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SOME ASPECTS ON MICROMILLING AND MACHINE-TOOLS

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ABSTRACT: *Micromilling is becoming an important manufacture technology due to the increasing demand for miniaturized products. In the recent years, the miniaturization of components and systems is advancing steadily in many areas of engineering and technology. The purpose of this study is to present some aspects on micromilling and machine tools. Finally, a case study on micromilling of aluminium alloy 2011 using a conventional CNC machining centre is presented.*
KEYWORDS: *Micromilling, machine tools, spindle technology, toolhoolder, surface roughness, burrs*

INTRODUCTION

Today, micromilling requires machine tools with high rotational speed capabilities and very high positioning accuracy. Dedicated ultra precision machine tools have begun to be marketed and such machine tools have a positioning resolution up to 10 nm and can provide rotational speeds up to 100,000 rpm. As an alternative, existing machine tools can be updated by means of high speed attached spindles which can provide a rotational speed up to 80,000 rpm with runout of less than 1μm. With such a configuration, the maximum positioning accuracy is limited by that of the machine tool. According to Bissacco, Hansen and De Chiffre [1] the cutting parameter most heavily affected by machining accuracy is the axial depth of cut which is the most critical when using micro end mills, due to the easy breakage particularly when milling hard materials.

One of the more devastating machining attributes of milling small, delicate and accurate parts is vibration. Like stiffness, damping is a critical element that needs to be under control during micromilling. Machine tools with increased damping will absorb more of the vibrations induced by cutting. Many machines' frames are constructed using cast iron or steel weldments, but these types of structural materials are not suitable for micromilling. The most suitable machine frame material for micromilling is polymer concrete, which provides as much as 10 times higher absorption of vibrations than cast iron. Polymer concrete also provides superior dynamic and static rigidity than cast iron and has substantially better thermal stability properties, which are crucial for achieving small-part accuracy [2].

SPINDLE TECHNOLOGY

Spindle technology has come a long way through recent years. There are many types of spindles on the market: gear driven, belt driven, motorized, air driven and hydrostatic but the more common high rpm spindles are motorized. A motorized 160,000 rpm spindle was unheard of only a few years ago. Although a 160,000 rpm spindle has its applications, the more common high-speed spindles are more applicable to have an rpm of as high as 50,000 rpm. With micromilling, tool size is relative to the application. Commonly, a Ø6 mm tool would be considered large and a Ø0.3 mm tool would be considered quite small. In this range, a spindle of 50,000 rpm would provide an adequate solution. The ideal spindle for micromilling is a closed loop or vector controlled spindle because they offer the range of rpm, full torque at low speeds, rigid tapping capabilities and spindle orientation [3].

TOOLHOLDER AND SPINDLE INTERFACE

Because micromilling uses high rpm, tapered toolholders are not the ideal toolholder type. HSK toolholders offer a number of advantages for high rpm spindles and thus are the preferred choice for micromilling machines. HSK toolholders are retained in the spindle by a set of internal grippers located inside the spindle. As rotational speeds are increased, metal-to-metal contact between the toolholder and the spindle is maintained because centrifugal forces cause the internal grippers to expand within the toolholder, pressing it firmly against the inside of the spindle shaft. HSK tooling is also a double contact interface. It locates on both a shallow taper and a flange, creating a rigid precision fit for both axial and radial cutting forces. This precision fit allows the interface to have superior runout conditions *compared to steep tapered tooling (HSK). In micromilling, runout inaccuracies can cause premature tool failure and excessive runout can also reduce the life expectancy of the spindle [4]. Tool runout is caused by a misalignment of the axis of symmetry between the tool and the toolholder or spindle. In macro-machining it is often ignored, as the diameter of cutting tools is relatively large compared to the tool run-out and the speed is relatively slow compared to micro-machining.*

CASE STUDY- MICROMILLING OF AN ALUMINIUM ALLOY

In order to perform a comprehensive study on surface roughness of the machined surfaces, cutting parameters such as feed rate as well as machining strategies were varied to optimisation micromilling [5]. To perform the machining, the CNC machining centre used was a MIKRON model VCE 500. It is a conventional full size, 11kW, 3-axis CNC machining centre with a spindle speed range between 60 and 7500 rpm. In this research, aluminium alloy (2011) was used. The tool used to machine the workpiece was a cemented carbide K10, 0,8 mm diameter endmill. Four feed rates (2, 4, 6, and 8 μm/flute) and one spindle speed 6,500 rpm were considered in this experimentation. Three machining strategies were used: constant overlap spiral, parallel spiral and parallel zigzag.

