Studies of Microdrilling Titanium and Titanium Alloys

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Abstract

The presented studies deal with adapting the process of microdrilling pure titanium and TiAl6V4 using tool diameters of one millimetre and less. The main focus is on generating a high surface quality with low tool wear and minor burr formation.

1 Introduction

For the increasing production of microstructured components, micro holes have to be manufactured with high process reliability. Compared to macro scale drilling, new problems occur, such as low tool stiffness, and chip removal [1]. Since the subsequent removal of burrs, especially in micro scale, is very difficult, the investigation of burr formation is already part of current research [2].

Titanium and titanium alloys offer a high potential for application in many fields since they exhibit favourable physical and mechanical properties, such as low density and high corrosion resistance [3]. They are part of the group of materials that are hard to machine due to their low thermal conductivity, low elastic modulus, and high yield strength. In the presented analyses, the microdrilling process is investigated to generate a high surface quality with low tool wear and minor burr formation. The transfer from macro to micro dimension is analyzed while focusing on process parameters and tool shape.

2 Experiments

For the investigations, three different drills with diameters of 1 mm, 0.5 mm, and 0.2 mm were tested, which are shown in Figure 1. Furthermore, the analyzed materials were the two most common titanium alloys, pure titanium (Ti Grade 1) with 159 HV 0.02 and TiAl6V4 (Ti Grade 5) with 382 HV 0.02. The process parameters feed per tooth f_z = 0.0013-0.013 mm, and cutting speed v_c = 2- 60 m/min were varied while reducing the number of experiments for each tool-material combination by

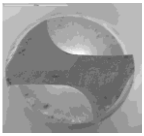
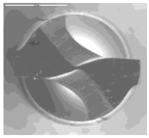
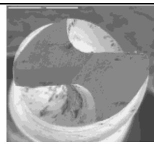
	Tool 1	Tool 2	Tool 3
			
Number of cutting edges [z]	2	2	2
Total length [L]	38 mm	42 mm	25 mm
Max drilling depth [l_4]	6.5 mm	6 mm	6.8 mm
Tool material	Cemented carbide	Cemented carbide	High speed steel
Coating	Uncoated	Duro-SD	Uncoated
Tip angle [σ]	130°	155°	118°

Figure 1: Comparison of various tool strategies for the different tools

applying design of experiments. Surface quality, and burr height are measured by confocal 3D withelight microscopy; mechanical stresses by 3-component dynamometer from Kistler.

3 Results and discussion

3.1 Types of Drills

In carrying out the experiments, the three drill types described above were compared. Tool 3 turned out to be not suitable here since it failed prematurely. This is caused by the fact that HSS tools, for stability reasons, have a larger chisel edge with a smaller chip flute, which impedes chip evacuation. Thus, there often is a clogging of the flute, especially when machining the ductile pure titanium, and thereby increased ploughing, which leads to increased mechanical stress in feed direction. This is illustrated in Figure 2, which compares the mechanical stress. Tool 3 generated the highest forces and, in addition, increased vibrations and thereby a triangular shape of the holes. The other two types of drill were very similar with regard to generated surface quality. Only the burr height and the resulting mechanical stress differed. Holes, which were manufactured with tool 2, had a slightly higher burr height. The essential difference which was significantly contributing to the burr formation is the coating. Analogously to the machining of aluminium, uncoated drills lead to less material adherence. However, the use of uncoated tools also results in slightly faster failure. Finally, due to the lower burr height despite the slightly greater mechanical stress and shorter tool life, tool 1 is recommended. Therefore, the further investigations were carried out with this type of tool.

