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Production technology of cores for hybrid laminates containing rubber powder from scrap tyres

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Abstract

Future technological and product developments will be measured by their improved resource and energy efficiency, as well as their competitiveness, while allowing for effective climate and environmental protection.

In this study, hybrid metal-plastic composites are developed combining lightweight design with high material stiffness. Therein, modifications of the polymer core with rubber powder are used to increase the damping properties for lower structure borne-sound as well as sustain high stiffness and low weight. For the elastomer filling, different polymer base materials are compared. Assuring a gentle processing of the thermal sensitive powder, an energy-efficient one-step direct manufacturing has been successfully developed.

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Keywords: resource and energy efficiency, lightweight structures, technology fusion, recycling, scrap tyres, rubber powder, thermoplastic-elastomer-blend

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1. Introduction

In general, hybrid laminates with metal and plastic layers offer various advantages mainly based on the different properties of the materials. Thick and stiff cores lead to significant improvements of the bending stiffness while thin and compliant cores enforce shear deformations and thus higher damping and lower the structure-borne sound. This leads to contradictory composite design capabilities of high damping and high stiffness while assuring light structures at the same time.

Even though these types of composites show benefits for a wide range of applications, they are mainly used in aerospace and defence industry [1]. The choice of material and thickness of every single layer is driven by structural requirements as well as process limitations and thus present a complex optimisation problem. Therefore, the performance and formability of these complex materials can been investigated numerically with different process parameters and materials [2, 3].

Within this study, metal-plastic composites with different core thicknesses are produced and experimentally characterised. The innovation is the utilisation of recycled tyre rubber in the form of powder as an elasticator for thermoplastics. This material is used for the production of cores for metal-plastic-composites (MPC), thereby following the ecological demands for elastomer recycling.

In detail, rubber recycling is still a challenging procedure due to restrictive environmental requirements and voluminous appearance. According to the International Rubber Study Group 26.8 million tons of caoutchouc were produced worldwide in 2015 [4], whereof more than two thirds are utilized for tyre production [5]. This sums up to over 1 billion tyres being made worldwide every year. The irreversible cross-linking of elastomers makes recycling difficult, resulting in the need for various highly specialized processing technologies depending on the quantity of residues and their degree of purity [6]. One of today’s most common recycling technologies for post-consumer tyres is size reduction through mechanical treatment and cryogenic grinding [7]. Thereby the structure of the material is destroyed, generating different types of materials, ranging from shred to microscopic particles. For the utilization of such recycling materials in applications of high quality and mechanical requirements, fine powders with particle sizes below 400 µm are indispensable [8].

First structural investigations showed promising results for damping and stiffness of rubber powder-polyamide-compounds as material for the cores of such laminates. However, it has been found that, to gain a significant damping in the MPC, the yieldingness of the material must be greatly reduced. Thus, a new core material generation has been further developed based on a thermoplastic polyurethane (TPU) matrix. Furthermore, a tailored one-step manufacturing process for an gentle, energy and cost efficient production was realized.

2. Sustainable hybrid laminates

Combining lightweight and damping properties metal-plastic composite (MPC) materials are developed joining the advantages of the individual components. In detail, a sandwich layup including stiff but thin metal face sheets as well as light and dissipating plastic cores was chosen. To enhance the shear damping of the MPC, the polymer core material has been modified using different volume fractions of rubber crumb. As an innovative approach, the sustainability of the core material should be increased using rubber powder from recycled tyres.

2.1. Polyamid6-rubber powder-compounds

First, the modifications of the core material have been investigated. In detail, the polar thermoplastic polymer polyamide 6 is used within this study to ensure an appropriate bonding either to the (polar) metal face sheets as well as to the rubber particles. The ground tyre rubber was taken from recycling processes by either cryogen or hot milling. Particles have been added in volume fractions of 10-70%. The unfilled polymer was used as a reference.

After successfully compounding all blends with increasing volume fractions of rubber, the test specimens were manufactured by injection moulding. Tension tests according to ISO 527 showed a significant reduction of the Young’s modulus for increasing rubber fractions (Fig. 1). It should be mentioned, that the elongation at break is