschaffenburg, Germany) carried out studies into an airbag container of lightweight construction. The basic strength is provided here by an organic sheet that is formed in the mold. It is very rigid in fiber direction, but relatively soft in the transverse direction. A sophisticated topology optimization was therefore necessary with ribs and wall thickness modifications in all directions in order to achieve the necessary strength. An additional problem was the lack of material data for organic sheets. The filling simulation was carried out with a modified Moldflow program and correlated with the filling study carried out later **(Fig. 2)**. The material chosen was an impact-modified polyamide. The weight of a conventional series-production part is 559 g. This was reduced by 200 g.

Fig. 3. Prototype of an all-plastic shift fork (figure: Sodecia)

The power train is one of the areas of a motor vehicle subject to the highest thermal and mechanical loads. Plastics have deficits in the mechanical properties which have to be compensated by geometric properties, e.g. increases in wall thickness. Uwe Koch-Reuß (Victrex Europa GmbH) and Detlef Tiedtke (Sodecia, FSG, Burgwedel, Germany) presented a gearbox shift fork **(Fig 3)** that reduces the gearbox weight by a total of 1 kg. Four shift forks are generally used in a standard gearbox. Dimensioning was carried out by means of structural analysis. PEEK is used as the material which, although having the lowest E modulus by comparison with aluminum or brass, but has an equivalent yield strength and and actually has advantages in the fatigue strength. The part is subjected mainly to bending loads. The breakdown of the costs is reversed: Whereas with steel 75 % of the costs are attributable to the process – the rest are material costs – with PEEK the material costs account for 75 % and the processing makes up only 25 %.

E-mobility Needs Plastics

As Thomas Jessberger (Mann+Hummel GmbH, Ludwigsburg, Germany) explained, the electric automobile has played a very modest role to date, not only in Germany. Of the more than 43 million vehicles on German roads, only one per mil has a hybrid drive and just 0.15 per mil are purely electric vehicles (as of 31.12.2011). And the figures do not look a lot different in other industrialized countries, either. The greatest obstacles are the low range and the high battery costs. While the battery costs in 2010 lay in the order of 873 EUR/kWh, they are expected to drop to 237 EUR/kWh by 2020. A series production vehicle is the Opel Ampera. Its high-voltage battery alone contains 40 kg of plastics, more than twice as much as in the whole power train of a modern vehicle with internal-combustion engine. The battery of the Ampera **(Title figure)** consists of 288 individual cells, 135 repeat frames and 18 end frames that together weigh 18 kg. Added to that are the housing and cover and the degassing units – and of course it needs a connector. Fiberglass-reinforced polyamide 66 is used in the battery.

Conclusion

The reduction in CO_2 emissions from automobiles demanded by the legislators, called for by the customer and owed to nature can only be achieved if the motor vehicle are put on a radical diet. This diet is the use of plastics, but which must go far beyond simple substitution. What are demanded are clever solutions with system integration and a tailored use of materials. ■

THE AUTHOR

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