Adhesion Promoter for Unequal Pairs

Primer Joins Metal and Plastic Components with Adhesive Bond

Plastic/metal hybrid structures for industrial applications have been established for years, e.g. for front-end carriers in automotive vehicles. Previously, in assembly injection molding joints were based on form/force fit or friction locking. Novel adhesion promoters now permit adhesive bonding of hybrid structures with improved component properties.

Established plastic/metal hybrid structures: Front-end carriers, for example, are mounted in automobiles (here in the Ford C-MAX) as mass-produced lightweight hybrid components (© LKT)

Suitable plastic/metal combinations enable component properties to be obtained, which are not possible by using just one material. Thus, plastics mainly offer a wide range of design freedom and low density, while metals introduce high rigidity and strength into the hybrid structure. Compared to a purely metal version, for example, metal carrier profiles with plastic ribbing have a lower weight or the component's mechanical performance is increased [1, 2].

An efficient mass-production method for manufacturing plastic/metal-hybrid components is in-mold assembly. Hereby, pre-shaped sheet metal assemblies are reinforced by overmolded plastic structures that also provide additional functional elements. Thereby, the quality and embodiment of the bond between plastic and metal is decisive in determining the component properties [3].

There are three basic approaches for joining metal and plastic components: form fitting, force fitting, and adhesive bonding [4]. In the past, mechanical fastenings dominated, e.g. rivet-like through-molding of the metal component to create a form-fitted joint.

An additional and important potential for highly stressed hybrid structures is offered by adhesive bonding, whereby the materials are durably joined by means of intermolecular or chemical forces over the largest area possible [5]. Due to the chemical incompatibility between metal and plastic, this approach represents a highly demanding task [6]. One valid concept is the use of adhesion promoters based on modified plastics, which enter an intimate interaction both with metal as well as plastics, thereby permitting a bond between these two materials to be established (**Fig. 1**).

Within the scope of the joint Hylight project, the project partners Ford-Werke GmbH, Evonik Resource Efficiency GmbH, Lanxess Deutschland GmbH, Kirchhoff Automotive Deutschland GmbH, Montaplast GmbH, Hühoco Oberflächenveredlung GmbH, the Institute of Plastics Processing (IKV) at RWTH Aachen, and the Institute of Polymer Technology (LKT) at the Friedrich-Alexander University in Erlangen/Nuremberg, developed and tested an innovative process for the economic production of plastic/metal hybrid structures based on novel adhesion promoters. Hereby, fundamental work by Prof. Gottfried W. Ehrenstein on hybrid technology, in particular for the design and evaluation of model components ("Erlanger Träger", Erlangen carrier, **Fig. 2**) [3, 7] within the scope of the Collaborative Research Center 396 (1996–2007), formed an important basis during the development of this joint project.

The Hylight Process

The Hylight process makes use of a newly developed lacquer system as adhesion promoter, which is based on Evonik's reactive copolyamide Vestamelt Hylink. The lacquer system was adapted for use with hybrid components, taking into account the demands of the automotive industry (e.g. corrosion and temperature resistance). For this, and apart from simple samples such as tension/shear specimens, also the Erlangen carrier was used as an established complex model component, which represents important design features of series components. Moreover, the lacquer system was optimized specifically for application by means of an efficient and fully automated coating process (coil coating) for semi-finished sheet metal parts. In this way, the usually necessary pretreatment and coating of the sheet with a lacquer system can be combined in a cost and time-saving processing line.

Following the coil coating step, and with the exception of the full-surface cathodic dip coating required for corrosion protection, the Hylight process follows the same processing steps as the conventional manufacture of form-fitted hybrid components. Consequently, established processes and equipment can be used (**Fig. 3**). Cathodic dip coating is no longer necessary, because the lacquer system simultaneously acts as corrosion protection. In terms of economy – and possibly ecology – this is particularly advantageous.

