Application Information

Hybrid Components in Series Production

Based on the first publication in Kunststoffe 87 (9/97 - H. Goldbach, J. Hoffner)

Taking the example of a front end design

In traditional construction methods, metal and plastics are fierce competitors. Hybrid technology, by contrast, selectively uses the advantages of the different materials to combine them with each other in a single molding.

For some time now, development projects have been focused on the equal-ranking use of metals and plastics in individual components, employing the hybrid technique. Industry has now come up with a large number of examples of this technological innovation being implemented in practice. The very first hybrid molding was the front end of the Audi A6 (C5), made of a combination of sheet steel and Durethan® BKV 130, an elastomer-modified polyamide PA 6 GF 30.

Figure 1 The Audi A6 front end is a hybrid construction, comprising a composite of metal and glass fiber reinforced, elastomer-modified polyamide 6.

(Manufactured by Faurecia, Audincourt/France)

A key feature of hybrid structures is that the materials employed complement each other as far as their specific properties and advantages are concerned. The composite material thus offers physical properties which could not be achieved with homogeneous materials. Production is likewise based on two proven production techniques:

- Metal forming
- Plastics injection molding.

Hence not only the properties complement each other but also the two most economical methods of series production, ensuring reliably reproducible production tolerances. The hybrid method is particularly attractive on account of the characteristic freedom of design offered by the injection molding process and the fact that it provides ready-to-fit parts that require no finishing work.

Design and production principle

A formed, perforated sheet metal part is placed in an injection mold in the same way as for the insert technique and has an appropriate polymer injected around it. The molten plastic penetrates the punched perforations and forms a rivet head between the cavity wall and the inserted metal part. This produces a highly stressable, form-fit joint between the two components. The sheet metal does not require either a coupling agent or any other additional treatment.

The standard corrosion protection achieved by cathodic dip coating of the metal remains fully functional after the injection molding process and does not impair the strength of the bond between the two different materials.

Hybrid technology offers many advantages: load-bearing metal structures can be designed with even thinner walls to satisfy the constant demand for weight reductions.

This is because the tendency for thin metal structures of this type to buckle and bend can be considerably reduced through carefully positioned plastic ribbing. Once this risk of deformation is excluded, the theoretically-calculated load-bearing capacity can be exploited to the full, while considerably reducing the component weight. The plastic structures demonstrably enhance the performance of the metal parts under both compressive and flexural stressing.

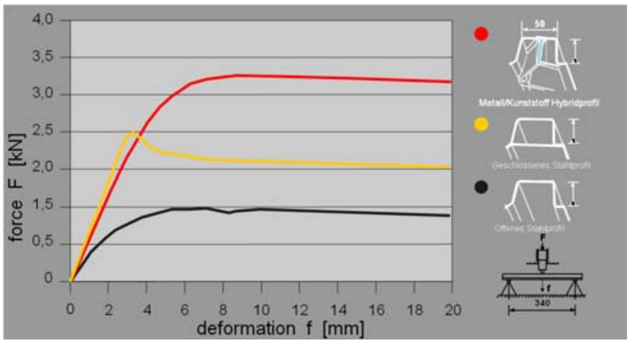

Figure 2 Verification of the force-deformation behavior under flexural load of a metal/plastic composite and an open and closed sheet-steel profile.

The load-bearing capacity of a hybrid profile was tested to compare it with the load-bearing capacity of pure metal versions, by way of an example. Under defined, identical conditions, an open and a closed U-profile in 0.7 mm sheet steel had to demonstrate their load-bearing capacity by comparison with an open U-profile incorporating plastic bracing. The parameters tested were force-deformation behavior under flexural load, (Figure 2), deformation behavior under longitudinal compressive load, and torsional strength under the action of torque (Figure 3).

The open sheet metal profile performed poorly for all three load cases.

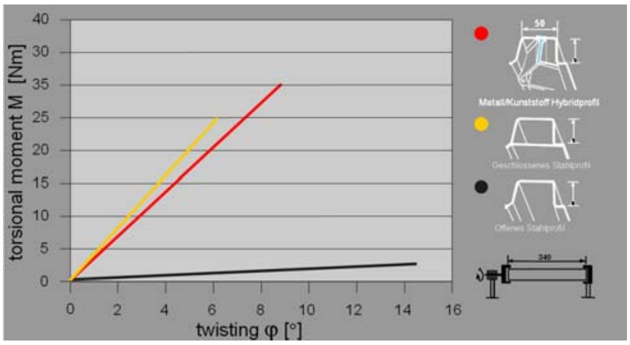

Figure 3 Verification of the resistance to torsional stress of a metal/plastic composite and an open and closed sheet-steel profile.

Under flexural stress, early failure through buckling causes the two edges to bend outwards. The compression and deformation behavior under longitudinal compressive stress similarly reveals a low dimensional stability, leading to deformation at only a low level of force. With somewhat higher forces, the edges bend outwards and the profile fails. The open sheet-metal profile similarly displays an extremely low torsional rigidity, as was to be expected.

