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"TOPOLOGY AND SHAPE OPTIMIZATION OF REAMER"

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Abstract: Reaming is a process of improving the quality of already drilled holes by means of cutting tools called reamer A reamer is a rotating cutting tool generally of cylindrical shape which is used to enlarge and finish holes to accurate dimensions to previously formed hole. It is a multiple edge cutting tool having the cutting edge on its periphery. A reamer consists of three mean parts 1. Fluted section 2. Neck 3. Shank The fluted part consists of chamfer, starting taper, sizing section and back taper length. Chamfer length or bevel lead insures proper and easy entry of the reamer into the hole. The main cutting action of reamer is done by starting taper, the sizing section and to guide the reamers and also smooth or size the hole. The back taper reduces friction between reamers and the whole surface. The industrial relevance of bore holes with small diameters and high length-to-diameter ratios rises with the growing requirements on parts and the tendency of components for downsizing. Examples for components requiring deep holes with small diameters exist in the automotive industry; for the production of injectors for fuel injection as well as for medical and biomedical parts. Based on growing functional requirements, for example with the increase in injection pressure to improve the efficiency of the combustion process in diesel engines, the requirements on the surface integrity of bore holes also increase. To meet these requirements, an adaption of the deep hole drilling process is necessary. In this paper the influence of tool geometry, coating and cutting data on the bore hole quality and tool wear will be presented. An improvement in the efficiency of the cutting process requires high tool performance. For the tool performance the microscopic cutting edge shape is very important. By preparing the cutting edge the tool performance can be improved due to the reduction of the cutting edge chipping and the creation of a defined stable edge rounding. In this study, the influence of a cutting edge preparation on the deep hole drilling process is investigated. The aim is to increase the feed rate by a specific cutting edge design. Drilling is probably the most common machining operation applied to composites since components made out of composite materials are usually near net shaped and require only holes for assembly integration.

Keywords: optimizing the reamer design stopping reamer breakage and tool cost reduction.

I. INTRODUCTION

Single lip deep hole drilling is commonly used in several industrial applications to manufacture bore holes with diameters in the range of d = 0.5 … 40 mm with a high length-to-diameter-ratio (l/d-ratio) up to l/d = 200. In addition to the high l/d-ratio, a major advantage of the single lip deep hole drilling is the ability to generate high bore hole qualities. The main characteristics are minor deviations in diameter and straightness, high shape accuracy and high surface quality of the bore hole. Thus, bore holes can be manufactured very efficiently without subsequent processes for increasing quality, such as reaming or honing. A disadvantage of single lip deep hole drilling is the high mechanical tool load during the cutting process that limits the feed rates in particular for smaller diameters. This adversely affects the the efficiency of the process. To improve the efficiency of the cutting process, the microscopic shape of the cutting edge is particularly important. to enhance the tool performance . In this research the influence of cutting edge preparation using an abrasive water jet blasting process is analyzed for single lip deep hole drilling. For this purpose, mechanical load, tool wear, bore hole quality and chip forms are ascertained for different cutting edge designs. The aim of the study is to investigate the influence of cutting edge preparation on the cutting process so as to generate a specific cutting edge design for an improved feed rate.

II. BACKGROUND

Cutting edge preparation aims to an improvement of tool performance through an increase in edge stability. This is achieved by reducing of cutting edge chipping and generating a defined rounding of the cutting edge. The cutting edge chipping Rs is a parameter representing the roughness along the cutting edge and a major factor with respect to microscopic quality. The cutting edge shape is specified by the average cutting edge rounding slateral that is used to quantify the material removal at the flank and rake face compared to cutting edge rounding leads to negative effective rake angles at low feed rates and an enhancement of ploughing in the cutting process. Ploughing means that most work piece material which is directly in front of the cutting edge rounding is pressed into the chip formation zone. A small amount of this work piece material is pressed into the machined work piece surface. The greater deflection and pinching of the work piece material, caused by ploughing, affect parameters such as mechanical load and the quality of the work piece . For the amount of ploughing the size of the average cutting edge rounding is not the only important parameter. The ratio of the size of the average cutting edge rounding to the un deformed chip thickness is significant as well. The un deformed chip thickness depends on the feed rate. Due to this, it is possible to generate a high and un favourable ratio of the size of the cutting edge rounding to the un deformed chip thickness for machining operations with low feed rates such as in single lip deep hole drilling. The applied single lip drills are prepared by an abrasive water jet blasting process which is based on the injector principle. The carrier medium water and the abrasive medium aluminium oxide (Al2O3) are mixed in a swirl chamber and accelerated in the tool direction. On hitting the cutting edge, the aluminium oxide grains cause a chip formation and/or a local deformation. Thus, a rounded and smooth cutting edge can be produced An ideal sharp cutting edge. To improve tool performance the cutting edge rounding has to be adapted to the specific machining task. An increase in the different areas of systems' components can help pinpoint and reduce inefficiencies, thereby reducing operating costs. Such a system can therefore prevent catastrophic failure & give maximum utilization of available assets, increase the life of plant.

