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Processing and characterization of cathodic dip coated metal/composite-laminates

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ABSTRACT

The current trend shows an increasing demand for novel technologies, that facilitate a functional integration of fiber reinforced polymers (FRP) in metal based structures, especially in automotive industry. To comply with the requirements of large-scale production the use of fiber reinforced thermoplastics in form of hybrid metal/composite-laminates seems advantageous. By targeted exploitation of their high lightweight potential, combined with suitable capabilities for mass production and good damping properties, cost-effective and weight-optimized parts with high stiffness and load capacity can be provided for future applications.

As there is little known about the processing and the mechanical properties of thermoplastic based FRP/metal-laminates, the study focuses on the development of novel hybrid laminates with low residual stresses, made of metallic steel sheets and continuous glass or carbon fiber reinforced polyamide 6. In this context, the influence of several pre-operations like sand blasting, cleaning or primer application on the interlaminar shear strength (ILSS) was examined in addition to their resistance to cathodic dip paint treatment.

1. Introduction

While continuous fiber reinforced polymer/metal (FRP/M)-laminates were used to increase the lightweight degree and damage tolerance in aircraft industry for several years [1], an augmented demand for materials with corresponding properties can be noticed nowadays in industries with large lot sizes, e.g. in the automotive sector. The use of available hybrid laminates (HL) with continuous fiber reinforcement, like GLARE®, ARALL® or CARALL®, is precluded due to the time-consuming cross-linking of the deployed thermoset matrices and low realizable degrees of deformation [2,3].

An auspiciously approach is the invention of thermoplastic based HL [3–6], that have been implemented in first serial products and shall be transferred to large scale production in the near future [7]. However, they are available merely without fiber reinforcement, which leads to disadvantageous

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Table 1 – Comparison of continuous fiber reinforced hybrid laminates and metallic constructions.

	Thermoplastic based hybrid laminates	Thermoset based hybrid laminates	Metal sheets
Processing time	+	–	++
Degrees of deformation	+	–	++
Damping properties	++	+	–
Damage tolerances	++	+	–
Strength	+	++	–
Stiffness	+	++	–
Impact strength	++	–	–
Fatigue strength	++	+	–
Lightweight degree	++	+	–
Recyclability	+	–	++

++: excellent; +: good; –: poor.

mechanical properties in comparison with fiber reinforced HL. To maintain the advantages of FRP/M-laminates in structural automotive components, the aim of the present study was the development and characterization of thermoplastic based HL with continuous fiber reinforcement.

Beneath larger achievable degrees of deformation and short cycle times, thermoplastic based FRP/M-laminates shall offer favorable damping properties, higher damage tolerances and excellent properties in terms of impact- and fatigue strength, compared to thermoset based HL or mono-material designs (Table 1) [1,3].

2. Structure and processing of continuous fiber reinforced metal/composite-laminates

Thermoplastic based FRP/M-laminates consist of stacked pre-impregnated textile layers (prepregs) and thin metallic sheets or foils (Fig. 1). The properties of those materials can be adjusted application-oriented by the use of different materials and layer structures. To obtain a strong joint between the metallic top layers and the reinforced polymer core, a suitable interface engineering and stable process parameters are of particular importance. For this purpose, different laminate structures, material combinations and surface pre-treatments were examined in fundamental investigations as a part of the present study.

In order to ensure a good formability of the HL, cold rolled micro-alloyed fine-grain steel sheets HC260LAD + Z100 (t = 1 mm) for cold working were used as metallic components. This kind of steel is widely used in automotive industry, e.g. in strengthening components. The thickness of the hot dip refined Z100 zinc layer is 5–12 μm and has a total grammage of 100 g/m^2.

Due to its suitable profile of properties, polyamide 6 based prepregs were used in the core. The impregnation of the unidirectional oriented fibers was realized in a film stacking process. Besides good mechanical and damping properties, polyamides possess a strong chemical resistance and good processing characteristics with relatively low processing temperatures, which is advantageous in terms of cathodic dip paint treatment and thermoforming of HL. Recommended application temperatures are about ~190 °C in short term or ~80 °C in long term loads.

The reinforcement of the HL is obtained by continuous glass (EC17, 17 μm) and carbon fibers (HTS40 24K, 6 μm). The investigated laminate structures are explained in Table 2 more detailed.

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 Fig. 2.

The manufacturing process can be divided into three main stages:

- Heating and plasticizing of the thermoplastic matrix (35 bar, 285 °C, ~10 min)
- Consolidation of the fiber reinforced thermoplastic (60 bar, 285 °C, ~5 min)
- Cooling and solidifying of the HL (60 bar, 180 °C, ~5 min)

During the consolidation of the fiber reinforced thermoplastic, the plasticized polymer matrix can adhere to the metallic top layers. This joint is based on adhesive interactions and therefore highly dependent on the surface properties of the individual components. Fig. 3 shows a microscopic microsection of an exemplary [HC260LAD/0_2^C]$_s$-HL with a fully impregnated and consolidated fiber structure.

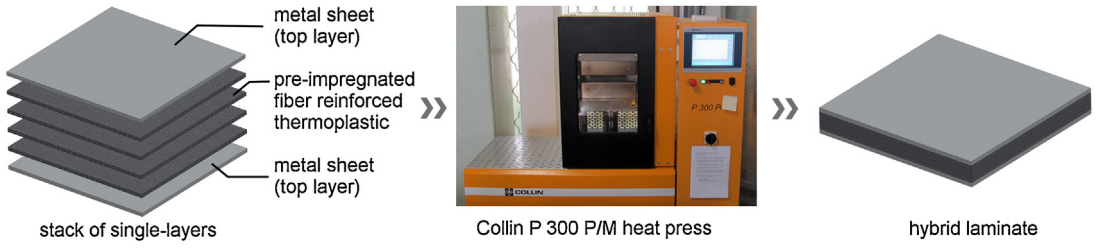

Fig. 1 – Structure of continuous fiber reinforced metal/composite-laminates.