Lighter than Steel

Weight reduction is achieved forward of the front axle. The result is better axle load distribution, which stabilizes the front of the vehicle and improves car handling (photo: Lanxess/Audi)

Hybrid Technology. As a result of the current climate protection debate, plastic-metal composite technology is more than ever in demand in automotive engineering. At the present time, automotive manufacturers are systematically examining their new model designs to identify possible applications for this lightweight construction method, which is also known as hybrid technology. New polyamide materials take account of this trend.

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Hybrid technology combines the strengths of plastic and metals such as steel and aluminum. The metals contribute a high elastic modulus, high strength and ductile behavior. The main plastics used are polyamide 6 grades (PA 6) because they are dynamically very strong and have good impact resistance at high and low temperatures. A hybrid component is produced in one operation. First of all, as a rule, several thin-walled, deep-drawn metal profiles are placed overlapping in the injection mold and then selectively reinforced with polyamide ribs (in-mold assembly or IMA process). To create a durable positive or non-positive connection between the metal and plastic, use is made of openings, beading and overmolding. At the same time, functions such as mountings and guides can be integrally molded in the plastic component, which is described as functional integration and opens up considerable savings potential. Post-mold finishing is unnecessary – unlike with aluminum or magnesium pressure diecast components, SMC or GMT. Despite the combination of two technologies, i.e. injection molding and metal deep drawing, process reliability is high. Reject rates in serial production of large, complex front ends are considerably less than 1 %.

Around 40 % Weight Reduction

The first industrial-scale application of hybrid technology was front ends. In the

Fig. 1. In the event of a crash, the hybrid brake pedal does not break but exhibits ductile failure (all the remaining figures are provided by Lanxess)

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last ten years, considerably more than 40 million of these highly stress-resistant vehicle body structural components have been produced from sheet steel and Durethan BKV 30 H2.0, a glass-fiber-reinforced PA 6 from Lanxess, Leverkusen, Germany. In 2008 alone, 70 different mass-production vehicles were fitted with front ends made from this material combination. Virtually all international OEMs rely on hybrid front ends produced from PA 6 and sheet steel – for both long and short production runs.

Now Lanxess, as the inventor and pioneer of hybrid technology, has widened its range of application. Besides components for car roof frames, brake pedals for small vans from various manufacturers are now being produced from Durethan BKV 30 H2.0 using hybrid technology (**Fig. 1**). Compared with its all-steel counterpart, the hybrid component achieves 60 kg higher loadbearing capacity, a weight reduction of around 40 % and cost savings of about 20 %. Another application for PA 6 is the world's first hybrid pedal bracket. (**Fig. 2**). In comparison with an all-plastic component, it is around 10 % lighter and also exhibits ductile behavior in the event of failure.

In hybrid front ends, aluminum can also be used instead of sheet steel. The first example of this was in the Audi TT (**Title picture**). This front end is around 15 % lighter than a comparable design with sheet steel. The plastic used was again Durethan BKV 30 H2.0.

On account of their weight-saving potential, there is currently a trend towards aluminum hybrid front ends. In many such projects, manufacturers are turning to easyflowing PA 6 variants to leverage design advantages and also reduce material and production costs. When high component stiffness is required, glass-fiber-reinforced PA 6 grades with high filler loadings are also used.

Fig. 2. The hybrid pedal bracket also integrates mountings for the brake light switch, clutch master cylinder and over-center spring

New Hybrid Applications in Demand

As all previous serial applications have shown, hybrid components open up great potential for weight reduction. Auto makers are therefore at present systematically searching for new applications and are particularly concentrating on large structural components for both vehicle interiors and exteriors (**Fig. 3**).

Hybrid front ends with built-in pedestrian protection are currently about to go into serial production. This protection is designed to prevent accident victims being dragged under the car. Consideration is also being given at present to the idea of directly integrating the crash-relevant bumper carrier into such front ends.

Hybrid concepts for doors, tailgates and hoods are very promising. Because of their complexity and the high crash requirements they have to meet, side doors and tailgates are among the most challenging hybrid applications. A side door produced using hybrid technology offers a number of advantages. It can be up to

Fig. 3. More recent applications of hybrid technology in automotive engineering

Fig. 4. Three-point bending tests on Erlanger test beams: with the glass-fiber-reinforced polyamide 6 Durethan DP BKV 60 H2.0, twice the load level can be achieved as compared with Durethan BKV 30 H2.0

20 % lighter than a sheet steel design and, through the use of functional integration, can be directly provided with mountings for the lock, airbag, loudspeaker, fasteners, window lifter mechanism and side-view mirror.

