Reaming in Microscale of Titanium and Titanium Alloys

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Abstract

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

1 Introduction

Micromachining is considered to be a suitable technique for cost-efficient manufacturing of microstructured parts in small or medium batch sizes such as molds for micro molding processes. For the increasing market of microstructured components micro holes with high quality are needed. In comparison to macroscale drilling and reaming new problems appear, such as low tool stiffness. This can lead to tool deflection or even to tool breakage. Because of this, high requirements concerning surface quality and accuracy of shape can´t be achieved. An additional process like reaming is expensive and complex, so, e.g. in [1, 2] the parameters are examined for high quality of the hole and minor micro burr formation when drilling brass, titanium, and aluminum.

Presently, there is an increasing trend to apply micro components and implants made of high strength materials such as titanium and titanium alloys. The main application area for micro components made of titanium alloys is the medical technology because of their favourable physical and mechanical properties such as low density and high corrosion resistance. However, titanium and titanium alloys belong to the group of materials that are hard to machine due to their low thermal conductivity, low elastic modulus, and high yield strength, causing a high thermal and mechanical load on the cutting tool. In macroscale, there are already many publications dealing with machining of these materials [3]. But in microscale basic researches are needed.

2 Experiments

In the present analysis optimal parameter values are investigated in order to generate a high surface quality, high accuracy of shape, low tool wear, and minor mechanical stresses. The focus of this paper lies on the analyse of the influence of process parameters (v_c = 3 – 30 m/min and f_z = 0.005 – 0.1 mm), radial allowance (a_r = 0.01 mm, 0.02 mm, and 0.03 mm), and lubrication system (dry, minimum quantity, flood, and dipping lubrication) on the cutting process. The drill holes used here are made by drill bits with diameter of d = 1 mm. The tested reamers have diameters of d = 1.01 mm, d = 1.02 mm, and d = 1.03 mm to investigate the influence of the width of the cut on process results. Furthermore, a comparison of 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 is carried out. Also different lubrication systems (dry, minimal quantity lubrication (MQL), flood lubrication, and dip lubrication) and their influence are investigated.

3 Results and Discussion

3.1 Parameter

To analyse the influence of cutting speed v_c and feed per tooth f_z on the microreaming process, these parameters were varied using design of experiments. The results prove the increasing of hole diameters and their deviation with the cutting speed (cf. Figure 1). But the mechanical stresses are independent of the speed. Neither cutting speed v_c nor feed per tooth f_z affect the surface quality of the bore wall. The important influence of cutting speed on hole diameter is caused by the increasing tool deflection in micromachining.

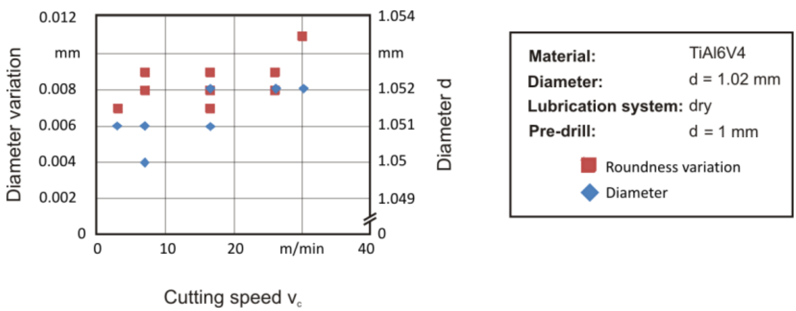

Figure 1: Influence of cutting speed on diameter and that variation

3.2 Radial allowance

Within the investigation of the influence of the radial allowance on the process, the results of three different reamer diameters d_1 = 1.01 mm, d_2 = 1.02 mm, and d_3 = 1.03 mm were compared. The use of the reamer d_1 = 1.01 mm could not improve the surface quality in comparison to drilled quality, and the tool with d_3 = 1.03 mm failed after only a few millimeter machining. The evaluation of the mechanical stress shows that the force in the feed direction increases with increasing radial allowance (cf. Figure 2). It can be concluded that when using the smallest reamer diameter the minimum chip thickness was not achieved. So it leads to almost no material removal. In contrast, the largest diameter achieves the best surface quality, but for an economic tool life the mechanical stresses are too high. In summary the optimal diameter is d_2 = 1.02 mm.

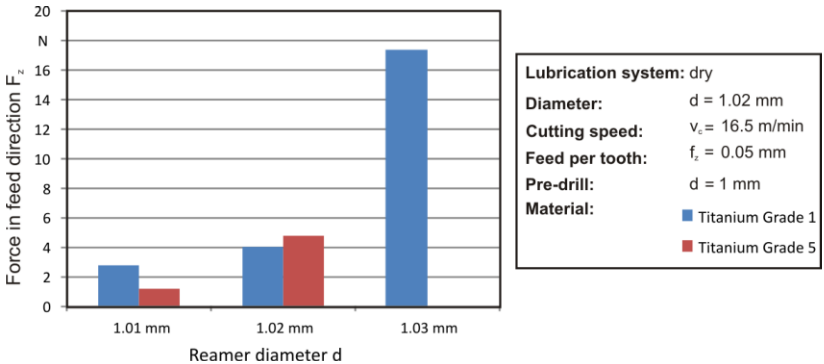

Figure 2: Influence of reamer diameter on mechanical stresses

3.3 Lubrication System

Evaluating the mechanical stresses and the resulting diameters, the values of dry machining and minimum quantity lubrication, and the dip and flood lubrication appear to be very close together. For the first two, the process creates a larger hole diameter and higher mechanical stresses in the feed direction (cf. Figure 3). When reaming, the slight lubrication film of the MQL does not sufficiently wet the cutting edges and the chip flutes. To gain the positive influence of the lubricant, the use of dip or flood lubrication is necessary.

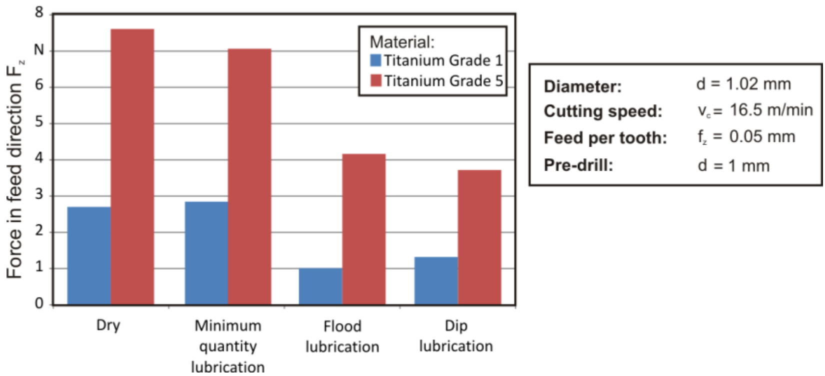

Figure 3: Influence of lubrication systems on mechanical stresses

4 Conclusions

The results show that a lower cutting speed is better for reaming pure titanium and Ti6Al4V. The use of reamers with diameter of d_2 = 1.02 mm is to recommend for machining drills with diameter of d_1 = 1 mm. Dry and minimum quantity lubrication is not as effective as dip and flood lubrication.

Acknowledgements

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