

EVALUATION OF SURFACE QUALITY OF GROUND Al/SiC_p METAL MATRIX COMPOSITES

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Abstract: A detailed study on grinding of metal matrix composites with resin bonded and plated diamond wheels have been carried out to evaluate the surface quality. The measurands namely grinding force and temperature during grinding were monitored online. Surface finish was measured offline using a stylus based instrument and the ground surface was observed through Scanning Electron Microscope (SEM) for process status evaluation. From the study, it was found that better surface quality (based on surface finish and SEM of machined surface) was achievable with resin bonded wheel as compared to electroplated wheel. Also electroplated wheel experiences higher order force.

Key words: Grinding, Resin bond, Electroplated bond, Surface finish

1. INTRODUCTION

Improvements in the performance of automobile and aircrafts have been closely linked to progress in materials development. Also due to more stringent requirements for improved fuel economy and emissions, there is a growing trend towards substituting conventional materials with materials like metal matrix composites (MMC), which can permit relatively higher temperature in engine, thereby leading to reduced emissions. MMC's have higher modulus, lower thermal expansion coefficient, improved tribology characteristics and higher hardness compared to unreinforced aluminium alloys. In comparison to blocks with coated bores, blocks with MMC liners have increased rigidity which can lead to increased cylinder roundness and reduce engine friction (Cole & Sherman, 1995). Particulate metal matrix composites (PMMC) are of particular interest, since they exhibit higher ductility and lower anisotropy than fiber reinforced MMCs, better dimensional stability over the corresponding unreinforced alloys and are economically cheaper by way of raw materials and fabrication process (Gul Tosun & Mehtap Muratoglu, 2004). Although components made of these materials, can be produced by near-net shape manufacturing (Cronjager & Meister, 1992) processes like grinding is needed to achieve high dimensional accuracy, desired geometry, assembling tolerance and surface finish. However it is difficult to machine SiC particle reinforced aluminium matrix composite, because the reinforcement and matrix of the composite possess widely different properties (Quan, et al. 1999). Unlike the investigations into the machining of traditional metallic materials, relatively little study has been carried out on machining advanced composite materials. Although it is known that electroplated bond is hard (prevents pull out of abrasive) compared to resin bonded wheel, during grinding, the resin bonded diamond wheel will enable self-sharpening of the diamond abrasive, enabling better grindability. But diamond being a costly abrasive (Durante, 1997), frequent dislodging, self-sharpening (partial fracture) of

the diamond will contribute to the tooling cost and thereby machining cost, and hence has to be avoided.

In this context, a detailed study on grinding performance for resin bonded and electroplated wheels has been carried out.

2. EXPERIMENTAL DETAILS

The workpiece was Aluminium 2124 alloy based metal matrix composite reinforced with SiC_p, (5µm/ 30% by volume) manufactured through the powder metallurgy route. The microstructure of the workpiece material in Fig.1 shows uniform distribution of the SiC_p reinforcement in an Aluminium matrix.

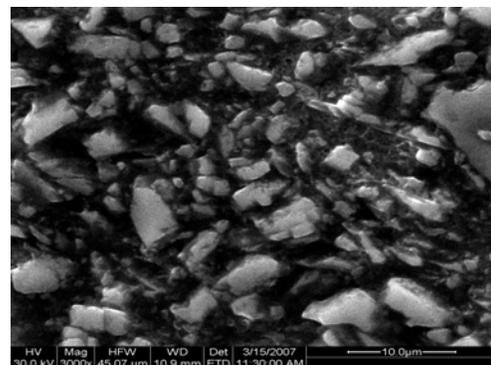


Fig.1 SEM microstructure of the workpiece material

Grinding experiments were carried out on a tool and cutter grinder (Schutte, WU3mS) by varying the wheel speed (V) in the 1000 – 2800 m/min range, work feed (s) from 0.2-0.9 (in m/min) and the depth of grinding (a) from 10-30 µm. The process performance indicators namely force and temperature were monitored online. The workpiece was mounted on a three component piezoelectric dynamometer in order to monitor the

normal (F_z) force during grinding. An infra-red radiation pyrometer was used to measure the temperature, during grinding. Surface finish of the machined surface was measured using perthometer. Ground surfaces were observed through scanning electron microscope (SEM), for assessing the surface texture. The schematic diagram of the experimental set-up is shown in Fig. 2.

