Improvement of surface flatness in high precision milling

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Abstract

The use of high precision micro components has increased in various industrial fields in recent years. Repeatable techniques are needed to face very tight tolerances and make micro fabrication processes industrially feasible against current micro machining limitation. Improving surface flatness in high precision milling is the main target of the present research. Critical issues such as machining strategy, spindle thermal transient management and tool wear compensation were considered for machining operations on a representative part.

1. Introduction

Micromilling quality improvement requires an accurate management of all the involved resources, namely machine tool, tool, fixture and workpiece (Fig. 1). In addition, machining strategies and tool and workpiece measuring strategies (Fig. 1) play a fundamental role in micro scale machining and have to be considered as important as the aforementioned resources [1-3]. Moreover, a couple of other factors should be considered since thermal transient and tool wear play a strong role on the micromilling overall performance. The aim of this paper is to demonstrate the importance of machine spindle thermal transients and tool wear assessment on the final workpiece quality through a simple but industrially significant case study. An accurate plane surface has been manufactured by an endmill on a quite large workpiece proving the proposed tool length compensation effectiveness.

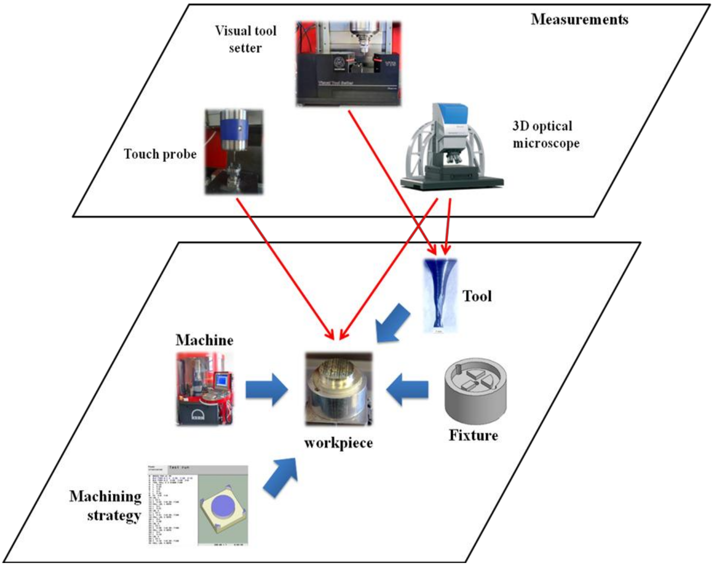

Figure 1: Resources involved in a micromilling operation.

2. Experimental setup

The case study of the present paper is a flat surface machining operation (workpiece diameter = 29.5 mm) on a Cu-Ni 12Zn30Pb1 copper-nickel zinc alloy. Where a strict flatness deviation is required tool diameter and process parameters are specifically selected to imply a long machining time. For this reason, the selected case study represents a typical challenge in molds machining where the workpiece quality requirements should be ensured for long machining times.

Table1:Characteristics and constant cutting parameters.

			Roughing	Finishing
Cutting parameters	Axial depth of cut	a_p	0.1 mm	0.04 mm
	Radial depth of cut	a_e	5 mm	0.02 mm
	Feed per tooth	f_z	0.03 mm	0.004 mm
	Cutting speed	v_c	116 m/min	157 m/min
	Spindle speed	n	6185 rpm	49780 rpm
Tool	Tool manufacturer		Sandvik	Seco
	Tool code		R216.12-06030-BS07P	512010Z2.0-SIRON-A
	Diameter		6 mm	1 mm
	Helix angle		35°	20°
	Rake angle		12 °	10°
	Flute number		2	2

Micro milling tests were performed on the Kern EVO ultra precision 5-axis machining center available at the "MI_crolab", mechanical micromachining laboratory of Dipartimento di Meccanica of Politecnico di Milano (nominal positioning tolerance ± 1 µm, precision on the workpiece ± 2 µm). The surface milling was performed with no coolant and using pure air to remove chips. A proper fixture was especially designed and machined on the same machining center for holding the target workpiece. Prior to machining, a 3D optical microscope (Alicona Infinite Focus) was used to determine the fresh tool geometry. Onboard tool measurements were carried out by means of the Marposs Visual Tool Setter (VTS)© whose thermal transient is managed by a proper warm-up strategy. Workpiece measurements were performed by means of the m&h 32.00-MINI infrared touch probe available on the Kern EVO machining center. As concerning the machining strategy, the roughing and finishing operations were performed by parallel passes at constant *Z* level along the machine *X* and *Y* axes respectively. In case of finishing, down-milling was alway applied by performing all passes along the Y positive direction.

3. Experiments and Results

In order to overcome spindle thermal transient issues, the spindle was warmed-up for 20 minutes at each one of the steps applied to achieve the working speed (10000 rpm, 20000 rpm and 50000 rpm). This procedure was carried out prior to each machining operation.

Tool wear was compensated by a proper strategy during the finishing operation. Tool Length was measured by VTS© after machining 1mm along the *X* direction (i.e. every 50 passes) then the new tool length was provided to the machining centre CNC. The final surface height was measured on the board of the machining center by the touch probe (Fig. 2a) at the positions indicated in Fig. 2b and off board by the Alicona Infinite Focus (Fig. 2c) along the lines at the same *Y* positions (Fig. 2d). Where each profile represented in Fig. 2c has been obtained as the mean of five profiles aligned by the Alicona microscope and 55µm width. The results in Fig. 2a and 2c are coherent and point out how the tool length compensation allowed to have a surface height variation lower than 10 µm.

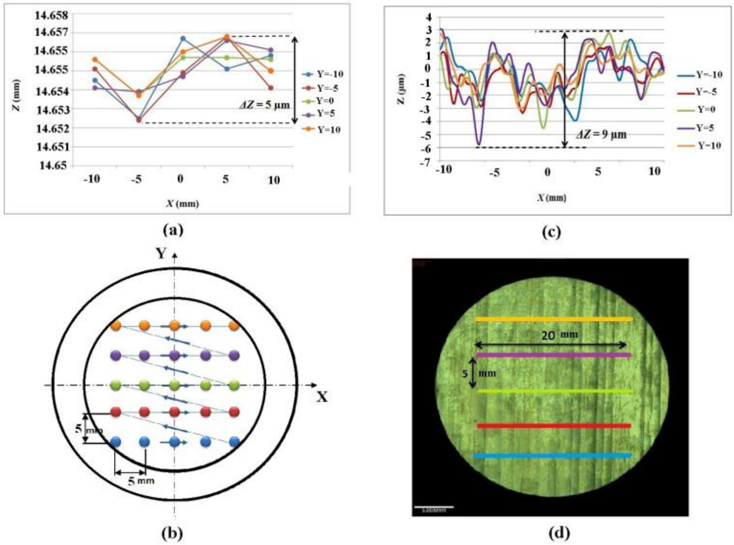

Figure 2: Surface height measurements obtained by a touch probe: a) results b) measurement positions, and by 3D optical microscope c) results d) measurement positions.

4. Conclusions

The present study demonstrates how machine spindle thermal transients and tool wear assessment play a fundamental role on the final accuracy of a micromilling operation. Surface height difference on a large workpiece area was used as a quality indicator and appropriate procedures were applied to reduce the effects of the machine spindle thermal transients and compensate tool length variations due to wear. Final results meet a 10 µm height variation on the workpiece surface.

References:

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