The coated and shaped metal inserts are then overmolded with the plastic component. Hereby, the hot plastic melt comes into contact with the pre-cross-linked lacquer coat and activates it. The result is the formation of a strong, large-area, adhesive bond. The adhesive bond concept permits a more uniform distribution of stresses with reduced stress peaks when compared to form fitting with local joining elements (**Fig. 1**). This permits material, i.e. weight and costs, to be saved without impairing component performance. Over- or through-molding can be reduced, and molded parts can be designed precisely according to application and load, e.g. with thinner walls.

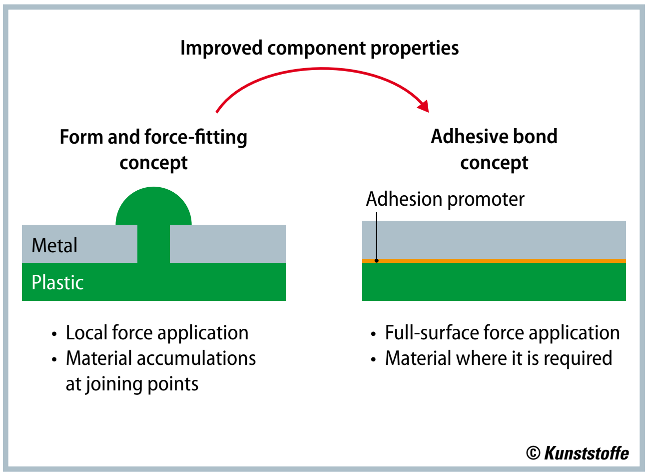

Fig. 1. Improved component properties: Concepts for joining metal and plastic components and their characteristics (source: LKT)

Confirmed by Close-to-Production Tests

To demonstrate the potentials of this process for a complex series component, the front-end carrier of the Ford C-MAX was used (**Title figure**). The carrier is mounted at the front of the chassis frame, where it serves e.g. as a carrier for bumper, cooler, and headlights under high demands in terms of function and dimensional accuracy. Polyamide 6 with 30 wt.% of chopped glass fiber is used for the plastic component, and deep-drawn galvanize steel for the metal component. Various component tests were to confirm the potential of the Hylight process. For this purpose, front-end carriers were produced by means of the conventional manufacturing process (form fitting/friction locked, no use of primers) as reference, and using the newly developed process (additional adhesive bond).

The first demanding component test was the hood-latch flexural test. Hereby, the front-end carrier is subjected to a tensile load that represents its real mounting situation in the vehicle' hood latch position. The test simulates the maximum load of the front-end carrier caused by the engine hood, and involves a mix of bending and torsion loads (**Fig. 4, left**). The stiffness of the Hylight front-end carrier is about 30 % higher than the one of the reference carrier (**Fig. 5, left**). The second component test was a torsional test, in which the carrier was fixed in different positions in a special device (**Fig. 4, right**), and one side was twisted by means of a lever mechanism. The results show a significant increase in torsional stiffness of the Hylight part that is some 24 % higher than that of the reference component (**Fig. 5, right**).

Finally, a corrosion test of the entire vehicle with a front-end carrier manufactured with the new process was conducted on Ford's testing circuit in Lommel, Belgium (**Fig. 6**). The corrosion test – which usually takes 12 weeks – is divided into 24-hour phases. At the start of each phase, the vehicle is thoroughly checked. »

