PRODUCTION AND MACHINABILITY OF SiCp-REINFORCED AL-2014 ALLOY MATRIX COMPOSITES

I. CIFTCI[1] and Y. SAHIN[2]

[1] *Gazi University, Institute of Science and Technology, 06590, Maltepe, Ankara, TURKEY*
[2] *Gazi University, Technical Education Faculty, 06500, Besevler, Ankara, TURKEY*

SiCp-reinforced metal matrix composites (MMCs) containing 8 wt % and 16 wt % of SiC_p-reinforced with 30 and 45 μm in sizes were prepared by a melt stirring-squeeze casting technique. Microstructural observation showed that particle distributions were reasonably well. Turning experiments were carried out on the composites using uncoated and triple-layer coated carbide tools at various cutting speeds under a constant feed rate and depth of cut. Coated tools indicated better performance than uncoated tools for all the materials while the poor surface finish was obtained for coated tools.

Keywords: MMCs, Machinability, Tool Life, Surface Finish

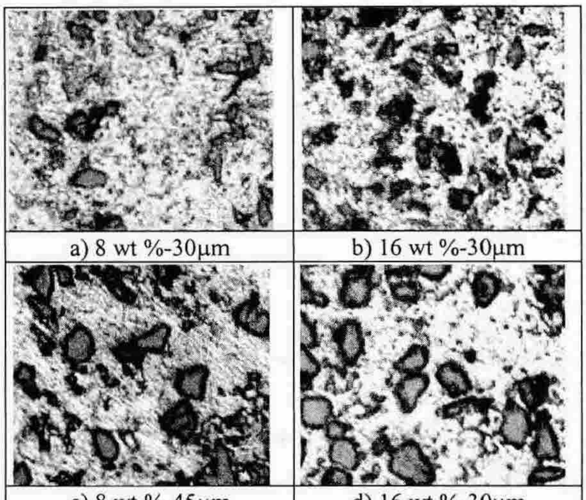
1. INTRODUCTION

Due to their superior properties over those of monolithic alloys, MMCs have received considerable attention [1]. However, the presence of hard ceramic particles makes them extremely difficult to machine as they lead to rapid tool wear [2,3]. Although attempts were made to eliminate machining operation, such as near net shape forming and modified casting, they are limited and therefore machining still remains an integral part of component manufacture. In addition, for many components, the production of good surface finish is essential [4,5].

Published literature on the machinability of particulate-reinforced MMCs indicates that only polycrystalline diamond tools (PCD) provide a useful tool life when machining these materials as PCD is harder than Al_2O_3 and SiC and does not have a chemical tendency to react with the workpiece materials [6-8]. However, due to the extremely high cost of PCD tools, less expensive tools like cemented carbides and ceramics were also tried to machine these materials [9,10]. Ceramic tools were found to be unsatisfactory while acceptable tool life could be achieved with cemented carbide tools when machining at low cutting speeds and high feed rates [5,11]. The aim of the present work is to investigate the effects of SiC weight fraction and its size on tool life during turning of SiC reinforced 2014 Al alloy MMC with uncoated and coated cemented carbide tools. This work also examines the effect of coating on tool life.

2. EXPERIMENTAL PROCEDURE

Four different MMCs containing two levels of SiC particles (8 and 16 wt %) of different mean particles sizes 30 and 45 μm prepared using a melt stirring-squeeze casting route. The matrix material was 2014 Al alloy. All the melting was carried out in a graphite crucible in a resistance furnace under argon atmosphere. A metered amount of matrix alloy was charged into the crucible and the furnace power was put on. Initially the furnace temperature was raised to 725 °C and held at that temperature until the matrix material was melted completely. Then, it was lowered to 675 °C to enable the particulate incorporation. Prior to the particulate addition, 0.5 wt % Mg was also added to improve the wetting. At 675 °C, the graphite impeller was started turning and SiC particles which were preheated at 1000 °C for 2 hours to make their surfaces oxidised were added at a uniform rate. During this stage, the temperature was gradually increased up to 725 °C to improve fluidity of the mixed slurry. After the particulate addition was completed, the stirring continued for 5 minutes more. When the stirring was completed, the mixed slurry was poured in a preheated steel die. The die was placed on the bed of a hydraulic press and the slurry was squeezed until complete solidification occurred under the pressure of 40 MPa. The microstructures of the MMCs are shown in Fig. 1.



a) 8 wt %-30μm | b) 16 wt %-30μm
c) 8 wt %-45μm | d) 16 wt %-30μm

Fig. 1. Microstructures of the MMCs (x 70)

The machining tests were performed dry by single point continuous turning of the four different MMC specimens in cylindrical form. A DYNA CNC lathe was used. The machining tests were conducted with triple layer coated (TiN, Al_2O_3 and TiCN) and uncoated recommended grade cemented carbide tools. The tools were commercial grade inserts produced by Mitsubishi Carbide with the geometry of SPMN 120308. The inserts were clamped mechanically on a rigid tool holder. This resulted in a cutting geometry of with side rake angle = 5°, back rake angle = 0° and side relief angle = 6°. Cutting speeds used ranged from 20 to 80 m/min. The cutting speed was increased in steps of 20 m/min. Feed rate and depth of cut were kept fixed, 0,12 mm/rev and 1 mm, respectively. Tool wear measurements were performed under a microscope. Surface roughness measurements were performed by using a Mitutoyo Surftest 211 instrument.

3. RESULTS AND DISCUSSION

The relationship between the tool flank wear and cutting speed for the four different MMCs for coated tools are shown in Fig. 2. The wear curves were plotted against a fixed volume (1250 mm³) of material removal. It is seen from Fig. 2 that increasing cutting speed, workpiece reinforcement size and weight fraction accelerates the tool flank wear.