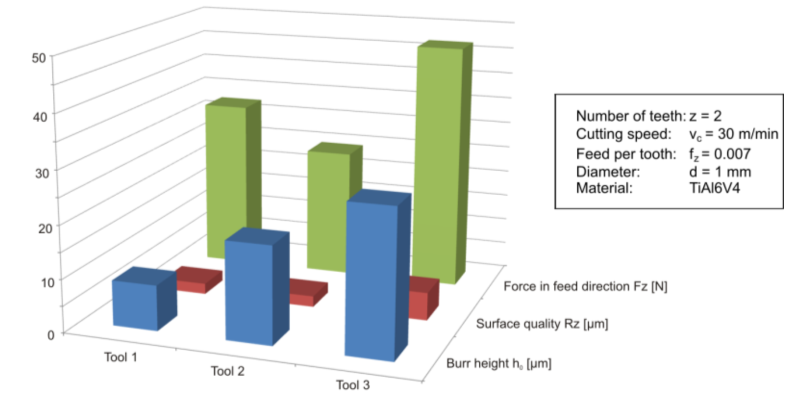


Figure 2: Comparison of the force in feed direction for different tool types

3.2 Parameters

The influence of the cutting speed v_c and feed per tooth $f_{z,}$ on surface quality and mechanical stresses were analyzed. A larger feed per tooth induced strain hardening, which is often encountered when working with titanium, while a higher cutting speed caused material softening because of the elevated heat input. The increased hardness resulted in improved cutting conditions due to the reduction of ploughing and thereby generated a higher surface quality. This also led to higher cutting forces for larger feeds per tooth and to a reduction of the cutting force for increased cutting

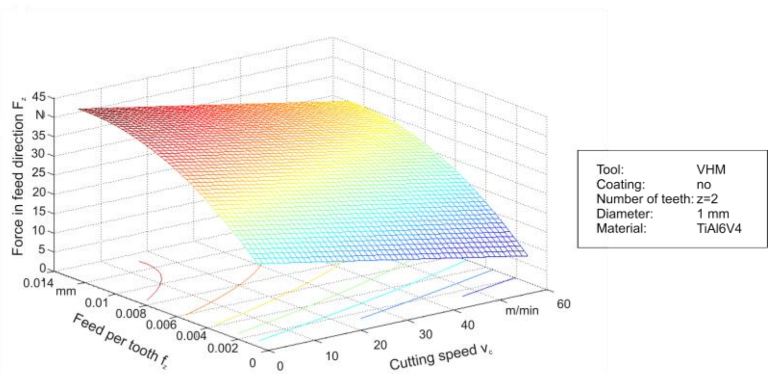


Figure 3: Influence of tooth feed and cutting speed on the cutting force

speeds. This is illustrated in Figure 3. However, the selection of the parameters must be made for the particular application.

While higher feed per tooth the surface quality decreases. The cutting speed has no influence on it. This is shown in Figure 4.

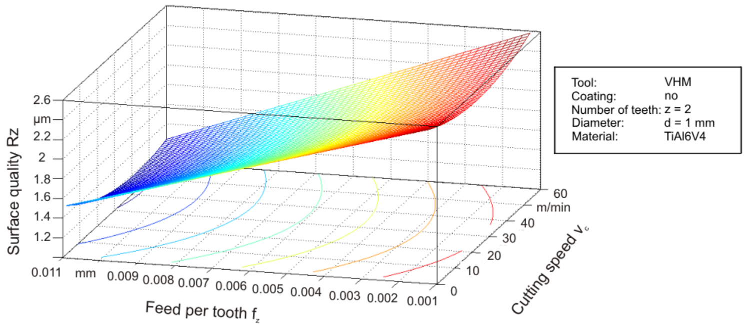


Figure 4: Influence of tooth feed and cutting speed on the surface quality

4 Conclusions

The results show that cemented-carbide drills are better suited for drilling pure titanium and Ti6Al4V than high-speed steel tools when using tool diameters of d = 1 mm, 0.5 mm, and 0.2 mm. As a trade-off between mechanical stress during the drilling process and the best achievable surface quality, high cutting speeds of v_c = 50 m/min and a feed per tooth of $f_z = 0.01 \times d$ are recommended.

Acknowledgments

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