The closed sheet-metal profile performs better under flexural and compressive stress but is clearly outperformed by the hybrid profile. The ribbing in glass fiber reinforced PA 6 weighs roughly the same as the sealing plate on the closed sheet-metal profile

Component behavior under torsional load is also better with the hybrid technique. The hybrid component attains a higher torsional rigidity as a function of the geometry of the plastic ribbing (x-shaped or z-shaped, for example) and the Young's modulus of the plastic employed (Figure 3).

These are the results of fundamental studies, which clearly reveal the design potential offered by the hybrid technique. The cross-shaped ribbing selected for all these tests, however, constitutes a compromise for stabilizing both flexural and torsional stresses. The results would be improved even further by ribbing designed to cope with specific load cases.

Requirements on the component and their implementation

During the design of the new front end, the chief focus was on reducing costs, achieving a uniformly high quality and keeping the weight down to a minimum. The new component thus weighs approximately 1 kg less than the previously-employed glass mat reinforced (GMT version), which had to be reinforced by a retrofitted metal support. This weight saving is particularly attractive in that it can be implemented ahead of the front axle and thus has a favorable impact on the axle load distribution. The axle load distribution has a direct influence on the driving performance of a car.

The front end has to absorb the continuous load of the engine's tilting moment of up to 7 kN, with the engine being supported by a bearing in this case. It is also important not to underestimate the load imposed by the hood catch – both during the closing operation and at high speeds. The component is additionally exposed to a temperature ranging from – 40 to + 90 °C, since it also serves as a support for the cooling units in the oil and water systems and air-conditioning components.

Extensive experiments and test series (performed by vehicle manufacturer Audi, system supplier Faurecia and raw material and patent holder, LANXESS), showed that a hybrid front end fulfils all the specified requirements.

Using the finite element net generated by Faurecia with CAD data, it proved possible to simulate the torque and the forces associated with the hood catch. The prototype of the front end was designed with the aid of this calculation method with weak points in the metal structure being detected and optimized at an early stage (Figure 4). The design of the prototype molds was then based on these findings. The last run of prototype molds, with the necessary final touches for fully automatic production, ensures series-production capability over the entire production run.

The gate concept was checked on the basis of Moldflow analyses, and the filling pattern of the mold optimized. The calculated filling time for the hybrid injection molding is 4 s, and the mold filling pattern is shown in Figure 1. The orientation of the glass fibers in the direction of the melt flow was exploited to keep the longitudinal thermal expansion of the components at a low level (Figure 2). A key advantage of the filling simulation is that it permits the different filling areas to be balanced in time terms, thereby avoiding pressure peaks in the mold.

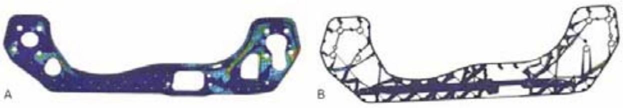

Figure 4 Using finite element analysis (FEA) in the development of the front end (A); in this way, weak points in the metal structure can be detected and optimized at an early stage (B).

A similarly important task that was solved with the aid of finite element analysis was the warpage calculation. Deformation due to the shrinkage differentials that prevail during component cooling was detected at an early stage, which meant that design countermeasures could be implemented in good time.

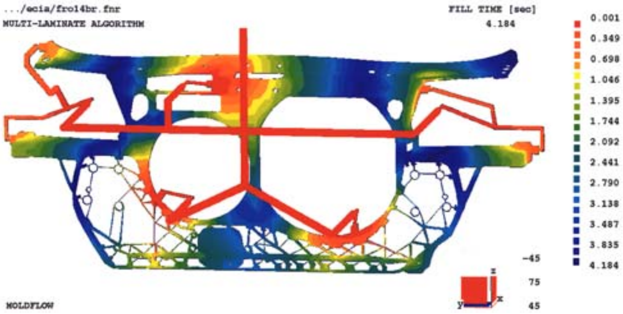

Figure 1 A Moldflow analysis permitted the gate design to be checked and the mold filling process to be optimized (the filling pattern for 100 % filling is shown).

The difference compared with the standard injection molding process lay in the adaptation of the metal part to the injection mold. Here, it was a matter of aligning complex structures measuring 1m x 0.4 m x 0.8 mm to the geometry of the mold, which is something that imposes particularly stringent requirements on the production accuracy of the mold. By virtue of CNC machining, it proved possible to manufacture the forming tool with the same data as for the injection mold, which meant that very little work was required to adapt the sheet metal part. The forming process supplied geometrically precise, warp-free inserts suitable for making up into precise-fit, ready-to-install structural components or assembly supports in a single operation by means of injection molding.