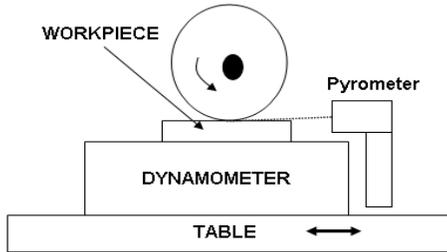


Fig.2 Schematic Diagram of the Experimental Set-up

3. RESULTS AND DISCUSSION

Grinding is usually carried out on hard ferrous materials. Relatively softer non-ferrous material usually is not an ideal material for abrasion. However composite materials of a non-ferrous material matrix (like aluminium) poses problems in turning and related processing due to the presence of harder reinforcement particles. Hence grinding is resorted to. During grinding of Al/SiC_p composites one can anticipate plowing and smearing of softer aluminium matrix, loading of the wheel, pull-out/dislodgement of reinforcement (SiC_p) and spalling of loaded material. This results in varied/inconsistent material response.

3.1 Observation on grinding force

Relative parametric influence on normal component (F_z) of grinding force for both resin bonded and electroplated diamond wheels is illustrated in Figs.3 & 4. It can be seen that mostly electroplated wheel experience higher order grinding force relative to resin-bonded wheel. Being relatively a soft bond, resin bonded diamond wheel present sharper/ keen edged abrasives unlike the presence of smeared (Coated) abrasive as in case of plated wheel, which could have resulted in the observed higher order forces. Also it is seen that the nature of grinding changes from plowing to steady state grinding above 1400 m/min wheel speed, in the case of resin bonded wheel, while a progressive reduction in grinding force with grinding speed can be seen in the case of electroplated wheel. This can be attributed to the flexibility of the resin bond. Among the wheels tried out, resin bonded wheel exhibits better performance, by way of lower order grinding force components.

3.2 Observation on temperature

Typical illustration on variation of grinding temperature with grinding condition is shown in Fig.5. The electroplated wheel experiences relatively higher

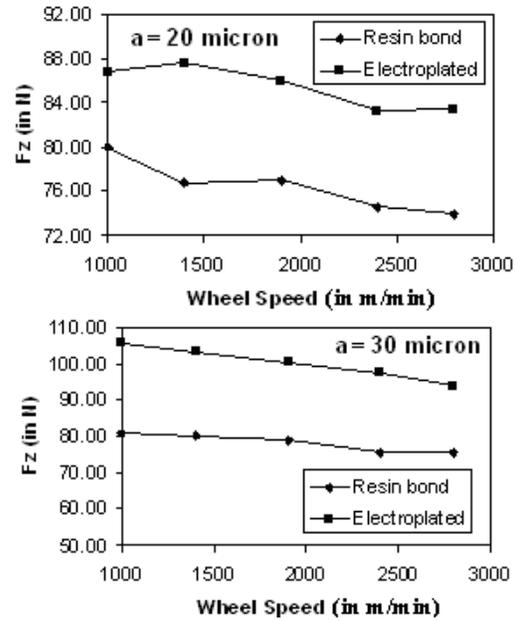


Fig. 3 Relative parametric influence on Normal force (F_z) at table speed of 0.2 m/min

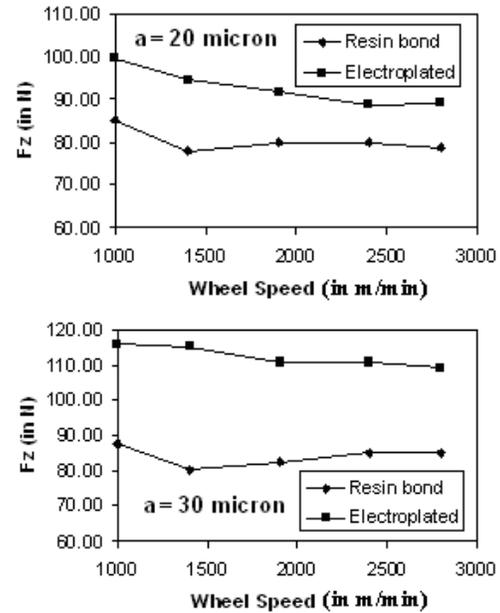


Fig.4 Relative parametric influence on normal force (F_z) at table speed of 0.9 m/min

temperature for low depth of grinding. This is because while the resin bonded wheel undergoes self-sharpening, the electroplated wheel is relatively a harder bond, and it undergoes deformation of abrasive grain and hence more of rubbing. With higher depths of grinding, the resin bonded wheel experiences a relatively higher temperature compared to electroplated wheel. Also, with increase in wheel speed, there is a steep increase in temperature for resin bonded wheel.

It is to be noted that, the temperature illustrated in the figure is the value, monitored with a stand off distance of 20 cm, from the wheel-work interface and emissivity correction of 0.02. This means that the temperature at the interface could be very much higher than illustrated in the figure.

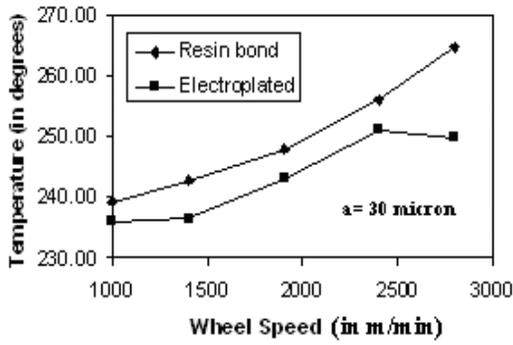
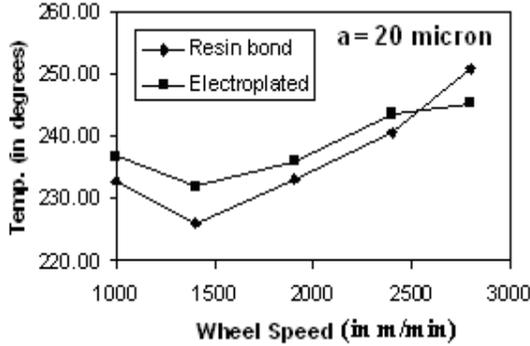


Fig.5 Grinding temperatures for resin bonded and electroplated diamond wheels at table feed of 0.2m/min

3.3 Observation on Surface finish

Relative influence of the type of bond on the quality of ground surface has been evaluated. Typical variation in the surface roughness (Ra) of ground surface, while grinding with resin bonded wheel as influenced by the grinding condition is illustrated in Fig.6. It is seen that upto 1400 m/min of wheel speed, an improvement in the surface finish occurs, above which only a marginal variation occurs. Higher grinding speed yield better results, for resin bonded wheel. With electroplated wheel (Fig.7), it is seen that mostly better surface quality (finish) can be attained with relatively lower grinding speed. But on comparison of surface finish values obtained with resin bonded wheel, electroplated wheels gave poorer surface finish.

3.4 Surface texture – Observation

Typical surface texture of Al/SiC_p metal matrix composites while grinding ($V = 2800$ m/min, $s = 0.9$ m/min, $a = 30\mu\text{m}$) with resin bonded diamond wheel is illustrated in Fig.8. The figure shows flow of surface material along the lay direction. Magnified view (A & B in Fig.8) of part of texture clearly shows intense flow of material, with whitening of the edges of flow pattern indicating possible oxidation of the hot material.

Texture also shows localized pull out of material due to intense adhesion of the work material on to the wheel surface, facilitating pull out of surface material by mutual transfer.

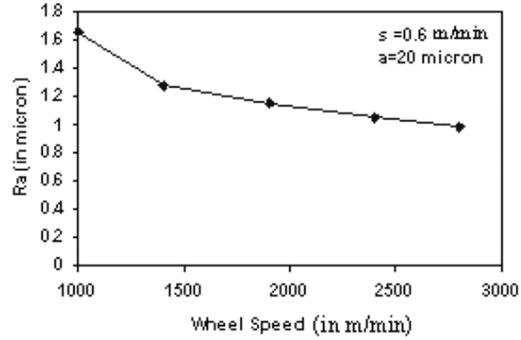


Fig.6 Typical Surface finish plot for resin bonded wheel

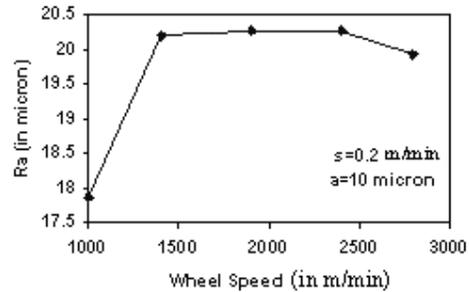


Fig.7 Typical Surface finish plot for electroplated wheel

Fig.9, shows a oval shaped marking indicating the region in which EDAX is taken for surface ground at same conditions as in Fig.8. Typical observed Energy Dispersive X-ray Analysis (EDAX) properties of the surfacial region is illustrated in Fig.10. Scanned region clearly shows dominant carbon peak, followed by peak of oxygen, silicon and Aluminium. The observed oxidation of the surface and consequent pick up of oxygen is attributable to higher order temperature prevailing on the surface during grinding with 2800 m/min of wheel speed. The intense carbon peak observed can be attributed to possible degradation of diamond at very high speeds. This is reflected in the observed reduction in the normal force component and higher order temperature, with higher order grinding speeds.

Typical observed surface texture of Al/ SiC_p composite ground (Wheel Speed =2800 mpm, $s = 0.9$ mpm, $a = 30\mu\text{m}$) with electroplated diamond wheel is illustrated in Fig.11 (“A” indicates magnified view of portion of the machined surface). The surface texture presents a distinct parallel lay with localized flow of material due to crest flattening. The relatively matte or smooth texture is indicative of rubbing/ sliding dominant grinding.

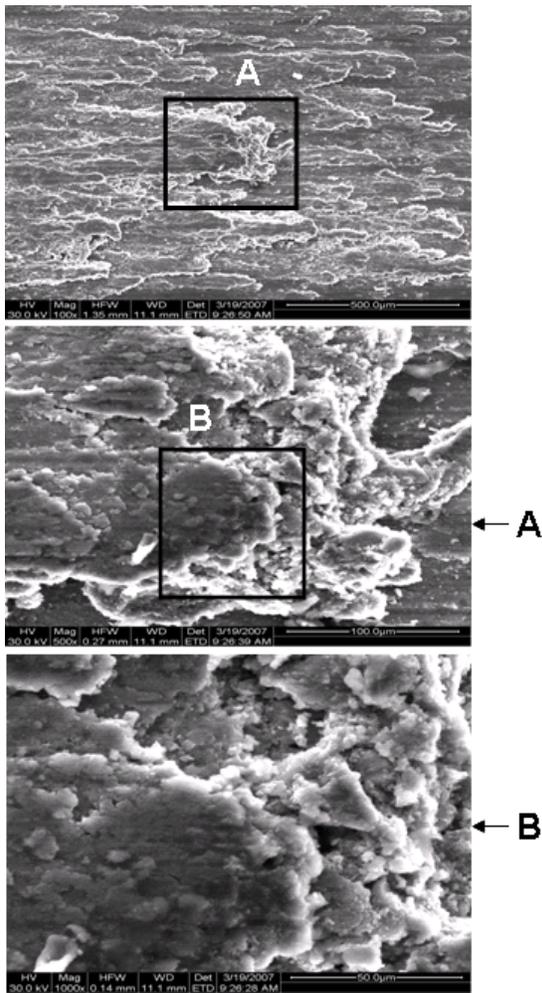


Fig.8 Typical Surface texture of ground MMC, while grinding with resin bonded wheel