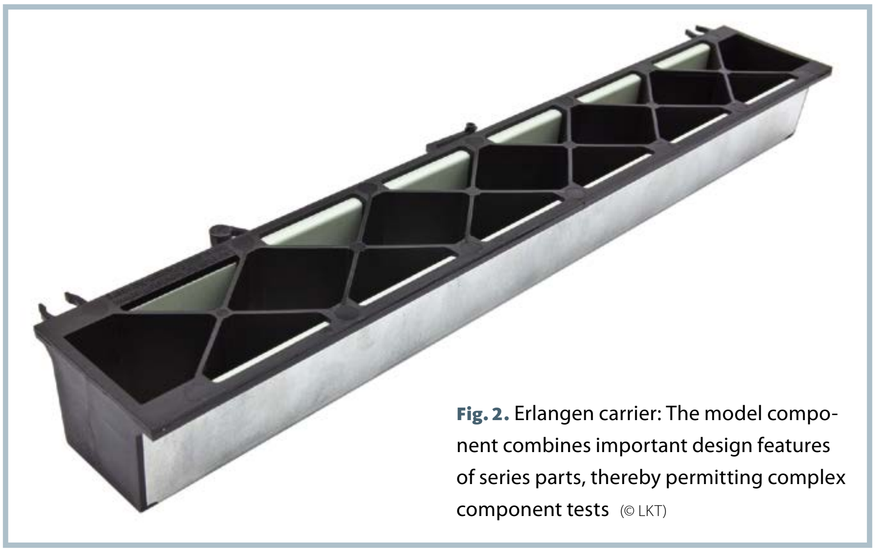

Fig. 2. Erlangen carrier: The model component combines important design features of series parts, thereby permitting complex component tests (© LKT)

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Dedication

Dedicated to Prof. em. Dr.-Ing. Dr. h.c. Gottfried W. Ehrenstein on the occasion of his 80th birthday.

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Reference

Additional information on the Hylight joint project and a comprehensive overview of the resulting findings is given in the "Handbuch Kunststoff-Metall-Hybridtechnik" (Drummer, D. (editor): Lehrstuhl für Kunststofftechnik 2015, ISBN 978-3-931864-67-5).

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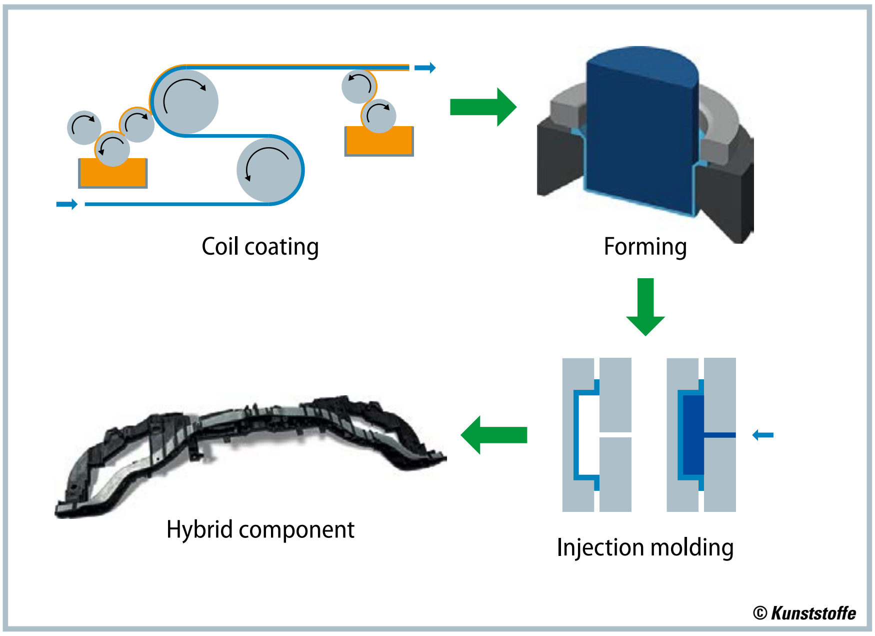

Fig. 3. Hylight process: The processing chain for producing plastic/metal hybrid components (source: LKT)

Then the vehicle is tested for four hours on different circuit tracks, whereby a distance of about 180 km is covered. Subsequently, the vehicle is sprayed intensively with a saline solution on a corrosion track, before it is subjected to changing humidity/temperature cycles for 20 hours in a climatic chamber. This test permits a prediction of the corrosion behavior during several years.

The front-end carrier passed the test successfully, thereby verifying the primer's corrosion protection for series production.

Weight Savings of Some 20 Percent Possible

By using the novel lacquer system as adhesion promoter for the front-end carrier, the increased rigidity and strength permits weight savings to be achieved. For a simulative assessment, material was removed from the design until the component properties corresponded to the initial values. Hereby, the following strategies are principally conceivable:

- Reduced wall thickness of sheet metal and/or of the plastic structure,
- elimination of entire parts of the construction,
- changed dimensions, i.e. changes in height and/or width of the hybrid profile.

