Effect of Reinforcement Coatings on the Dry Sliding Wear Behavior of Al6061/SiC Particles/Gr Powder Hybrid Composites

Zakaulla, A.R.Anwar Khan, P.G.Mukunda

Abstract— Aluminum matrix composites with Silicon carbide (SiC) and Graphite (Gr) particles are finding increased applications because of improved mechanical and tribological properties. SiC particles are used to increase the hardness of composite while Graphite acts like a solid lubricant. The present investigation deals with Dry sliding wear of an Al6061 reinforced with both Cu coated SiC particles and Cu coated Graphite powder. Copper coating improved the wetting of SiC and Gr by molten aluminum alloy during processing and then dissolved in aluminum matrix to increase the hardness and improve antifriction properties. The wear resistance of hybrid composites having reinforcements coated with Copper is better than that of composites with same content of uncoated reinforcements. Worn surfaces of the pins are analyzed using Scanning Electron Microscope to study the wear mechanisms and to correlate them with the wear test results.

Index terms: Electroless technique, Hybrid composites, Cu coated SiC, Specific wear rate.

I. INTRODUCTION

Metal matrix composites have evolved as newer materials and are being increasingly used in aerospace, automobile industries due to their improved properties such as hardness, tensile strength and elastic modulus over unreinforced alloys [1-3]. For MMCs SiC, Al_2O_3 and Gr particles are widely used as particulate reinforcements. The ceramic particulate reinforced composites exhibit improved wear resistance and find application as brakes, pistons, piston insert rings and cylinder blocks [4, 5, and 6]. Composites with combined reinforcement of Al, SiC and Gr are known as Al-SiC-Gr hybrid composites. The use of SiC and Gr in aluminum matrix composites yields better tribological properties over composites with a single reinforcement [7, 8]. It is reported that addition of graphite which acts like a solid lubricant improves not only antifriction properties but also wear and machining properties [9, 10]. Rohatgi et al. have reported that friction coefficient of Al-10%SiC-6%Gr is very low due to combined addition of SiC which increases bulk mechanical properties and formation of graphite film [11]. Basavarajappa et al. on Al-15%SiC-3%Gr composites have concluded that wear rate in graphite composites is less than that of graphite free composites and indicated degree of subsurface deformation [12]. Properties of MMCs highly depend on interfacial phenomena between reinforcement and metal matrix [13-15].

Manuscript received December 2013

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To achieve high interface bonding strength the wettability of reinforcement by liquid metal is a key factor[16-17]. Unfortunately the wettability of SiC Particle reinforcement by molten Al is generally poor. To improve interfacial properties several methods like coating of reinforcement, controlling process parameters and modification of matrix composition are widely used. Among these, Electroless Copper coating of reinforcement which is a simple, low cost and easy to process has been widely used [18, 19, and 20]. In present investigation, dry sliding pin –on – disc wear test method (ASTM G99) is employed to investigate the wear resistance of specimens containing coated and un-coated reinforcements in aluminium alloy by varying parameters like speed and load.

II. EXPERIMENTAL PROCEDURE

A. Electroless copper coating on silicon carbide particles and Graphite powder.

The Electroless copper coating on silicon carbide particles depends on sequence of cleaning, sensitizing, activating and plating. The conditions used are detailed in Tables 1and 2.

Table 1. Steps in Electroless copper coating

Step	process	Chemical	concentration	Time (min)
1	cleaning	Deionised water	-	10
2	Sensitization	$SnCl_2HCl$	20g/l 80ml/l	15
3	Rinse	Deionised water	-	10
4	Activation	$PdCl_2HCl$	1g/l 5ml/l	20
5	Rinse	Deionised water	-	10
6	Copper coating	See table 2		30

Table 2. Electroless copper solution

Chemical	Concentration
Copper sulphate ($CuSO_4.5H_2O$)	20g/l
Sodium hydroxide	20g/l
Potassium sodium tartrate	100g/l
Na_2EDTA	20g/l
Formaldehyde.	20ml/l

B. Composite preparation

The Experimental setup used for preparing the composite consists of Electrical resistance furnace and a stirrer. About

3kg of Al alloy was melted in a crucible. The metal was superheated to 800^0 C and then degassing was carried out. The mechanical stirrer was inserted into it and rotated to create necessary vortex. Copper coated SiC particles (containing 30% copper as coating) and copper coated Gr powder were added into the vortex. Melt was stirred for atleast 8 minute. Stirring was stopped and stirrer was taken out of crucible. The crucible was taken out of the furnace and melt was poured into permanent moulds.

