Effect of Cutting Tool Materials on Surface Roughness and Cutting Forces in Machining of Al-Si_3N_4 Composite Produced by Powder Metallurgy

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Abstract

Aluminum-based composites reinforced with various amounts of α-Si_3N_4 were produced by powder metallurgy (P/M). The machinability properties of MMC_s were determined by means of cutting forces and surface roughness. Machining tests were carried out by using PCD and K10 tools. Increasing of Si_3N_4 volume fraction in the matrix resulted in a decrease of the surface roughness and turning forces. PCD cutting tools showed better cutting performance than K10 tools.

Keywords : Metal matrix composites (MMC_s), Powder metallurgy (P/M), Machinability, Cutting tool

1. Introduction

Among fabrication methods for MMC_s, powder metallurgy is particularly attractive since it is relatively cheap and can accommodate a wide range of materials and processing conditions. Reducing the particle size of reinforcement results in better machinability and mechanical properties of MMC_s [2]. Machining tests have been carried out on Al-based composite by using poly crystalline diamond (PCD) and tungsten carbide (K10) tools and have been found that PCD exhibited better properties with respect to tool life and surface quality [3-6].

2. Experimental Procedure

Materials. In this study, Al powders (-200 μm) and α-Si_3N_4 powders (0.1 - 0.3 μm) were used to produce the samples. Al and α-Si_3N_4 (5, 10 and 15 wt. %) powders were mixed in an attritor for 1 hour. Mixed powders were compacted at 800 MPa. Sintering was performed at 650°C for 2 h in N_2. Physical properties of the samples are given in Table 1.

Table 1. Physical and mechanical properties of MMC_s

Sample Code	Density [%]	Hardness [VH5]	TRS [MPa]
Al	98	23	174
5% Si_3N_4	95	41	102
10% Si_3N_4	94	60	117
15% Si_3N_4	92	69	77

Machining Test. Ring-shaped MMC blocks were machined by dry turning on a CNC lathe with an uncoated tungsten carbide (K10) and PCD cutting tools. Table 2 summarizes the details of the machining conditions.

Table 2. Details for machining tests

Tool holder	CSBPR 25x25 R12
Tool inserts	K10 and PCD / SPGN 120304
Cutting parameters	Cutting speed (V): 50-200 m/min Feed rate (f): 0.12 mm/rev Depth of cut (a): 1 mm

3. Experimental Results

Surface Roughness. High Ra values were obtained during machining of MMC_s with K10 cutting tool (Fig. 1). With increasing the cutting speed up to 150 m/min surface roughness decreased significantly. This feature was attributed to large built-up edge (BUE) formation which particularly formed at lower cutting speeds. Formation of minimum Ra value on

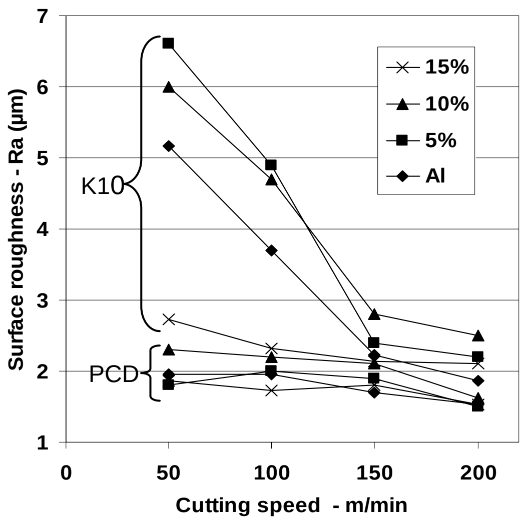

Fig. 1. Effect of cutting tool material and cutting speed on surface roughness.

pure Al and the sample containing 15% Si_3N_4 was probably due to the formation of built up layer (BUL) or formation of small amount of BUE. During the machining of ductile and pure materials, BUL generally forms instead of BUE formation [8]. Surface roughness difference value of about 0.5 Ra was obtained on the sample machined between 50-200 m/min speed with PCD tool. This value is quite lower than the one with the K10 cutting tool. There was no evidence of BUE formation on the sample at the lowest cutting speed with PCD cutting tool.

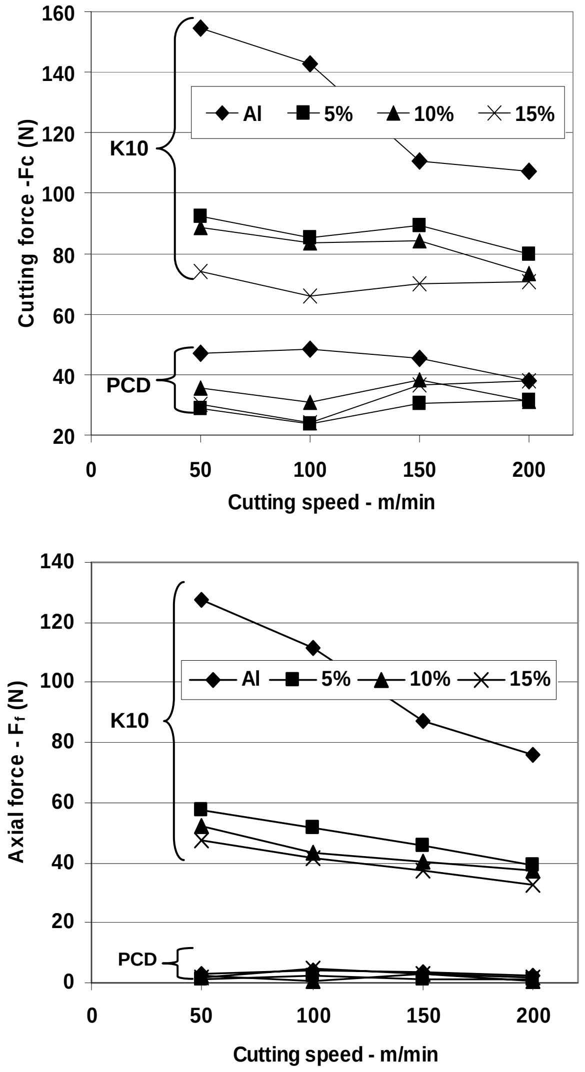

Fig. 2. Effect of cutting tool and cutting speed on turning forces (F_c, F_f).

Turning Forces. K10 tool generated high forces compared with PCD tool (Fig. 2). Forces generated by K10 tools showed a decreasing tendency with increasing material hardness and decreasing transverse rupture strength (TRS) value. High volume fraction of porosity in the matrix reduces the TRS value however; those pores or particles in the cutting plane increases stress concentration which facilitates the chip braking and consequently reduces the cutting forces [9, 10].

During machining with K10 tool, both forces (F_c and F_f) decreased with increasing cutting speed. This can be explained by low yield strength of MMC_s due to high cutting temperature caused by high cutting speeds. Turning forces generated during the machining of MMC_s with PCD tool were very low and axial force was negligibly small.

4. Conclusion

The following results were concluded:

- PCD tools exhibited very low surface roughness compared to K10 tools. Surface quality increased with increasing the cutting speeds when machining with K10 tool. Large BUE formed at low cutting speeds was found to increase the surface roughness.
- Minimum turning forces were obtained in machining with PCD tools were not related to cutting speeds. Turning forces generated by K10 tools were considerably higher compared to PCD tools at lower cutting speeds.

5. References

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