There is even potential for using hybrid technology under the hood. For example, hybrid concepts for loadbearing polyamide oil sumps are being studied. These must have far higher structural rigidity than their non-loadbearing counterparts to ensure force transmission from the bell housing to the engine block. However, polyamide is not sufficiently stiff for this. The problem is solved with a design „trick". The polyamide oil sump is provided with two small hybrid struts, which take over force transmission but scarcely increase the overall weight of the assembly.

The cross member, side member and rocker panel for the underbody structure are further "candidates" for hybrid technology. They would be around 20 to 30 % lighter and behave much more favorably in a crash than comparable steel solutions. These frequently undergo localized failure, which could be cost-effectively overcome in hybrid construction by selective plastic reinforcements.

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Hybrid construction also offers advantages for dashboard carriers. It enables cable and air ducts, mountings for the steering column and pedal box, and fixing brackets for the dashboard to be integrated. Another potential application is that of carrier modules for panoramic roofs made from glass or polycarbonate. Work is being conducted on module concepts that use poly butylene terephthalate (PBT) rather than PA 6 as the "metal partner" – because of its better dimensional stability, among other reasons.

More Efficient Polyamides

To help these new potential applications of hybrid technology become established, Lanxess is developing both new, specially tailored polyamide materials and improved production technologies. Good examples of this are the easyflowing polyamides Durethan EF (Easy Flow) and Durethan XF (Xtreme Flow). With the EasyFlow range, over 50 % longer flow paths can be achieved than with comparable standard grades of Durethan. Especially in the case of large hybrid components, such materials once again permit wall thickness and part weight to be significantly reduced and considerable cost savings to be made. For example, the replacement of Durethan BKV 30 H2.0 with Durethan BKV 30 EF in the front end of a van and sedan manufactured by an American auto maker led to far lower production costs. Because injection pressures are reduced by 40 %, tool wear is lower and there is less risk of core breakage, which cuts tool repair costs. In addition, flow aids are no longer necessary. Other savings are achieved from lower injection temperatures (energy consumption, cycle time).

Entirely new possibilities for the design of hybrid parts are opened up by highly filled but easyflowing polyamides such as 60 % glass-fiber-reinforced Durethan DP BKV 60 EF H2.0. This PA 6 is extremely stiff, with a tensile modulus of over 20,000 MPa (dry, room temperature). It enables twice the load level to be achieved as compared with Durethan BKV 30 H2.0 (**Fig. 4**). Hybrid components produced from 60 % glass-fiber-reinforced Durethan DP BKV 60 EF H2.0 can therefore offer higher performance or, if requirements are unchanged, can be designed as thinner-walled, lighter-weight structures. The high stiffness of this material allows the plastic content of a hybrid structure to be increased, which pays off especially in geometrically complex component areas. This polyamide also has higher thermal conductivity and, even at elevated temperatures, a high tensile modulus. Hybrid components produced with this material can therefore be removed from the mold much sooner, which shortens cycle times. The potential savings offered by the

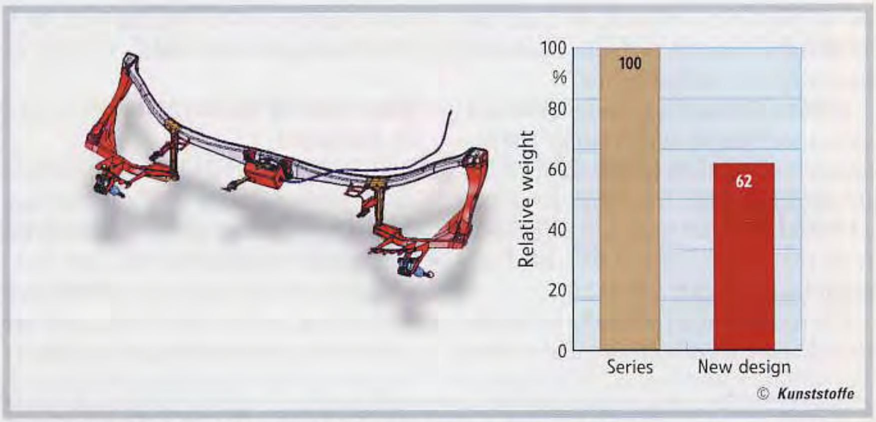

Fig. 5. Calculations showed that the front end of a German compact class car model would be some 38 % lighter if produced with highly reinforced PA 6 instead of Durethan BKV 30 H2.0

