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The effect of particle size on tool wear of SiCp-reinforced metal matrix composite

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The effect of particle sizes of the metal matrix composites containing 10 wt.%SiCp was investigated with using various tools. The results showed that tool life decreased considerably with increasing particle size and cutting speed. The wear resistance of TiC-coated tools was considerably higher than that of the other tools. It was observed that abrasive wear was the main responsible mechanism for wear of the tool while thermal cracks were at high speed while a built-edge formation was also evident at lower speed.

Key words: SiCp, Composite, Wear, Particle size, Aluminium alloy

1. Introduction

Metal matrix composites (MMCs) are multiphase materials with stiff and hard reinforcing phases in metallic matrices which include light metals such as aluminium, magnesium, titanium, copper and their alloys. The reinforcing phase in the composites can be in the form of continuous, discontinuous fibres, whiskers, short or particles. Ceramic fibres or particles such as, carbon, boron, alumina and silicon carbide have been supplied commercially. The particle-reinforced MMCs which are among the most widely used composites materials, can be produced through a number of routes including melt processing and powder metallurgy. Melt processing has some important advantages, e.g., better matrix-particle bonding, easier control of matrix structure and simplicity. In particular, SiCp-reinforced aluminium composites have found many applications in aerospace and automotive industry since they not only have good wear properties but are also economically viable [1-3]. However, due to hard ceramic reinforcing components in MMCs, they : difficult to machine and attempts to do so result frequently ... accelerated tool wear and premature failure. Therefore the available literature concentrated on the study of wear characteristics of various tool materials including coated carbide and polycristalline diamond (PCD) tools [4-18]. However, few works related to the effect of particle size on the tool wear have been reported [7,8,12]. The purpose of the current study, therefore, was to evaluate the effect of particle size on the wear of cutting tools when machining the MMCs under various conditions.

2. Experimental Details

The composites were fabricated by a molten metal mixing of Al-2014 alloy using an electric induction. For manufacturing of MMCs, 10 wt% and 20 wt% SiC particles with average sizes of 110, 45, 29 μm were used. When the melt temperature reached to 500°C the graphite mixer was inserted into in a crucible, the molten mixture was poured in the pre-heated mould. Machining tests were conducted under different conditions using a CNC lathe machine. All tools are commercially available inserts. TNMA 160412, TNMG 160412 and TNMG 160412-MF2 were supplied by Sandwick and Seco respectively. TiN coated on K15-GC3015 carbide grade denoted by the term of A tool, a TiC coated on K15-CA100 ceramic grade, denoted by the term of B tool, and Al_2O_3 coated on K15 grade denoted C in this study.

3. Results and Discussion

Fig.1 shows a variation of flank wear width with cutting ·ne when machining the 10wt.%SiCp-reinforced composite with 29 μm particle size. Among the tools, insert B showed better performance than the others. TiC in tool B may be higher than that of SiC but SiC is also brittle. Its hardness (27 GPa) is lower than that of TiC (30 GPa). The insert A indicated lower wear resistance because there is a transitional structure which is brittle between the matrix of the tool and the coating layer. The tool life decreased with increasing the cutting speeds in all conditions due to thermal softening of the workpiece materials. However, the tool life also changed dramatically when the material type changed. Such sample is shown in Fig.1b which indicates that the flank wear width. The tool wear also increased with the increase in SiC particle size. This might be since the effect of shocking by coarse particles in the composites was bigger than that of the fine particle-reinforced composites.

The wear patterns of tools B are shown in Fig.2 and 3 for 29 and 110 μm particle-reinforced composites respectively. It can be seen that the flank wear was caused by the abrasive nature of the hard SiC particles in the workpieces. The grooves observed on the flank face of both tools could have formed by loss of coated layer and/or sintered particles through Al seizure and pull-out process. The flank wear is observed to be associated with fairly uniform and close-packed abrasion marks due to the slightly smoothness of coating process. The hardness of these TiN coated tools is about 2700 Hv while the microhardness of the alloy in range of 75 Hv. The presence of grooves which were parallel to cutting direction on the worn flank surface also indicates that two-body abrasion is the mechanism of dominating the tool wear. It is evident that a smooth surface was observed (Fig.2ab). The BUE formation was observed with decreasing the speed. The rate abrasion increased with increasing the cutting speed. The worn surface of the tool B seems to be smooth than the C due to lower particle size. Higher stresses and temperature on the cutting edge caused by the chipping process to take place on the cutting edge (Fig.3). The larger the size could interfere with neighbouring reinforcement particles since the larger size particles required longer paths when they are dislodged or embedded. This finding is also reported by Li et al.[12] on the effect of various particle size on the tool wear. The high wear rates obtained when SiCp percentage is above the critical band value band and critical values decreased with increasing the particle size. However, no critical weight percentage of particles was observed because the higher weight percentage used here.

At higher speed, as shown in Fig.3a, the amount of erosion was greater because of generation of high temperature for the tool and craters formed. At lower cutting speed, a very small amount of erosion of particles separated from tungsten carbide grains having taken place. The BUE formation tended to increase with decreasing speed. The SiCp particles in the composites also microcut these tools randomly and densely in the formation between the workpiece and the tool so that the abrasive wear occurred quickly in the tools. The particles affect the characteristics of composites not only due to their high hardness but also due to size. In the machining of composites reinforced by fine SiC particles, the matrix could make a concession to the SiC particles and coordinate them into deformation. Under the pressure of the tool edge the matrix around the particles deform plastically, the tool can press the particles into the chip or the machined surface. In the machining of composites reinforced by coarse SiC particles, however, a large number of high dislocations will occur in the matrix around the SiCp when the composites deform, the matrix being strongly hardened. Similar results were found by Quan et al.[7] and Yanming et al.[8] for cutting SiCp-reinforced Al matrix composites.