III. EXPERIMENTAL SETUP

It consists of following 3 steps

- Work Piece Material
- Drilling Tools
- Machining Test
- Results and Discussion

WORK PIECE MATERIAL

The material used in the tests is CFRP, consisting of an epoxy matrix system reinforced by HT (high tenacity) carbon fibers. The laminate has a fiber volume content of about 55%, a thickness of 9 mm, a tensile strength (0°/90°) of 800 MPa and a Young´s modulus of 67 GPa in the same direction. The weave type, the carbon fibers are placed into the matrix, is a 4H Satin.

DRILLING TOOLS

The applied tools are made of cemented carbide with hardness HV30 of about 1600 N/mm² and the same tool geometry except for the angles at the main cutting edge and the point angle, which can be seen in Figure The angles at the cutting edge are measured in the point angles are 155° for tool T1, 175° for tool T2, 185° for tool T3 and 185° with a center tip of 178° for tool T4. The differences in the angles on the main cutting edge are a result of the variation of the point angles and differ only in a small range. The shown angles are measured on the tool nose. All the used drilling tools have a diameter of D = 6.8 mm. As the wear progress is 5th CIRP Conference on High Performance Cutting 2012in a small range (cutting edge rounding up to 10 µm at the end of the test series), the same tools were used for one test series.

MACHINING TEST

The cutting tests were performed on a machining center of the type Ex-Cell-O XHC 241. Figure shows the machining center and its technical details. The feed forces and the drilling torques were measured with a rotating dynamometer of Kistler company. The images to calculate the delaminating factor Fd and the fraying were taken with a stereomicroscope (Leica MZ6). The burr height was measured with a Keyence laser triangulation sensor and evaluated with a self-designed software tool. Fig. illustrates the delaminating factor Fd and the measurement of the burr height h0. The experiments concerning the variation in point angle were conducted with the following parameters, which can be seen in table 1. As the feed is the critical parameter in drilling CFRP, only the feed was varied. Due to former tests, the cutting speed was remained constant at a low level to achieve clear signals while drilling.

RESULT AND DISCUSSIONS

At the beginning the influence of the point angle on drilling forces as well as on delimitation, fraying and burr height is presented. Afterwards the influence of elevated cutting speeds vc and feed rates f are analysed. The intention in applying a tool geometry like T4 (point angle 180°) is to cut the material at first with the outer area of the cutting tool. Hence the primary cutting of the CFRP, especially the carbon fibers, takes place at the drill hole wall. At this time the fibers are still embedded in the matrix material and thus the pre stress of the fibers is maximal. This should lead to a definite cut of the fiber at the drill hole wall and thus to an improved quality in the peripheral zone of the drill hole. Figure depicts the feed forces Ff obtained when drilling with the four toolsThe comparison of the four tools in show that T1 and T2 possess almost the same trend and produce the smallest feed force Ff. Higher feed forces Ff are achieved when using tools T3 and T4, which also have quite the same trend. Hence the conclusion can be drawn that with the rise of the point angle also the feed forces Ff increase. The drilling torque Td shown in displays the same trend

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. As shown in Fig. , the difference in the amount of drilling torque Td of the tools T1 to T4 is only marginal. The same can be seen at the range of parameters analyzed. In contrast to the drilling torque, delamination is strongly affected by the point angle. depicts the delamination factor Fd at the drill hole entrance and exitof the drilling tool when using T1 to T4. The selected parameters are a feed rate of f = 0.05 mm and a cutting speed of vc = 42.7 m/min. The bold line at value 1.00 of Fig. 7 is the minimal value which can be achieved when using the delamination factor Fd according to ChenIt can be seen that the point angle has great influence on the delamination factor Fd. At the entrance T3 and T4 attain the best results due to their point angle $\alpha > 180°$.

