Material removal evaluation in micro endmilling of RSA6061-T6

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Abstract

In this paper micro end milling tests were carried out in a fine grain aluminium alloy (RSA 6061-T6 – Average grain size of 1 μm). Results showed that the mean cutting force (Fc) varied in the range of 180 mN up to 400 mN for both cutting tools. Smaller cutting forces were probed for the cutting tool with the smallest cutting edge radius. The surface roughness presented better results for the tool with the largest cutting edge radius and the smallest feed per tooth condition and it was 0.17 μm Rq. The specific cutting force was estimated 364 N/mm^2 and the constant z =0.27.

1. Introduction

During micromachining of polycrystalline metals, the mean grain size is normally much greater than the chip cross-section area generated by the cutting tool edge lentgh/material interaction. Consequently, the material's response to cutting tool interaction is considered to be heterogeneous: grain crystallographic orientation may result in both different grain heights and, consequently, chip thickness variation. This difference in chip thickness may be caused by shear angle change from grain-to-grain, since the shear angle is affected by material properties such as elastic modulus (E). Given the microscale of tool/material interaction during micro end milling, it is important to choose the appropriate scale of material microstructure to study the material removal mechanism so as to avoid problems related to polycrystalline material anisotropy. This anisotropy effect may be attenuated or even eliminated by means of grain refining before machining. It is accepted that grain refining could be seen as a possibility of achieving better response to the tool/material interaction.

When a larger number of grains are simultaneously cut along the cutting edge length, chatter vibrations due to the crystallographic change may be attenuated.

2. Experimental Method

Two end mills were used in the tests, with diameter of 0.8 mm. The cutting edge radius of both tools was measured using an Olympus OLS 4000 3D laser microscope. The values were 2.368 μm and 3.287 μm, respectively. An experimental design was proposed with replica. Two feed per tooth conditions (f_t) (5 μm and 10 μm), two width of cut (a_e) (200 μm and 400 μm) with constant depth of cut (50 μm) and cutting speed (50 m/min). Cutting force was measured using a micro dynamometer Kistler model 9256C2 piezoelectric 3-component and 5233A signal conditioner. An optical profiler WYKO NT1100 was used to evaluate the surface finish.The work piece material is an aluminum alloy (RSA 6061-T6 – Average grain size of 1 μm) and was fixed on the piezo plataform as shown in Fig. 1(a). The machining strategy used was to cut a channel with the same size of the micromill diameter and then the tool was moved aside in order to carry out an end milling operation with different a_e. Figure 1b schematically shows the channels opened and the size of them, rotation sense and feed direction.

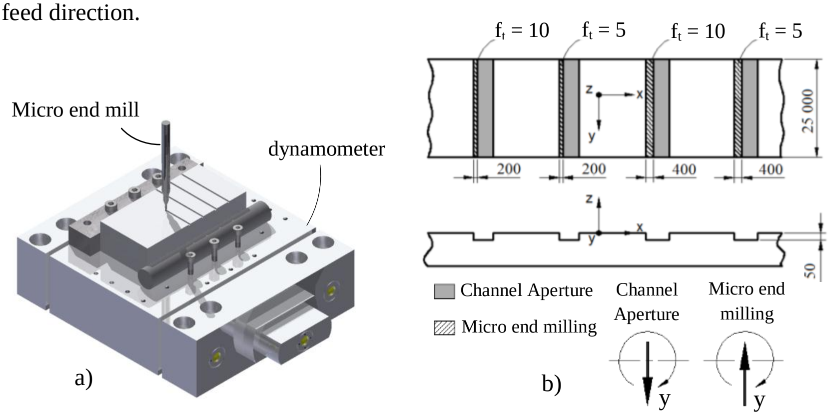

Figure 1. Machining strategy: a) wokpiece fixture; b) cutting tests sequence.

3. Results and Discussion

Figure 2 shows the value of the average cutting forces measured during the machining tests. The results show that the micro end mill with the smaller cutting edge radius presented the smaller cutting forces as expected.

