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High Precision Machining of Hybrid Layer Composites by Abrasive Waterjet Cutting

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Abstract

In industrial applications the increasing variety of high performance materials and their combination to material composites is challenging for the common machining processes. Their high application range combined with minimal forces and no significant thermal loads predestinates abrasive waterjet cutting for machining such complex structures.

This paper verifies the high precision machinability of 2D- and 3D-layer composites out of CFRP and a lightweight metal such as aluminum or magnesium using the abrasive waterjet. Therefore, different cutting strategies were determined as well as process influences to the joining zone and characteristics of the machined component.

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Keywords: Waterjet machining; Fiber reinforced plastic; Hybrid layer composite

1. Introduction

Lightweight design gains importance in the automotive or the aircraft industry when it comes to product optimization [1]. Therefore, novel high-performance materials are applied to improve the quality of single components by adjusting their mechanical properties [2]. As a result the variety of materials continuously increases, predominated by lightweight metals and carbon fiber-reinforced plastics (CFRP) [3].

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In numerous applications transmissions of forces and torques between those components are essential. Thus, the present research focusses on suitable technologies to combine CFRP and lightweight metals such as aluminum or magnesium [4]. Additionally, secondary shaping of those hybrid layer composites is challenging for conventional cutting processes, especially for those with geometrically defined edges [5, 6]. Also laser cutting as an alternative process has to manage major difficulties in this field such as different absorptivities or decomposition or melting temperatures of carbon fibers, epoxy resin and metal [7]. As a consequence novel laser machining strategies are focusing on an ablation of CFRP in multiple steps before cutting the pure metal [8].

Regarding CFRP, drilling and milling are the most common machining technologies, but abrasive waterjet cutting is also suitable for this purpose, as already discussed in [9]. Having already a share of nearly 20% [10] when machining CFRP its importance increases continuously [11, 12]. Machining lightweight metals by using this technology is already state of the art [13, 14]. As it is illustrated in Fig. 1, there is a linear correlation between feed rate and hardness of each material, while feed rate and thickness of uncut material are non-linear related. Thus, the feed rate for cutting the composite cannot be predicted when knowing the individual feed rates for the CFRP and the lightweight metal. Due to this, the machining of the composite has to be investigated in greater detail.

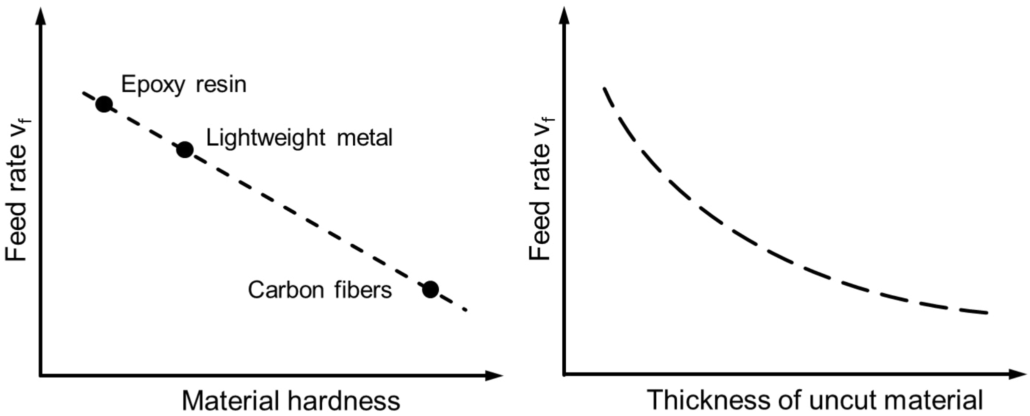

Fig. 1. Variation of the feed rate depending on material hardness and thickness.

Nevertheless, with its geometrical flexibility and its great variety of processible materials, the abrasive waterjet seems to be applicable for machining composites out of CFRP and lightweight metal, even though their properties are highly differing [15]. Furthermore, abrasive waterjet exhibits advantageous process characteristics due to the minimum level of mechanical and thermal impact during machining compared to other cutting processes [16, 17].

Although abrasive waterjet cutting offers numerous benefits for trimming a metal-CFRP composite, several challenges need to be faced. On the one hand the different materials could cause differences in roughness and kerf geometry on the cut surface in the CFRP and the metal layer. On the other hand water as well as the abrasive garnet may weaken the joining zone between the two material partners or affect the bonding of fibers and plastics inside the CFRP [18]. Both effects could have an influence on the quality of the product, e.g. by reducing its mechanical properties or increasing the time for reworking.

2. Experimental setup

While in conventional machining the jet has a diameter of 0.8 up to 1.0 mm, fine jets for precise machining are characterized by diameters smaller than 0.5 mm [19]. The investigations were conducted using a 5-axis abrasive fine jet system with a special positioning accuracy of ± 0.01 mm based on the injection principle (Fig. 2).