This point angle cuts at first the fibers and the matrix at the drill hole wall and therefore leads to best results regarding delamination at the entrance. Due to the greater chip thickness and the higher forces at the outer area of the tools T3 and T4, the results at the exit are poor. Quite the opposite can be detected when looking at the tools T1 and T2. These tools achieve better values at the exit but lead to increasing delamination factors Fd at the entrance. The images of the drill holes and the peripheral zone show the fraying and the delamination Figure 8 shows the drill hole quality at the entrance . The images of the drill hole entrance manufactured with the tools T1 to T4 with a cutting speed of vc = 42.7 m/min and a feed rate of f = 0.05 mm show visible differences.

While the tools T1 and T2 generate fraying at the drill holes, the tools T3 and T4 lead to no fraying and delamination because of the initial cutting at the drill hole wall. The drill hole quality at the exit with the same parameters is different Concerning fraying, the result at the exit is almost the same. While T1 produces an apparent amount of fraying, this amount is clearly reduced when using T2 to T4.

However, there are disadvantages as well when using the tools with elevated point angles (T2 to T4). These types of drilling tools lead to a drastic increase in delamination at the exit, which can also be seen in figure 7. Another problem when applying tools with point angles α 180° is the tendency to form a lid or cap. In the presented results, T1 produced no lid while T2 produced a lid in 16.7% of the produced holes. The amount of lids rose with T3 to a maximum of 30%. To reduce this effect tool T3 (point angle $\alpha = 185°$) was applied with a center tip (178°) to cut the material at the inner area as well The applied center tip (tool T4) leads to a reduction down to 23.33%.Another problem is burr formation, which seems to be linked to delamination and fraying.

Moreover it is sometimes difficult to differ between these criterions. Figure shows the measured values of the burr height h0 and the best-fit curves at the entrance at varying feed rates f generated with the four drilling tools. To find a clear trend when analyzing the burr height h0 is quite hard because of problems at the measurement and the irregular burr formation due to the connection to fraying and delamination.

At low feed rates the burr height produced with the four tools is quite similar and the amounts are rising with increasing feed rates due to the greater displacement of the material. Only at elevated feed rates, tool T4 has an advantage over the others. At the exit, the results are different. According to the scatter of results at the exit, no clear trend for tools T2, T3 and T4 is visible. Only tool T1 shows a clear trend and achieves the best results while the tools T2, T3 and T4 attain greater amounts of burr height. One possible reason for the elevated burr height with tool T3 and T4 could be the higher axial force compared to T1 where the forces are also axial deflected. The progress of burr height h0 with the feed rate f is slightly decreasing. The trend in burr height at the exit with the four tools corresponds to a great extent with the delamination illustrated in fig. Besides the influence of the point angle of the drilling tools on drilling forces and drill hole quality, the effects of cutting speed vc are investigated in this paper using tool T1.

It shows the connection between feed force Ff and cutting parameters. Figure shows that feed force Ff not only rises with elevated feed rates but also increases with elevated cutting speeds. This gain of feed forces Ff is partly due to tool wear but also due to dynamic effects.

The development of drilling torque Td is different. It can be seen that the drilling torque decreases with the increase in cutting speed but rises with elevated feed. One reason can be that at elevated cutting speeds no material (especially matrix material) adheres at the tool, therefore less friction is generated and thus the drilling torque shrinks. Further investigations need to be conducted to prove other possible reasons for the decrease of drilling torque at higher cutting speeds. Looking at the drilling forces the attendance of a HSC effects may be assumed. However the resulting delamination factors at the produced drill holes are not significantly affected by elevated cutting speeds.

IV. CONCLUSION

- Smoother chip movement
- Elimination of additional stresses on the tool

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- Prevention of oversize due to chips acting as cutting surfaces
- Prevention of oversize even in case of small machine imperfections like wobbling etc due to smaller basic size
- Prevention of coolant hole blockade & tool breakage because of chip accumulation

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