Analysis of micromilling cutting forces effect on thin walls geometrical precision

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Abstract

This paper presents the study of thin walls manufactured by the micro milling process, with tungsten carbide tools (UnionTool C-CES 2005-0150), in two different materials, brass (CuZn36Pb3) and aluminium (Al6061-T4). Experimental tests have been carried out on a micro milling machine [1], [2], where main the features are spindle speed 120.000r/min, 400x210x200mm working volume, and +/-1micron positioning accuracy. The height of the wall is 1.5mm and two different thicknesses have been studied: 50 and 75 microns. Different manufacturing strategies and machining parameters have been analysed in order to improve overall quality of the feature. Thickness of the wall is considered as a quality indicator, where two thicknesses are measured by microscopy (Sensofar PLu Neox): these are the upper side of the wall and the thickness along vertical direction. Moreover, machining forces have been measured using a piezo electric dynamometer, Kistler 9256C1 (MiniDyn), with a specified force range of +/-25N, for the micro milling process investigations. A good correlation between machining forces and measured error in the walls has been achieved. These errors and deformations are due to wall flexibility in two directions (longitudinal and transversal) and tool stiffness. The preferred machining conditions and strategies have been selected and an error below 5% in thickness was achieved.

1. Introduction

The miniaturization of products and components has increased in different markets and sectors, where electronic devices have had a key role in this race towards size reduction and efficiency increase [3],[4]. Manufacturing methods in those applications are based on etching and lithography processes, with a great

development of the involved technology. But these processes show their limitations in true 3D features manufacturing, mainly in metallic parts. Mechanical micro milling processes overcome the mentioned drawbacks and fit well in the manufacturing of 3D complex metallic micro parts, as exposed in this work. Micro milling processes have several aspects that have to be considered in order to make a proper analysis of its mechanics, quite different from classic milling operations. These aspects are: tool and parts deflection due to its tiny dimensions, scaling effect and its effect in process dynamics [5], chip formation effect linked to size effect [6], material heterogeneity at such a small size and the appearance of burrs. Regarding thin walls manufactured by micro milling, and due to the low stiffness of the feature, machining conditions and strategies have to be carefully selected. In this field, very high quality diamond tools have been extensively studied [7],[8] but due to a significant cost difference tungsten carbide tools will be analysed in this work [9]. Thus, the present work will analyse the operating conditions given by the tool manufactures and their suitability to obtain high aspect ratio thin walls with the highest precision.

2. Experimental results

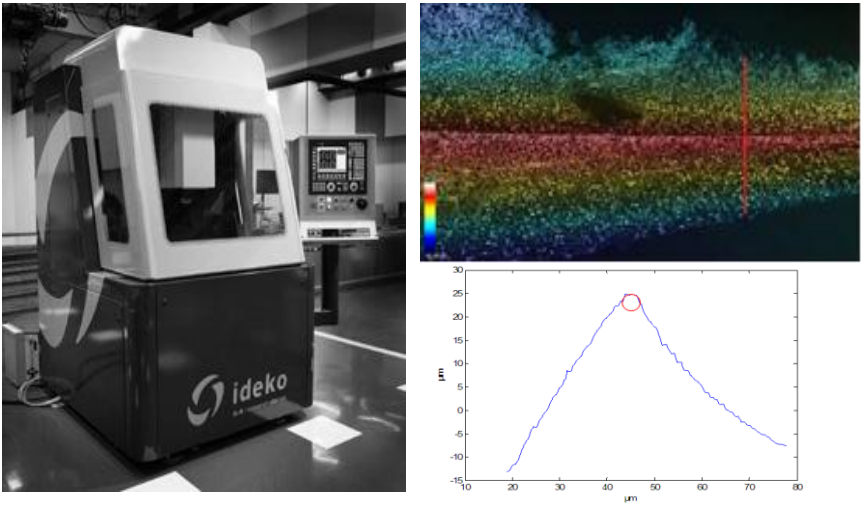

Figure 1: Experimental set up, micromilling and tool cutting edge

The experimental study has been carried out in the micro milling machine shown in figure 1, with cutting tools characterized by confocal microscopy in order to determine tool diameter and edge radius. Operating conditions for this material/tool pair have been selected in previous research work [in press] where the best conditions are shown in the next table. Spindle speed is 35000rpm in brass and 25000rpm in aluminium, working at down milling in all 9 experiments:

Run no.	Thickness (mm)	Path strategy	ap (mm)	fz Brass (mm/tooth)	F Brass (mm/min)	fz Al (mm/tooth)	F Al (mm/min)
1	25	Z Step	150	0,7	50	2	100
2	25	Var. Z	250	1,4	100	3	150
3	25	Ramp	500	2,1	150	4	200
4	50	Z Step	250	2,1	150	4	200
5	50	Var. Z	500	0,7	50	2	100
6	50	Ramp	150	1,4	100	3	150
7	75	Z Step	500	1,4	100	3	150
8	75	Var Z.	150	2,1	150	4	200
9	75	Ramp	250	0,7	50	2	100

Table 1. Summary of machining conditions

Machining forces generated in the tests are measured and postprocessed as shown in next figures:

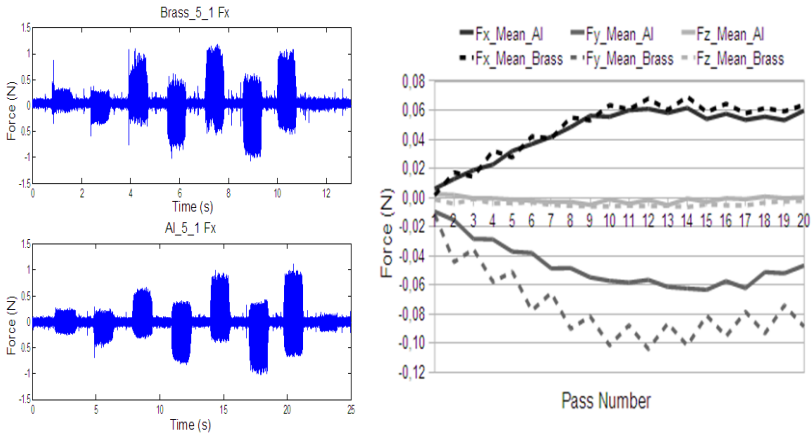

Figure 2: X,Y,Z component of the cutting force from test 5 on brass and aluminium, and mean value in X,Y,Z components in each pass

3. Conclusions

The forces for all tests have been analyzed, achieving a very good correlation between machining forces and thin walls quality. Therefore, thin walls have been optimized by the analysis of machining forces and the overall reduction of mean values. Maximum deviation in the thickness of the walls (vertical and upper side) has been limited to 5%. On the other hand, the cutting conditions provided by the tool manufacturer seem to be selected to ensure some force values which avoid the tool breakage.

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