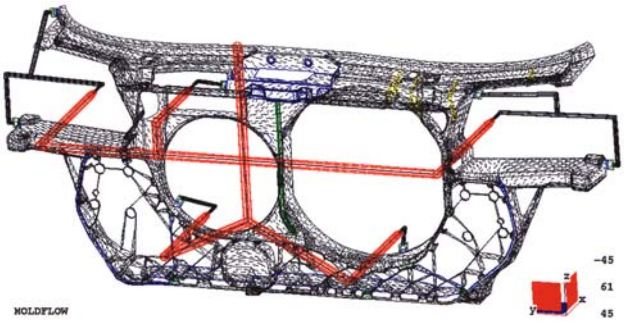

Figure 2 The Moldflow analysis also permitted the orientation of the glass fibers to be established.

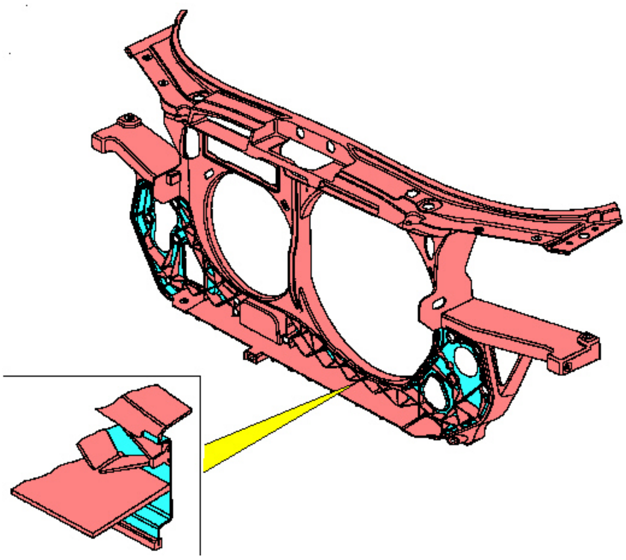

Figure 3 Hybrid structure of the front end for the Audi A6 (metal structure: green, plastic: red).

Integration of additional functions

Since any number of additional functions can be integrated in the part through the injection molding process, the hybrid technique holds highly promising potential for the efficient production of ready-to-assemble modules. On the front end version described, mounting bushes for the engine bearing and other attachment elements are placed in the mold, together with the formed sheet metal, and have plastic injected around them (Figure 3). A precision opening can be formed for the cooling system fan, together with all the perforations required, and the fan motor support can also be incorporated (on this version it was still fitted on afterwards, since an existing design had to be retained).

Reinforcing ribs and undercuts can be implemented much more readily than with the GMT technique. This then gives a structural component with a level of integration that could not be achieved with the same level of mechanical properties in just a single material. In terms of rigidity and cost, steel provides the design engineer with an extremely favorable structural component. Its combination with plastic, as an equal-ranking partner, by the hybrid technique enables the steel designer to dispense with cost-intensive assembly and welding work.

Property profile of the polyamide component

The polyamide materials, Durethan BKV 130 and Durethan BKV 30, have been successfully used in technical applications for many years in parts that are subject to a high level of stressing and for load-bearing structures. Both materials have a high impact strength and are suitable for applications involving impact and dynamic loads. The glass fiber reinforcement gives a high stiffness, coupled with a low tendency to creep and a high dimensional stability, while the material offers an extremely high heat resistance.

The strength level of this material, with 30 % glass fiber reinforcement, means that it can be used at temperatures considerably in excess of 100 °C. The good dynamic strength (fatigue limit) under permanent, alternating load is also important for this application. The material is not susceptible to stress cracking and displays good overload behavior on account of its toughness.

Durethan BKV 130 and Durethan BKV 30 are particularly suitable for use in composites with metals thanks to their ability to eliminate, through relaxation, the stresses that occur during the injection process. Their low tendency to creep, including at high temperatures, is similarly important and gives them very good dimensional stability and resilience under load.

Problem-free recycling

Parts that have been joined together by this simple and cost-effective means can be just as readily separated again. A hammer mill can shred the composite parts, which are held together simply by a form-fit joint, in a matter of seconds in just a single operation. Screens and magnetic separators reliably segregate the materials into single-sort fractions. These can then be processed and fed back directly into the production cycle.

Concepts for further products

The composite approach opens up weight-reducing solutions for the majority of structural components in automotive engineering, including for instrument panel supports, tailgates, and automobile seats and doors, while simultaneously offering potential for reducing assembly work. This, however, places extremely high demands on design engineers. They need to move away from familiar, proven methods and venture into unknown territory. A knowledge of metalworking is required, together with specific plastics know. Even nine years after the introduction of the front end described above, the application engineers in LANXESS Semi-Crystalline Products Business Unit are thus still available to provide advice and assistance in the joint development of new hybrid applications.

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Unless specified to the contrary, the values given have been established on standardized test specimens at room temperature. The figures should be regarded as guide values only and not as binding minimum values. Kindly note that, under certain conditions, the properties can be affected to a considerable extent by the design of the mold/die, the processing conditions and the coloring.

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