3. Conclusions

The tool life decreased with increasing the speeds in all conditions. The coarser the size of the SiCp, the more severe is the flank wear of the tool. The major wear form of the tool was the abrasion on the flank face of the tool. A thermal cracks and edge was observed at high speed while a BUE formation were also appeared at lower speed.

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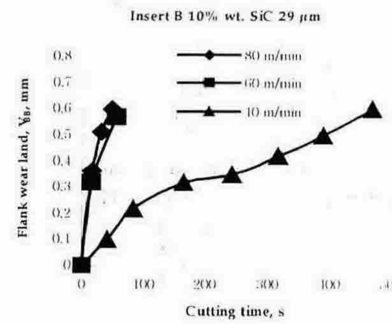
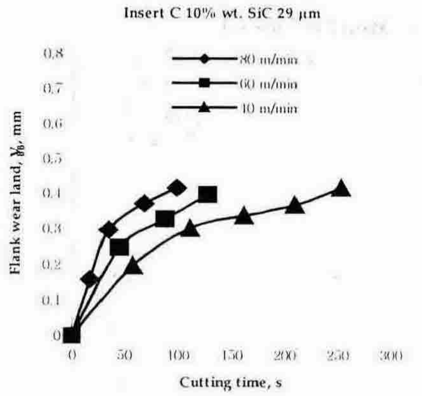
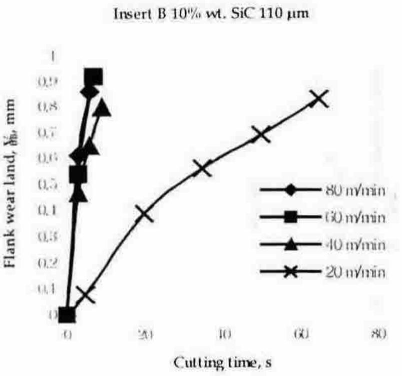


(a)



(b)

Fig.1. Variation of flank wear land with cutting time in the machining of 10wt%SiCp-reinforced composites with 29 μm particle size.(a) Tool B, (b) Tool C.



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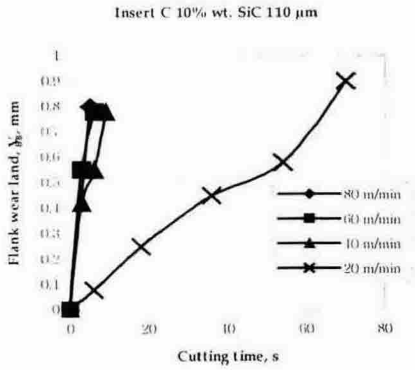

(b)

Fig.1. Variation of flank wear land with cutting time in the machining of 10wt%SiCp-reinforced composites with 110 μm particle size. (a) tool B. (c) Tool C.

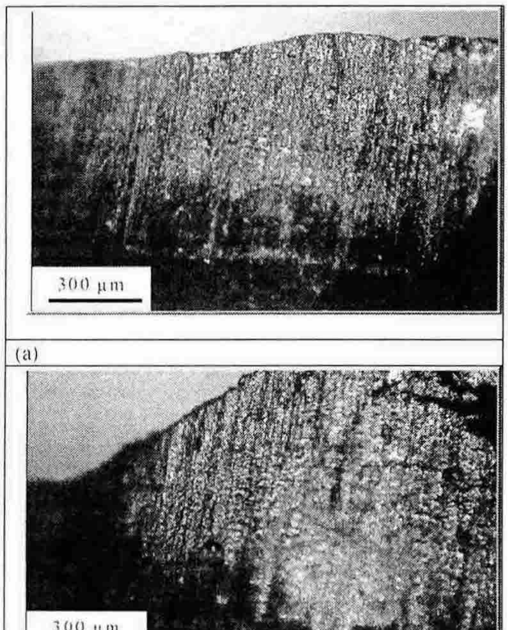

Fig.2. The worn surface of tool B when machining the 29 μm particle-reinforced composite tested at : a) V=60 m/min, b) V=40 m/min.

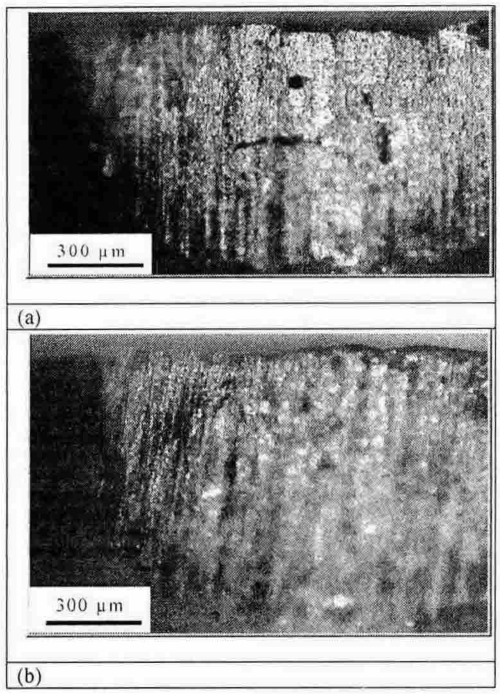

Fig.3. The worn surface of tool B when machining the110 μm particle-reinforced composite tested at : a) V=60 m/min. b) V=40 m/min.