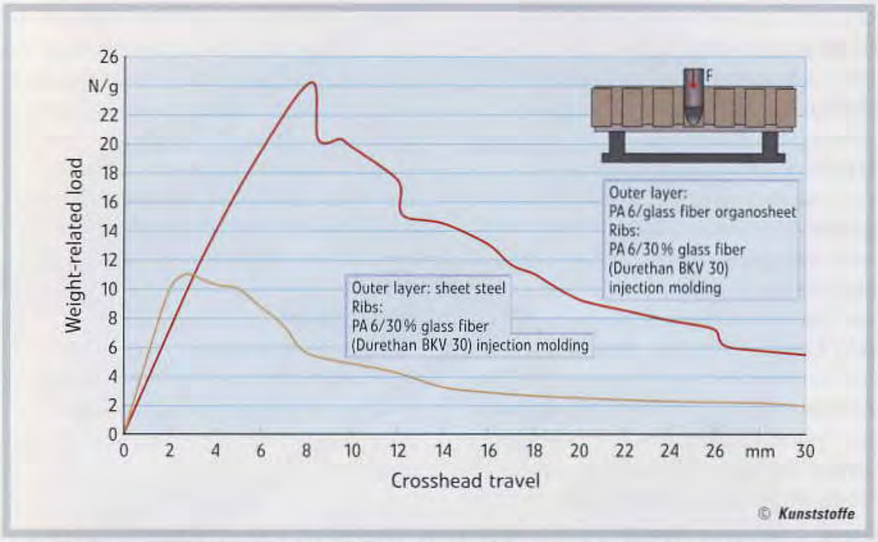

Fig. 6. The maximum loading limit of the organosheet hybrid design (Erlanger test beam) in the 3-point bending test is nearly twice as high as that of its sheet metal counterpart

new PA 6 are shown by the following. According to calculations by Lanxess, the production costs and weight of serially manufactured hybrid front ends, designed to withstand high mechanical stresses, can be reduced by 30 to 40 % **(Fig. 5)**.

OrganoSheets for Large-scale Production

Another approach to increasing the application and performance potential of hybrid technology is based on using lightweight organosheets instead of sheet steel. These flat sheet semi-finished products consist of a thermoplastic matrix reinforced with a woven or laid fabric made from glass, carbon or mixed fibers. The semi-finished products are selectively provided with polyamide ribs and stiffening in an injection mold. The molten thermoplastic polymer forms a close material bond with the organosheet.

The mechanical performance of organosheet hybrid components was analyzed in 3-point bending tests with the hybrid components in the form of Erlanger test beams. The test beams studied were a hybrid beam combining organosheet (2 mm, Tepex from Bond-Laminates, Brilon, Germany) with glass-fiber-reinforced polyamide 6 (Durethan BKV 30) and a hybrid beam combining steel sheet (0.7 mm) with Durethan BKV 30. At the beginning of flexural loading, the organosheet hybrid component is not quite as stiff as the plastic-metal composite. However, it absorbs considerably more energy because its strength or maximum loading limit is nearly twice as high **(Fig. 6)**. Under torsional stress **(Fig. 7)**, the material bond between the organosheet and polyamide even shows higher torsional stiffness.

The manufacturing process for organosheet hybrid components has now been developed to the point where high annual quantities can be economically produced. At the end of 2009, large-scale production of a highly integrated, load-bearing body part for a luxury car model was started.