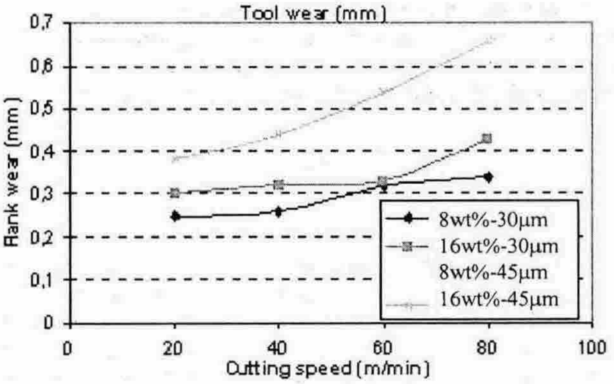


Fig. 2. Wear curves of coated tools for the turning of the MMCs

When machining MMCs, the tool wear is dominated by the hard abrasive ceramic particles. In this study, the results are in agreement with those of previous researchers [10,12]. With increasing cutting speed, the kinetic energy of the abrading particles and the interface temperature increase, this is, in turn, increases the flank wear. Increasing particle content means increased number of particles which the cutting edge of the tool encounters. Similarly, the size of the reinforcement particles have an important effect on tool wear. Increasing particle size shortens tool life.

Further turning tests were carried out with uncoated carbide tools on the same workpiece materials under the same conditions to determine the effect of coating on tool life. Fig. 3 shows the wear curves of coated and uncoated tools. In all the tests performed the coatings prolonged tool life to some extent.

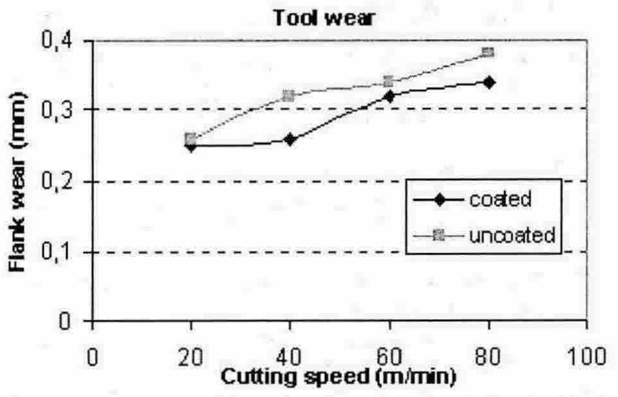


Fig. 3. Wear curves of coated and uncoated tools for the turning of 8 wt% 30 μm SiCp reinforced MMCs at 20 m/min.

In the case of MMCs, coating is worn away during the initial period of cutting and tool life improvement is attributed to the presence of built up edge (BUE) on the cutting edge [3]. In this study, in terms of means of Ra values coated tools produced poorer surface finish than the uncoated tools. The surface roughness values support the claim that the presence of BUE prolongs tool life when turning with coated tools. However, further research is required to clarify the formation of BUE and its effect on tool life during machining with coated carbide tools.

4. CONCLUSIONS

1- Increases in cutting speed, reinforcement weight fraction and reinforcement size accelerated tool wear when turning a fixed volume of material.
2- Coated tools performed better than uncoated tools for all the materials tested in terms of tool life. The improvement in tool life in the case of coated tools can be attributed to the formation of a protective built-up-edge. However, further research is required to clarify this phenomenon

REFERENCES

[1] Cole, G.S., and Sherman, A.M., "Lightweight materials for automotive applications", Materials Characterization, 35, pp3-9, 1995.
[2] Quigley, O., Monaghan, J., and O'Reilly, P., "Factors affecting the machinability of an Al/SiC metal-matrix composite", J. Mater. Process. Technol., 43, pp.21-36, 1994.
[3] Barnes, S., Pashby, I.R., and Mok, D.K., "The effect of workpiece temperature on the machinability of an aluminium/SiC MMC", Trans. ASME, J. Manuf. Sci. Eng., 118, pp.422-427, 1996.
[4] Paulo Davim, J. and Monteiro Baptista, A., "Relationship between cutting force and PCD cutting tool wear in machining silicon carbide reinforced aluminium", J. Mater. Process. Technol., 103, pp. 417-423, 2000.
[5] Coelho, R.T., Yamada, S., le Roux, T., Aspinwall, D.K., and Wise, M.L.H., "Conventional machining of an aluminium based SiC reinforced metal matrix composite (MMC) alloy", Proc. 30th MATADOR, pp. 125-133, 1993.
[6] Brun, M.K., and Lee, M., "Wear characteristics of various hard materials for machining SiC-reinforced aluminium alloy", Wear, 104, pp. 21-29, 1985.
[7] Winert, K., "A consideration of tool wear mechanism when machining metal matrix composites (MMC)", CIRP Annals, 42, 1, pp. 95-98, 1993.
[8] Cronjager, L., "Machining of fibre and particle reinforced aluminium", CIRP Annals, 41, 1, pp.63-66, 1992.
[9] Chambers, A.R., "The machinability of light alloy MMCs", Composites: Part A, 27A, pp.143-147, 1996.
[10] Yanming, Q., and Zehua, Z., "Tool wear and its mechanism for cutting SiC particle reinforced aluminium matrix composites", J. Mater. Process. Technol., 100, pp.194-199, 2000.
[11] Looney, L.A., Monaghan, J.M., O'Reilly, P., and Taplin, D.M.R., "The turning of an Al/SiC metal matrix composite", J. Mater. Process. Technol., 33, pp. 453-468, 1992.
[12] Li, X., and Seah, W.K.H., "Tool wear acceleration in relation to workpiece reinforcement percentage in cutting of metal matrix composites", Wear, 247,pp.161-171,2001.