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Machining of carbon and glass fibre reinforced composites

E. Uhlmann[a], F. Sammler[a]*, S. Richarz[a], G. Reucher[b], R. Hufschmied[c], A. Frank[c], B. Stawiszynski[a], F. Protz[a]

[a]*Institute for Machine Tools and Factory Management (IWF), Technical University Berlin, 10587 Berlin, Germany*
[b]*BMW Group, MT-402, Ohmstraße 2, 84030 Landshut, Germany*
[b]*Hufschmied Zerspanungssysteme GmbH, Edisonstr. 11 d, 86399 Bobingen, Germany*

* Corresponding author. Tel.: +49 (0) 30 314 25689; fax: +49 (0) 314 23349. *E-mail address:* Fiona.Sammler@iwf.tu-berlin.de

Abstract

The combination of carbon and glass fibres in new reinforced composite components makes the machining of these promising materials challenging. The abrasive carbon and glass fibres cause tool wear and cutting edge rounding which results in higher process forces and insufficient workpiece quality. At the IWF, innovative process strategies for the machining of these materials have been developed, combining these with new cutting tool geometries. Furthermore, the classification of workpiece quality for reinforced plastic components has not been sufficiently addressed thus far and is also a focus of the work being undertaken. In order to adequately describe the workpiece quality, fibre pull-out and fibre protrusion must both be analysed. Using the example of a carbon and glass fibre composite material, the dependency of these characteristic quality parameters on process and tool parameters shall be analysed. The work described here compares an axial drilling with an helical milling process from both a technological (workpiece quality) and an economical (processing time) point of view.

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Keywords: composites; process strategy; drilling; milling

1. Introduction

The use of lightweight materials continues to grow in importance in the aeronautical and automotive industries, with more stringent guidelines on fuel consumption and emissions coming into place in the next years. The demand for economical machining strategies for fibre reinforced composites is therefore high, as these materials possess a high potential for the substitution of, for example, heavier aluminium alloys. Various research works have studied the machining of fibre reinforced composites in recent years [1,2,3]. However, the focus lay mostly on carbon fibre reinforced composites in the aeronautical industry [1], with some work also being undertaken on glass fibre reinforced materials [4]. The development of machining strategies for automotive components and the combination of both carbon and glass fibres in a single workpiece has thus far been studied only in a limited capacity.

2. Aim and current state of the art

The aim of the presented work is to develop a machining strategy for high quality bore hole machining in a CFRP/GFRP combined workpiece material, as shown in Fig. 1. Currently, the fibre protrusion and fibre pull-out requires manual post-machining, which is costly and time-consuming in series production. In both the automotive and aeronautical industries, drilling is one of the most important operations, with up to 55,000 holes being drilled in the production of an Airbus A350 aircraft and over 200 bore holes per car in the BMW i Series cars [5,6]. The aim is therefore to make manual reworking obsolete by achieving the required quality with the machining process alone. This can be achieved by controlled buckling and fracturing of the carbon and glass fibres during machining [5,7].

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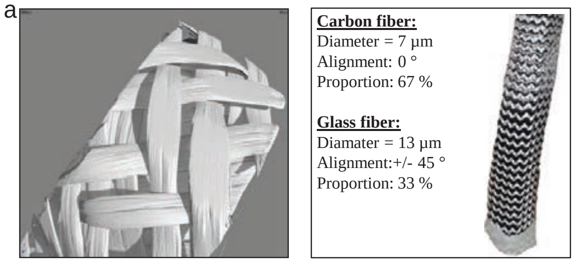

Fig.1. Carbon and glass fibre reinforced composite used in the investigations

Previous work by the authors has shown that the use of high speed cutting parameters has led to substantial improvements in the machining result [8,9]. This concept was thus transferred from peripheral milling to bore hole machining within the work described in this paper.

As also stated by [1], the conventional machining process outputs such as tool wear and surface quality are not sufficient for the classification of reinforced composite components. For the work undertaken here, quality criteria were therefore determined by the end-user, BMW AG. The quality criteria relate to fibre pull-out and fibre protrusion.