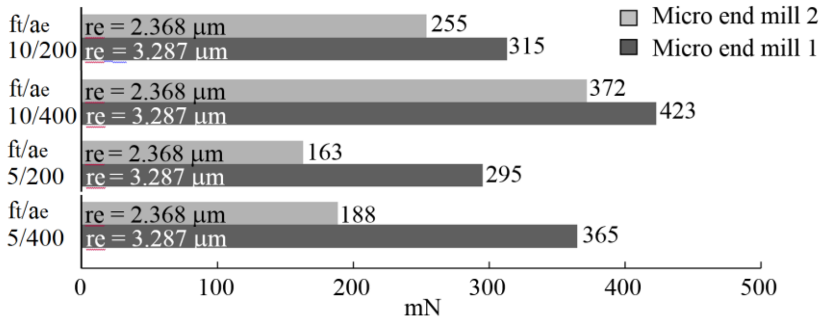

Figure 2. Average cutting force (Fc).

Since the cutting force variation was established during the micro end milling tests, the specific cutting pressure analysis was carried out. Figure 3 presents the behaviour of the Specific cutting force (k_s) during machining. A regression analysis provided the average values of K_{s1} and z as proposed by Kienzle [2]. The values were 364 N/mm² and 0.27, respectively.

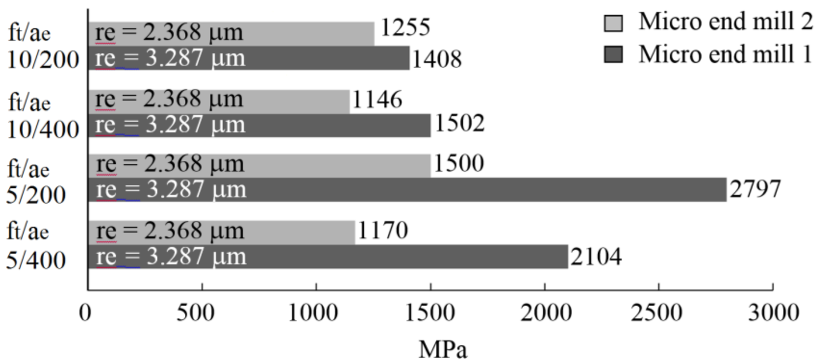

Figure 3. Specific cutting force (ks).

The cutting force for the pair material/tool (RSA 6061-T6/Micro end mill) and the sampling space of the experiments, can be approximately estimated by mean of the equations:

$k_s = 364 \cdot h^{-0.27}$ [N/mm²] ; h: thickness of cut [mm] (1)

$F_c = k_s \cdot h \cdot a_p$; a_p: depth of cut [mm] (2)

The surface roughness parameter Rq was used to evaluate the surface finish under the cutting conditions tested as shown by the letter “A” in Figure 4 a). The best results were obtained for the end mill with larger edge radius (r_e = 3.287 μm) e the smallest feed per tooth values (f_t = 5 μm/tooth) as shown in Figure 4 b). The results obtained were expected since the larger cutting edge radius may play a role in flattening the machined ridges formed by material tool interaction.

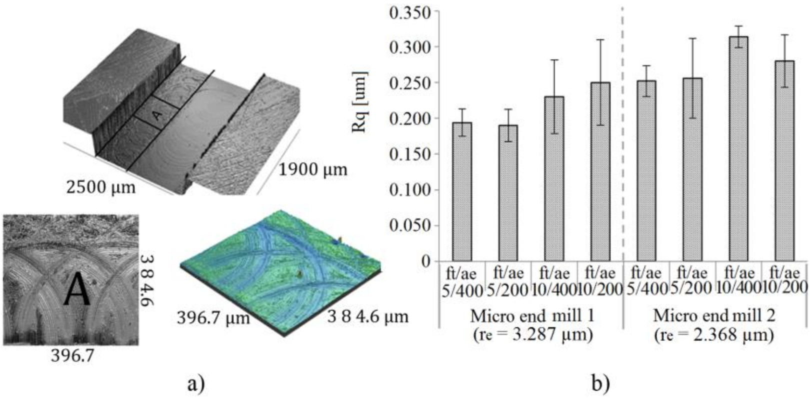

Figure 4. Surface roughness Rq: a) surface image of the surface protion measured; b) Rq values.

4. Conclusions

Smaller cutting forces were probed for the cutting tool with the smallest cutting edge radius. The surface roughness presented better results for the tool with the largest cutting edge radius and the smallest feed per tooth condition and it was 0.17 μm Rq. The specific cutting force was estimated 364 N/mm^2 and the constant z =0.27.

Acknowledgements:

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References:

[1] Tschätsch, H. Applied machining technol., Springer, 2009, 398p.

[2] Kienzle, O. e Victor, H., 1957 “Spezifische Schnittkräfte bei der Metallbearbeitung”. Werkstattstechnik und Maschinenbau. 47(5): 224-5.