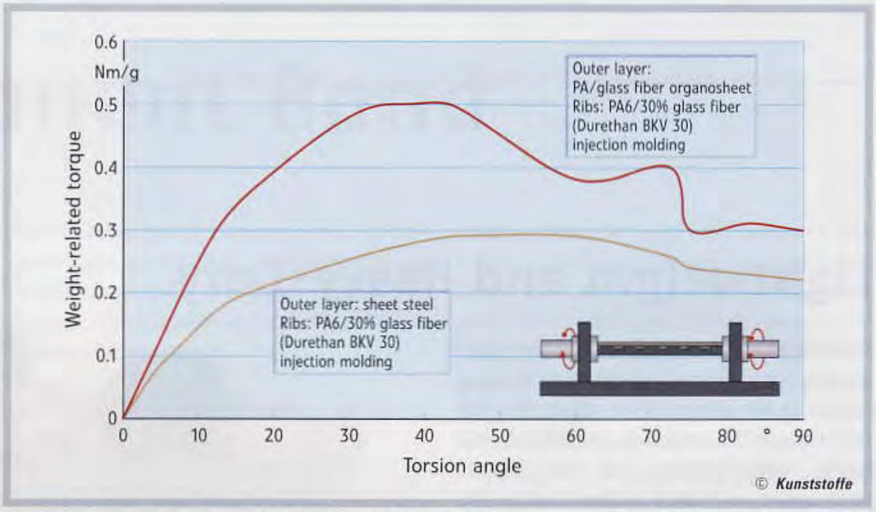

Fig. 7. The torsional stiffness of the organosheet hybrid design (Erlanger test beam) in the torsional test is twice as high as that of its counterpart based on sheet metal

Full-surface "Hybrid Adhesion"

In an early development phase, tests are being carried out at Lanxess on a new variant of hybrid technology in which steel sheets coated with an adhesion promoter are used. After shaping, the sheets are provided with and adhesively bonded to a polyamide rib structure in an injection mold. Unlike in "conventional" hybrid technology, a full-surface bond is obtained between the metal and plastic rather than spot bonds. The quasi-static simulation of 3-point bending (Erlanger test beam) showed that this adhesive bonding method achieved a load absorption value more than twice that obtained with a "standard beam" **(Fig. 8)**. Torsional stiffness increased by 40 %, flexur-

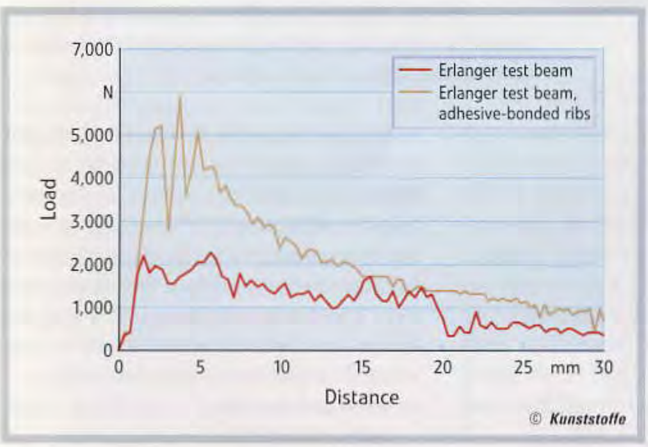

Fig. 8. Simulation of 3-point bending tests on Erlanger test beams (0.6 mm sheet steel, Durethan BKV 30 H2.0): the adhesive bonding nearly doubles the load absorption value

al strength by as much as 150 % and the dynamic flexural strength relevant to crash behavior by 30 to 40 %. These improved values make it possible to design components with thinner ribs and smaller cross sections and in this way to save weight and material. At the present time, the effectiveness of different adhesives is being studied. The aim is to make the properties of "adhesive-bonded" hybrid components calculable so that parts can be designed by simulation.

Conclusion

Hybrid technology has continually demonstrated its potential for lightweight construction in the economic production of structural components for automobiles. Opportunities for the use of this technology will continue to increase in future. This will be assisted by newer materials such as highly filled polyamides, new calculation methods such as topology optimization or integrative simulation, new composite construction methods such as organosheet hybrid technology and further improved processing methods. Lanxess is driving these innovations forward with its long-standing experience of industrial production projects involving hybrid components. The objective is always the same – namely to expand the limits of design possibility in order to exploit all available weight and cost advantages. To do this, the company relies on close cooperation with system suppliers and OEMs. It brings to this collaboration the full scope of its expertise, ranging from concept development of the hybrid component and material selection to part design, mold construction and production process optimization. ■

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