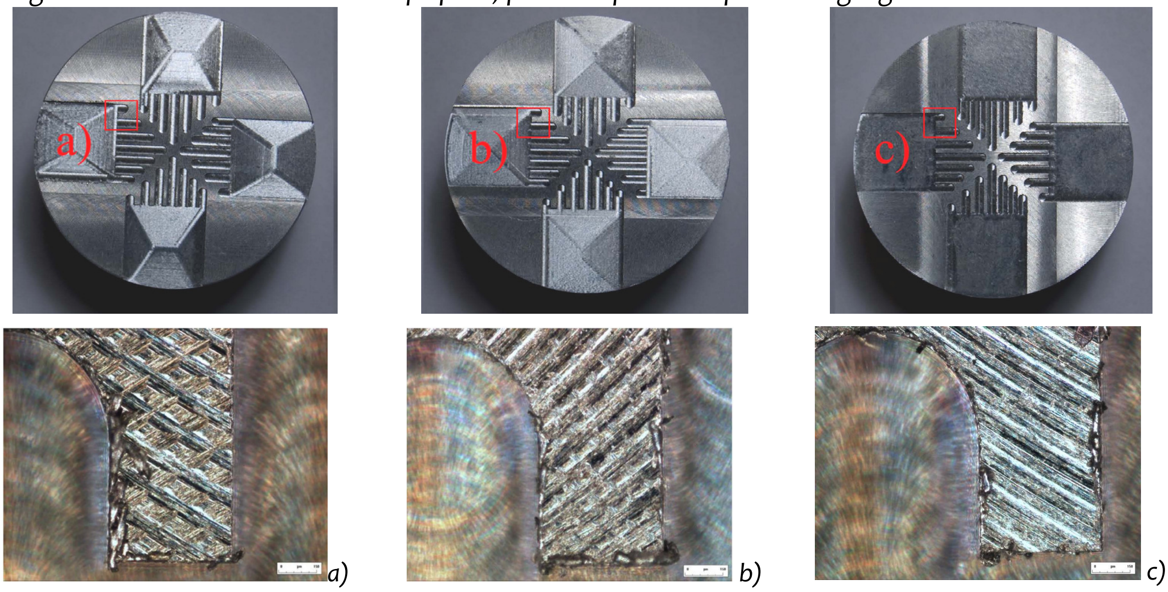
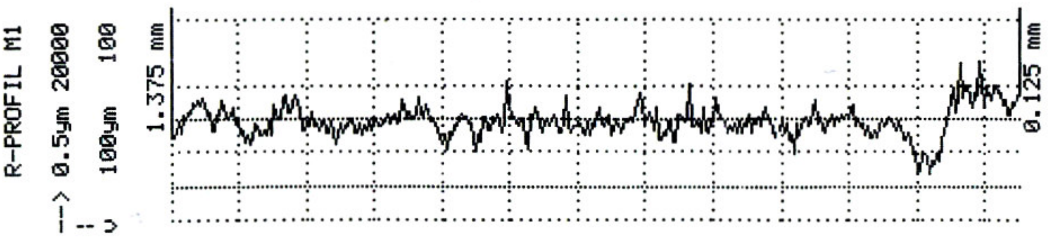


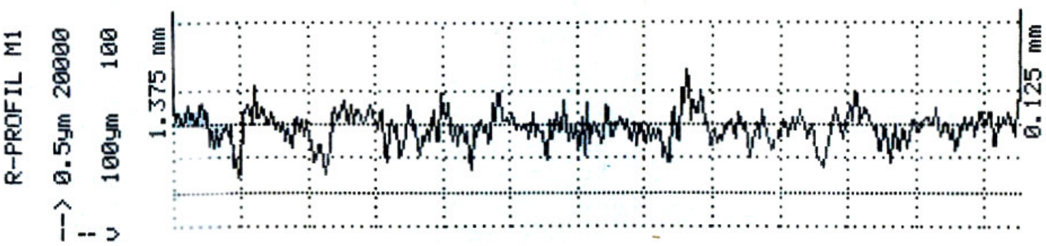
Figure 1. Comparison of strategies for the same 8μm/tooth feed rate:
(a) constant overlap spiral, (b) parallel spiral and (c) parallel zigzag

Figure 1 shows the comparison between the three different strategies. The burrs produced with the second strategy (parallel spiral) are much pronounced. The constant overlap spiral strategy was the one that presented the best result.



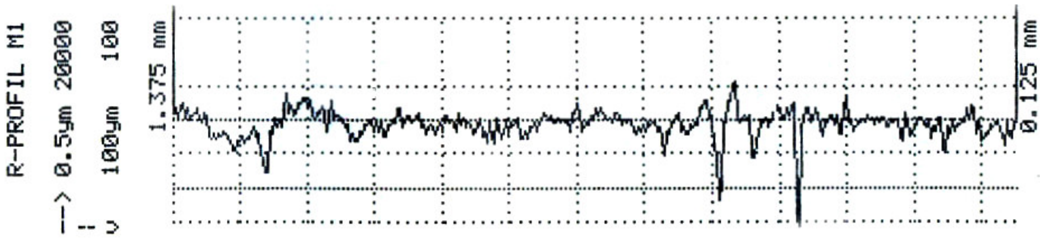
a) RzI=0,81 μm

Figure 2a. Surface profile comparison between strategies
for the same feed rate of 8 μm /tooth: constant overlap spiral.



b) RzI=0,91 μm

Figure 2a. Surface profile comparison between strategies
for the same feed rate of 8 μm /tooth: parallel spiral.



c) RzI=0,85 µm

Figure 2c. Surface profile comparison between strategies for the same feed rate of 8 µm /tooth: parallel zigzag

Surface roughness profiles and the value of RzI (Ten-point eight - ISO 4287/1) comparison are shown in Figure 2. Also the constant overlap spiral strategy was the one that presented the best result to RzI (Figure 2a).

CONCLUSIONS

This short article reported some important aspects of current machine tools, spindle technology, toolholder and spindle interface used in micromilling. Based on the experimental results presented in the case study, the following conclusions can be draw from micromilling of an aluminium alloy with a conventional CNC machine centre:

- *it is possible to machine micro surface almost without burrs;*
- *machining strategy influences the surface finish and the presence of burrs.;*

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