

**Dissertation title:****Beitrag zur Verbesserung der spanenden Bohrbearbeitung von CFK auf Basis von Schädigungsmechanismen****Tobias Pfeifroth**

There is a strong increase in the industrial use of carbon fibre reinforced plastic (CFRP) due to its advantages of high specific strength and stiffness and due to its potential of near net shape manufacturing. The composite material CFRP is used not only in the aerospace industry but also in the automotive and machine tool industry. Due to high cost pressure, in particular in the automotive industry, costs for CFRP parts need to be significantly reduced in the whole production chain. However, there is still a lack in basic knowledge in this field and, consequently, further research is also needed in the machining of CFRP, which is an important processing step in the production chain.

This work discusses the challenges in CFRP machining and, based on that, explores different approaches and solutions. With regard to the workpiece, the major challenges are machining errors, such as delamination, fraying and burr formation. As to delamination, the maximum achievable delamination  $F_{d,max}$  needs to be determined and taken into account. It can be calculated by combining the bore diameter and the fibre structure of the laminate. In this work the machining error 'fraying' is defined as follows: Fraying is the protrusion of a fibre strand, which is geometrically inexactly cut at the bore envelope, into the bore hole or, generally, into the intended shape. Fraying occurs due to the bending of the inexactly cut fibre strand around the hold point and can be explained by a loss of prestress, by the fibre cutting angle and by the angle position of the cutter. In order to be able to objectively assess the fraying, the following factors have been developed in this work: fibre factor  $F_{fibre}$  and area factor  $F_{area}$ . Another machining error is burr formation, which is caused by two mechanisms, either by a deposit of molten matrix material at the edge of the borehole or by an extensive deformation in the laminate with deposited swarf. Besides these machining errors, tool wear represents another challenge in CFRP machining. It is mainly determined by cutting edge rounding, land wear and flank wear. Advanced wear with increasing number of drilled holes causes an increase in forces, while the machining quality hardly deteriorates.

On the basis of these results, this work investigates solutions and concepts in order to avoid these machining errors. The approach includes an analysis of the machining parameters and of the vibration-superimposed drilling. The investigation of the machining parameters shows an increase in feed force with increasing feed and rising cutting speed, while the torque decreases with rising cutting speed. The influence of the cutting speed on the machining quality is very small. In the vibration-superimposed drilling, the machining forces decrease with increasing ultrasound amplitude, while the influence on the machining quality remains unclear. The variation of the point angle of drilling tools aims at the first cutting of the fibre strands in the area of the bore wall and hence at a reduction of the machining errors. The tests show a considerable improvement in machining quality at the bore inlet when drilling tools with a point angle of  $\sigma > 180^\circ$  are used. At the bore outlet, however, these tools show lower machining qualities than the drilling tools with a point angle of  $\sigma < 180^\circ$ . The coating of HSS tools with particular coating systems for CFRP cutting aims at increasing the tool life and improving the machining quality. Although the coated tools reduce the machining forces, a significant increase in machining quality and tool life cannot be achieved.

Finally, the results gained in this work with regard to machining errors and solutions are applied on selected composite materials. While the cutting behaviour in the machining of hybrid composite materials is similar to CFRP machining, MMC machining differs considerably from CFRP machining, but is similar to metal cutting with regard to the type of machining errors.