Nomenclature

v_c	Cutting speed
v_f	Feed rate
v_{fmill}	Milling feed rate
v_{fdrill}	Drilling feed rate
D	Diameter
I_F	Fibre protrusion
I_{PO}	Fibre pull-out
CFRP	Carbon fibre reinforced plastic
GFRP	Glass fibre reinforced plastic
CVD	Chemical vapour deposition
BMBF	Federal Ministry of Education and Research

3. Experimental set-up

The milling and drilling tests were undertaken on a 5-axis High Speed Cutting Machine from Roeders GmbH, Type RXP600DSH with a spindle speed up to n = 60000 rpm.

In order to allow an analysis of the machining processes for the CFRP/GFRP material, in a first step quality criteria had to be defined. Two criteria, fibre pull-out and fibre protrusion were chosen based on the requirements of the end-user, as shown in Fig.2. Fiber pull-out can reduce the workpiece thickness and therefore influence the strength and parallelism of parts for subsequent riveting and assembly processes. Fiber protrusion is less important for assembly activities, but becomes relevant in the varnishing of the workpieces. During this production step protruding fibers can break loose and fall into in the varnishing bath. This causes impurities in the paint layer and requires a high cleaning effort. The end-user defined the length of the fibers to be the most critical factor. The appearance of fiber pull-out and protrusion is due to an interplay of various influencing parameters. In addition to the location of the hole in the fiber braid and the resulting cutting angle, the condition of the cutting edge plays a major role. The cutting speed and feed rates are also important influencing process parameters as these impact the fibre seperation mechanism [10].

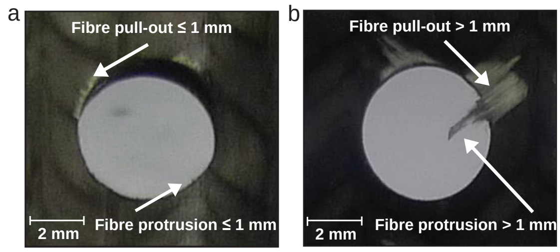

Fig. 2. Quality criteria for bore holes

The criteria were evaluated both at the hole entrance and exit, as shown in Fig 3. Additionally tool wear was also determined using scanning electron microscopy (SEM) images.

A study of process parameters was undertaken, as shown in Table 1. The two processes were compared from both technological as well as economical points of view, with an analysis of tool wear, drilled hole quality and time consumed.

Table 1. Process parameters for drilling and helical milling

Test/Parameter	Milling feed rate v_{fmill} (m/min)	Drilling feed rate v_{fdrill} (m/min)	Cutting speed v_c (m/min)
Helical Milling 1	7	0.75	678
Helical Milling 2	17	0.75	678
Drilling 1	-	0.6	700
Drilling 2	-	0.9	925

For all investigations, tools from Hufschmied Zerspanungssysteme GmbH were used. Fig. 3 shows the implemented process strategy for helical milling. As the first step, a hole with a depth of half the workpiece thickness is drilled. This is followed by the first milling process along a circular path. Subsequently, a further drilling step is carried out up to the full workpiece thickness before the tool moves at maximum feed to the depth of the second cutting stage. After a second milling process, the tool moves out of the hole.

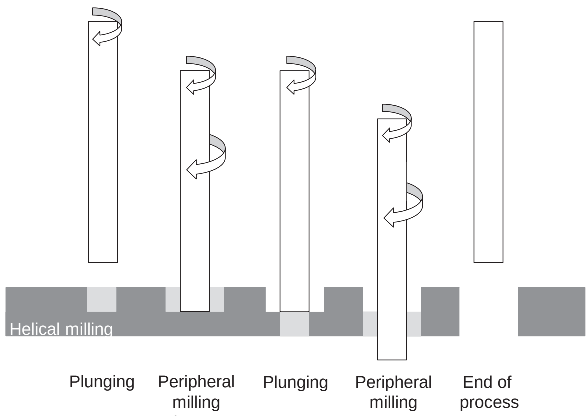

Fig. 3. Process strategy for helical milling