These strategies are subject to the following limitations:

- Formability of the sheet metal requires a minimum wall thickness,
- injection molding of the plastic structure requires a minimum wall thickness, and also depends on the material used.
- parts of the plastic structure are required to fill the mold, and cannot be removed arbitrarily,

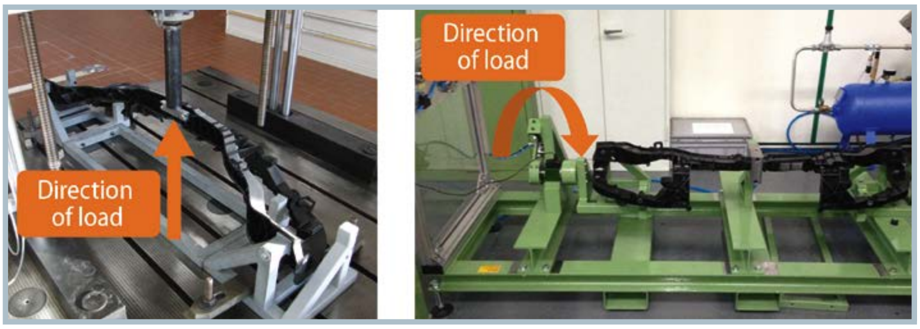

Fig. 4. Test setup: Hood latch test (left), and torsion test (right) (© LKT, acc. to [8])

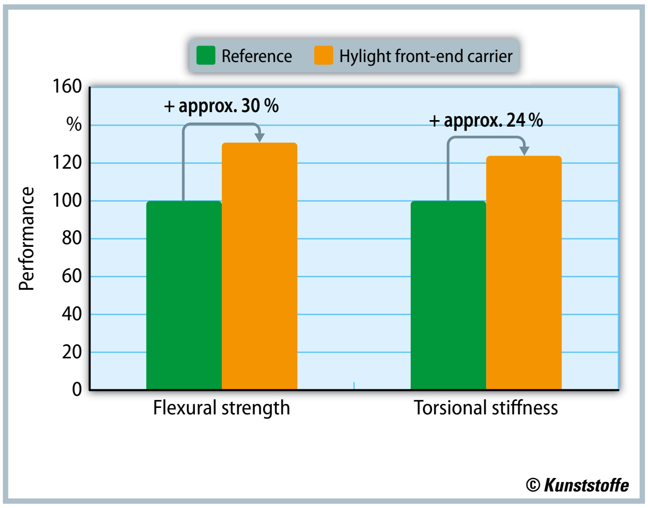

Fig. 5. Overview of the front-end carrier's performance increase (source: LKT)

Fig. 6. Ford C-MAX test vehicle with integral Hylight front-end carrier (© [8])

- dimensional changes may not infringe constructional space nor interfere with other functions, and all connecting positions must be retained.

The described measures were implemented in several simulative optimization steps, and their influence on component weight was assessed. Hereby, achievement of latch and torsional stiffness of the series component were defined as marginal conditions. Taking the specified limitations into account, the overall simulative improvement resulted in a 21 % reduction of component weight (referred to the top box section and under assumption of a perfect bond).

Conclusion

Plastic/metal hybrid structures have enjoyed a wide range of industrial applications for many years. The use of novel adhesion promoters now permits adhesively bonded hybrid structures to be created. Using the front-end carrier of the Ford C-MAX as an example, the described process shows that the newly developed lacquer system permits better component performance to be achieved with the same materials and using established series manufacturing procedures and equipment. By means of specific redesign and optimization, this experimentally determined performance increase of a front-end carrier resulted in weight savings of about 20 % in the hybrid section of the demonstrator during simulation calculations, thereby underlining the potentials for lightweight construction of this process. In addition, a newly developed simulation method permits an improved prediction of the mechanical component properties of adhesively bonded plastic/metal hybrid components.

Thanks to the newly developed lacquer system, the Hylight process enables the production of hybrid components that also meet the high demands of the automotive industry regarding corrosion resistance. ■