C. Wear test

The dry sliding wear tests were performed using a pin-on-disk type machine according to ASTM G 99 standard. The composite pins were run against rotating hardened disk of die steel with Rc60 hardness. Wear tests were carried out under dry sliding conditions at a sliding speed of 0.42 m/sec, 0.84m/sec and 1.68m/sec under a load of 10N, 20N and 40N respectively. The wear loss was measured directly as the height loss of the specimen using LVDT. A fixed wear track diameter of 80 mm was used for all the tests.

III. RESULTS AND DISCUSSION

A. SEM analysis

Fig. 1 & Fig. 2 show that the surface of silicon carbide particles and Graphite powder are uniformly coated by copper using Electroless process.

Fig.1 SEM image of Cu-coated SiC particles.

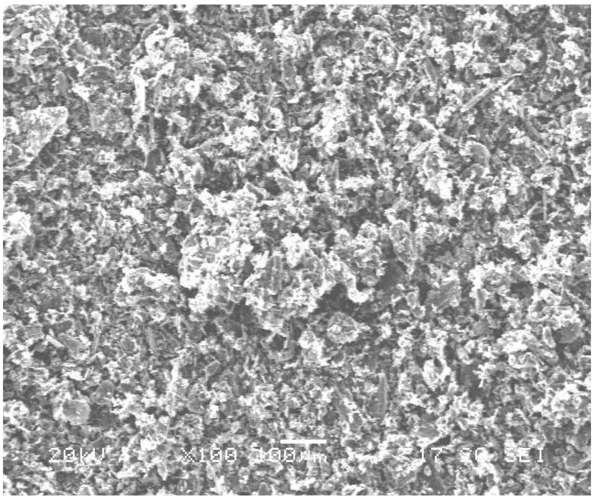

Fig. 2 SEM image of Cu-coated Graphite powder.

B. EDX/XRD ANALYSIS

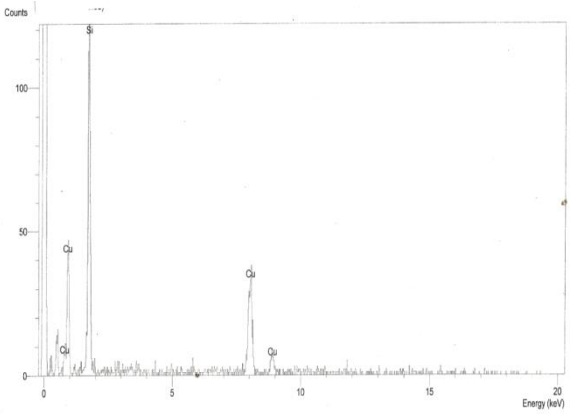

Fig 3. EDX of copper-coated silicon carbide particles.

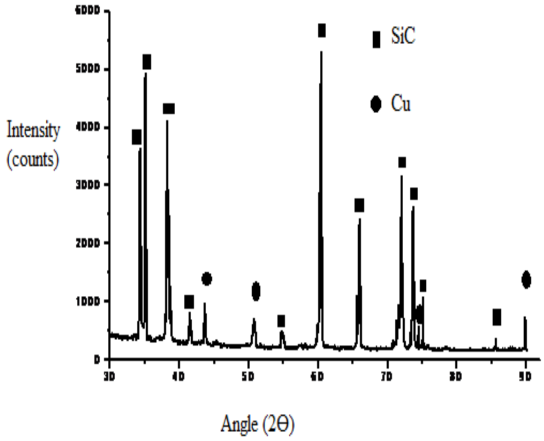

Fig 4. XRD of copper-coated silicon carbide particles.

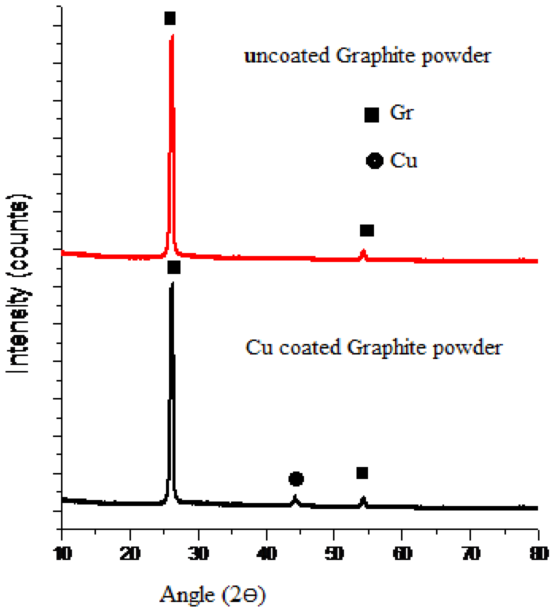

Fig 5. XRD of copper-coated Graphite powder.

EDX analysis confirms presence of copper and Silicon in fig.3. From fig.4 & Fig. 5, X-ray diffraction studies clearly indicate the presence of copper on SiC and Gr. Hence it can be concluded that after Electroless coating process Cu has been successfully deposited on SiC particle surface and graphite powder.

C. Tribological Behavior

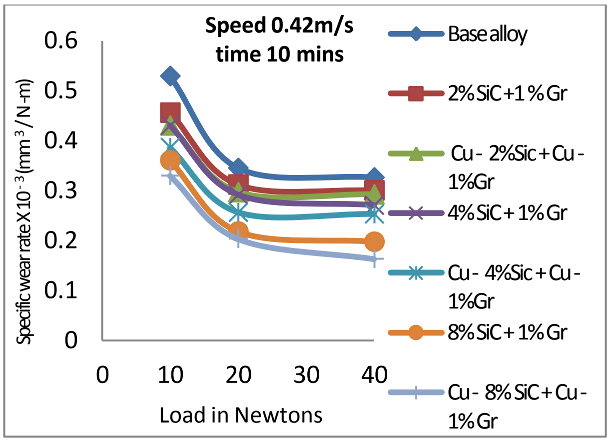

Fig (a)

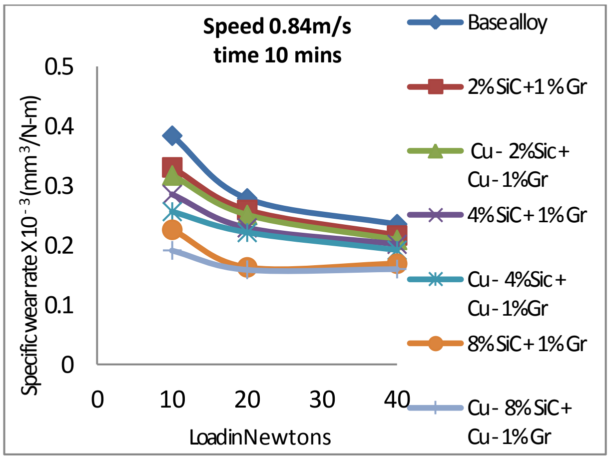

Fig (b)

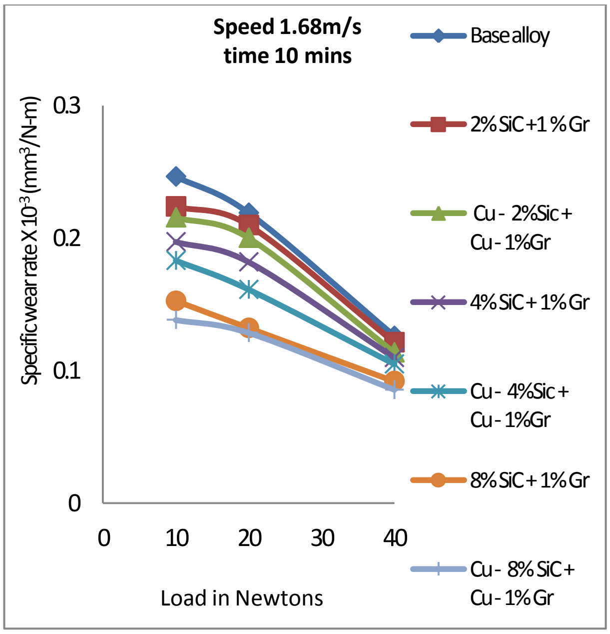

Fig (c)

Fig 6. Effect of load on specific wear rate for constant Speed.

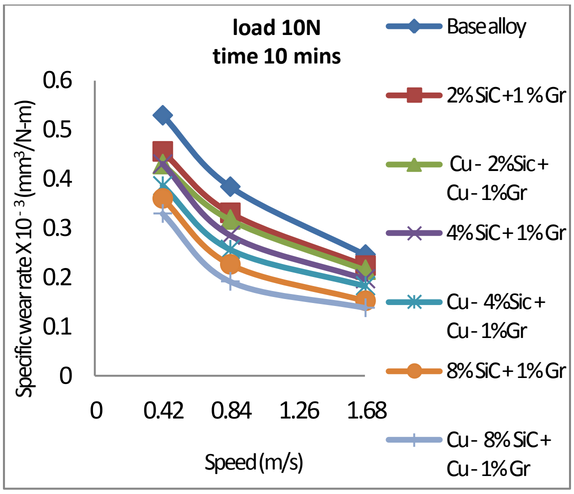

Fig (a)

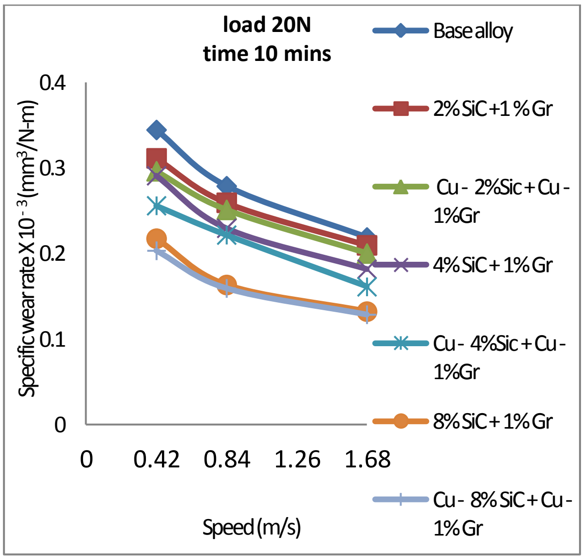

Fig (b)

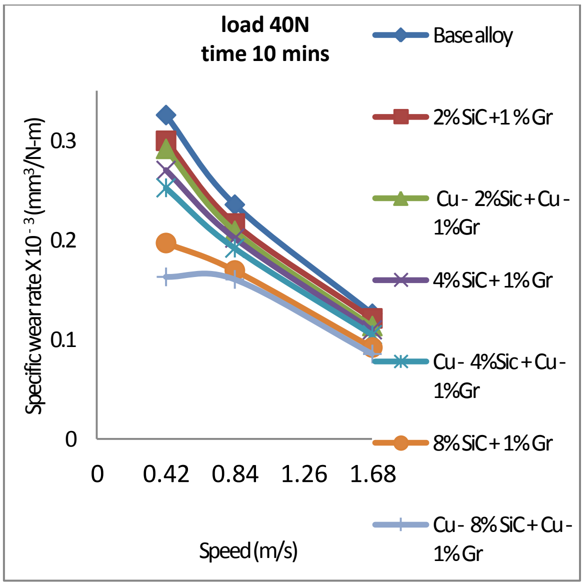

Fig (c)

Fig 7. Effect of Speed on specific wear rate for constant load.

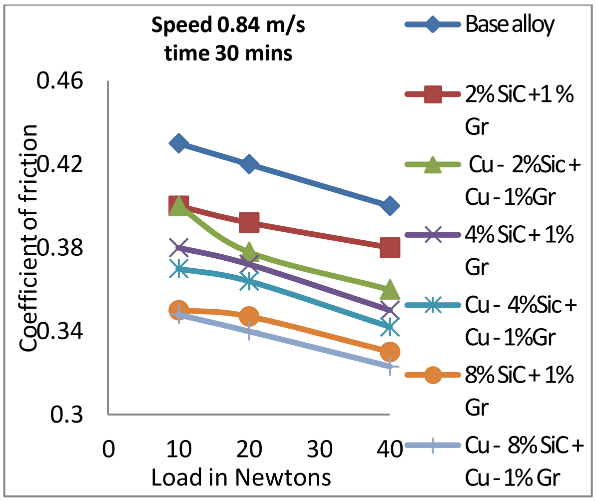

Fig 8. Variation of Coefficient of friction at different loads for composites

The specific wear rate for different Hybrid composites (Fig. 6a, b, c) & (Fig. 7a, b, c) indicated that the combination of both Cu coated SiC particles and Cu coated graphite powder was the effective solution to improve the wear behavior of aluminium alloy composites. Among these Cu - 8% SiC+ Cu-1%Gr hybrid composites provided good results. The value of specific wear rate with respect to uncoated reinforcements indicated mild wear regime while the use of Cu coating on reinforcements brought these values to ultra mild wear regime. Specific wear rate was decreased due to the application of copper coating on reinforcements, while the use of uncoated reinforcements only shows a small improvement in wear behavior. This indicated that the presence of SiC and Graphite had beneficial effect when their adherence to matrix was optimized using Cu coating.

The Coefficient of friction reduced when SiC_P and Graphite powder were Cu coated in relation to that of same hybrid composites manufactured with uncoated reinforcements for different loading conditions (Fig. 8). This behavior is due to better wettability of Cucoated reinforcements, Improvement in wetting, formation of intermetallic phases (Al_2Cu) and also presence of smeared graphite layer which acts like a solid lubricant and this graphite layer becomes more adherent.

D. Characterization of worn surfaces.

Micrograph of unreinforced alloy (Fig. 9a) shows severe delamination and deep grooves formed on surface.

The shape of worn surfaces in Hybrid composites (Fig. 9b, c and d) reinforced with uncoated SiC particles and uncoated Graphite powder was not uniform and wear tracks are easily observed which indicates that material was being removed because of abrasive wear and material was plastically deformed and accumulated at both sides of wear surface. The worn surfaces of Hybrid composites (Fig. 10a, b and c) reinforced with Cu coated SiC and Cu coated Graphite indicate that the surfaces obtained were smooth and uniform and a small amount of coating metal was incorporated to MML and there were no superficial cracks. This attributed for better wear resistance.

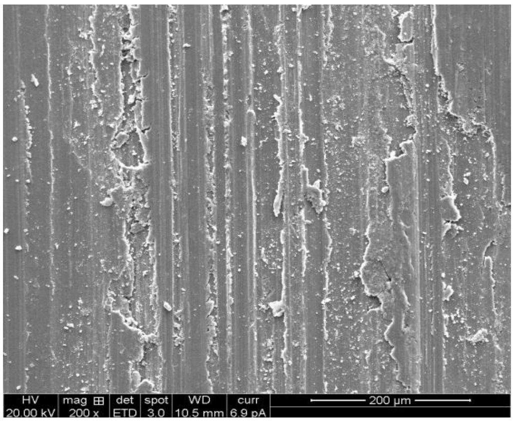

Fig (a) