THERMOPLASTIC FIBER REINFORCED/METAL-HYBRID LAMINATES FOR STRUCTURAL LIGHTWEIGHT APPLICATIONS

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Introduction

Especially in automotive industry the use of multi-material designs will rise in the near future, as these can provide a significant contribution to weight reduction, energy conservation and therefore to the protection of natural resources. Particular attention is paid to the new material composition made of fiber reinforced thermoplastics and metallic (M) components. By targeted exploitation of the excellent mechanical properties, combined with suitable capabilities for mass production, cost-effective and weight-optimized parts with high stiffness and load capacity can be provided [1-2].

An approach that follows this idea is the combination of metal and fiber reinforced plastics (FRP) in form of hybrid laminates (HL). Such FRP/M-hybrid laminates are characterized by excellent mechanical properties at high damage tolerances.

Laboratory scale production of hybrid laminates

For the preparation of thermoplastic based FRP/M-hybrid laminates, textile semifinished products are preconsolidated to continuous fiber reinforced prepregs. In the following step the prepregs and the metallic top layers are processed by a hot press under defined temperature and pressure conditions. To achieve high strength and stiffness values, strong adhesive forces between FRP and metallic components are required. So the interface has to be optimized by an appropriate surface pretreatment [3].

In the present study continuous carbon fiber reinforced hybrid laminates were examined, whose structure is explained in table 1 more detailed.

Tab.1 Structure of the investigated hybrid laminates

Metal	HC220Y+ZE
Matrix	Polyamide 6 (PA 6)
Reinforcement fibers	Carbon fiber (G)
Fiber volume content	60%
Layer structure	HC220Y+ZE/0_5^c/HC220Y+ZE
Thickness metal	2 x 0.25 mm
Thickness FRP	0.75 mm
Thickness buffer layer	2 x 0.20 mm
Thickness HL	1.65 mm

The preparation of the hybrid laminates was accomplished on a Collin P/M hot press with a corresponding mold. The curve shape of the temperature and pressure during the pressing process is shown in figure 2, wherein the required consolidation time is highlighted. The manufacturing process can be divided into three stages:

A. Heating and plasticizing of the thermoplastic matrix (20 bar, 260 °C, 6.5 min)
B. Consolidation of the fiber reinforced thermoplastic (30 bar, 260 °C, 3.5 min)
C. Cooling and solidifying of the thermoplastic melt (30 bar, 80 °C, 16.5 min)

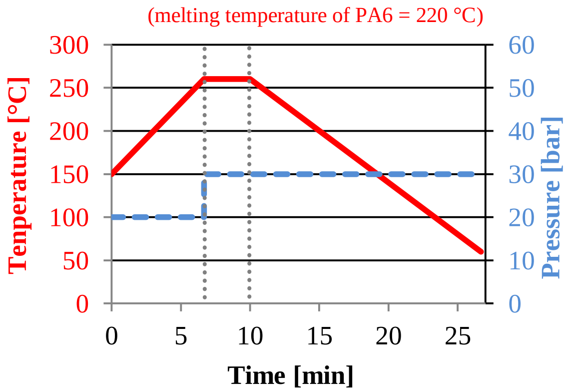

Fig.1 Temperature and pressure profile of hybrid laminate production

During the thermoforming process , the highly viscous thermoplastic polymer matrix is pressed against the surface of the metallic component so that adhesive forces between the materials can occur. At the same time the reinforcing fibers are fully impregnated and consolidated, as can be seen in figure 2.

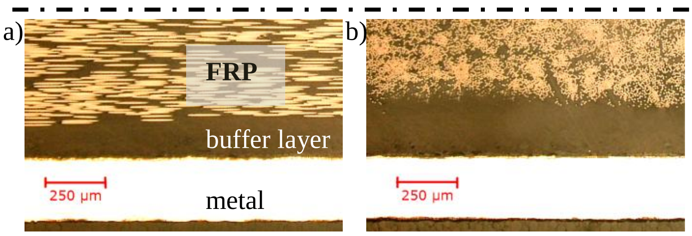

Fig.2 Sectional microscopic microsection of a hybrid laminate a) in fiber direction b) transverse to the fiber direction

Three point bending test of hybrid laminates

The three point bending flexural test provides values for the modulus of elasticity in bending Ef, flexural stress σf, flexural strain εf and the flexural stress-strain response of the material. The main advantage of this test is the easy way of specimen preparation and testing procedure, although it is to be noted, that the results are sensitive to specimen and loading geometry and depend on the strain rate. In the current study the bending flexural properties were carried out referring to DIN EN ISO 14125 (Fig.3).

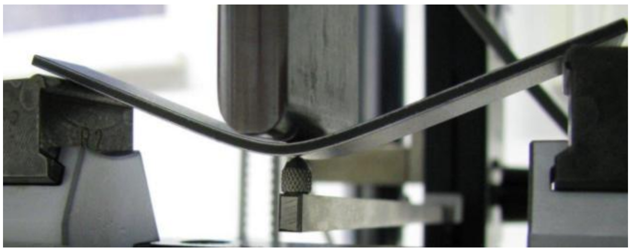

Fig.3 Sample in the three point bending test in referring to DIN EN ISO 14125

Results

The results of the three point bending flexural test is shown in figure 4. The results were compared with an unidirectional carbon fiber reinforced plastic (CFRP) with a thickness of 2.0 mm and a fiber volume content of 60%.

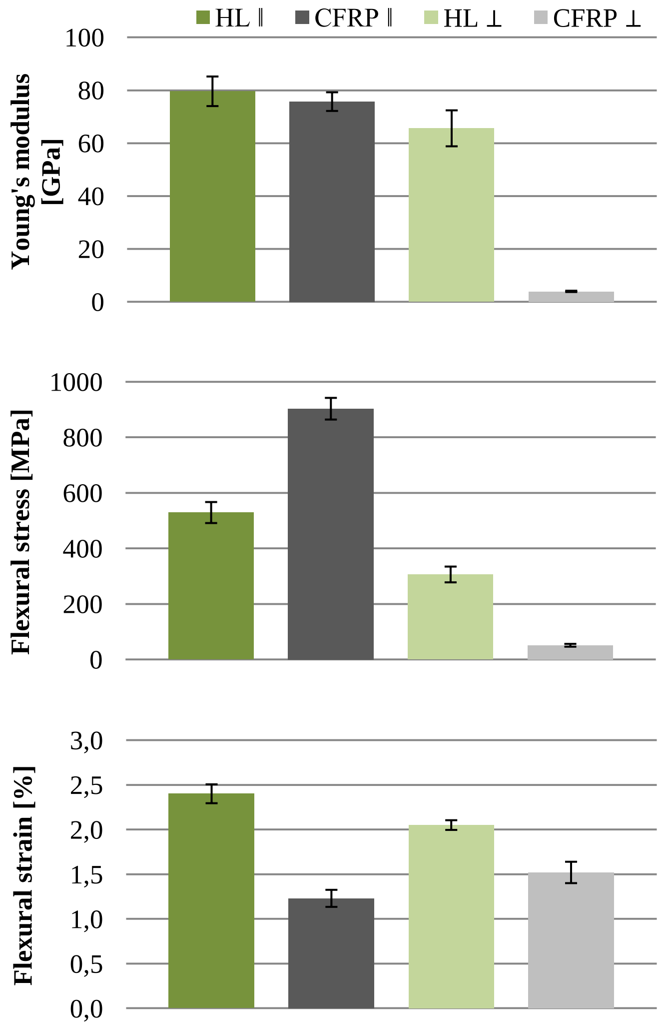

Fig.4 Mechanical properties of HL and CFRP

The design principle of hybrid construction allows the manufacturing of weight-optimized structures with high stiffness and resistance that meet the increasing demands for energy-efficient production processes and components with high lightweight potential. Particularly in the automotive industry, there is a rising demand for such designs. Especially the use of fiber reinforced thermoplastics offers advantages for automotive components, due to its good specific characteristics and its suitability for mass production. In conjunction with traditional isotropic materials such as steel or aluminum heavy-duty lightweight structures can be produced, whose properties can be specifically adapted to the given component requirements.

In the present study the development of innovative hybrid laminates with low residual stresses, made of steel sheets/foils and carbon fiber reinforced thermoplastics is shown.The biggest advantage has resulted in the Young's modulus and the flexural stress in transverse to the fiber direction. For a further characterization and comparability with other conventional automotive materials, such as steel and aluminum, additional investigations are planned for the future, e.g. tensile tests, whereby the preliminary study already shows the high potentials of the novel material.

Acknowledgements

The IGF-Project 17688 BR and the participating DFG-Projects KR1713/16-1 and /17-1 were managed by the European Research Association for Sheet Metal Working (EFB) as a part of the DFG-AiF-Cluster “Großserientaugliche Prozessketten für hoch-integrierte Bauteile aus hybriden Faser-Kunst-stoff/Metall-Verbunden“ and financed by the German Federation of Industrial Research Associations (AiF) within the Industrial Collective Research program (IGF), funded by the Federal Ministry for Economic Affairs and Energy (BMWi) pursuant to the decision of the German Bundestag.

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