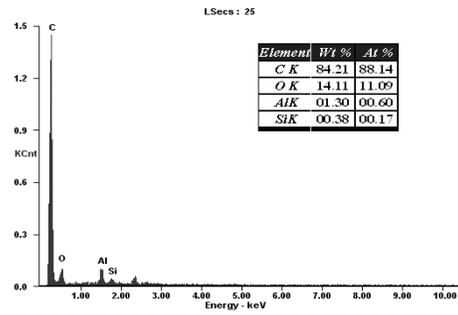


Fig.10. EDAX of the portion marked oval shaped in Fig.9

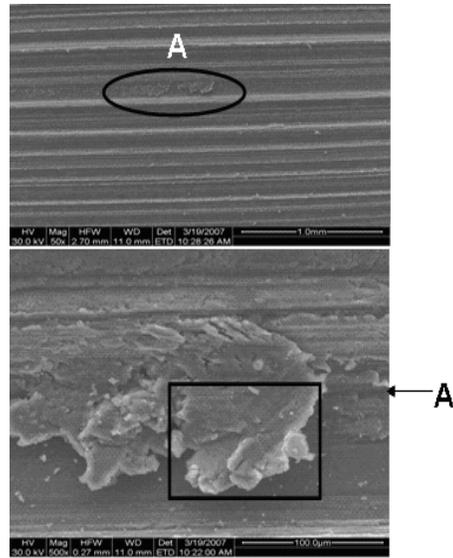


Fig.11 Typical Surface texture while grinding with Electroplated wheel

A typically observed EDAX properties of a portion of the ground surface, marked rectangular in Fig.11, is illustrated in Fig.12. The properties clearly indicate dominant Al and Si peaks. This is in contrast to the EDAX properties observed in the case of grinding with resin bonded wheel. This indicates that grinding with electroplated diamond wheel occurs with relatively lower order temperature, with discrete/ localized sliding of surface material (crest flattening).

The dominant (higher intensity) carbon peaks seen in the case of resin bonded wheel indicates the surface degradation of diamond during grinding with higher order temperature, leading to pick up of carbon by the surface material.

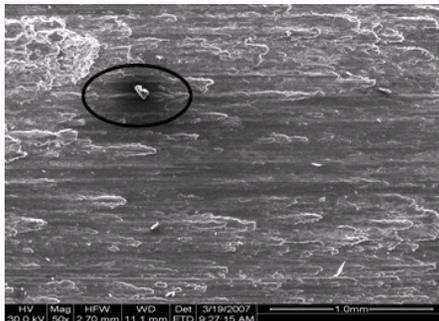


Fig.9 SEM of the machined surface

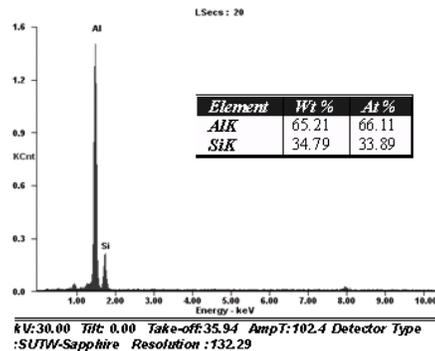


Fig.12 EDAX of the portion marked rectangular in Fig.11

4. CONCLUSION

The study on the surface quality of metal matrix composites, ground with resin bonded and electroplated diamond wheels indicate better surface quality achievable with resin-bonded wheels. Possibly the loosely held status of the abrasive, with resin bonding could have imparted better grinding action. The electroplated diamond wheel experiences relatively higher order grinding force with relatively lower order grinding temperatures.

Resin bonded wheel gave better surface finish, compared to electroplated wheel, although surface texture of material ground with electroplated wheel, showed localized sliding of surface material, with relatively smooth texture, compared to surface ground with resin bonded wheel. As a whole resin bonded wheel performed better than electroplated wheel.

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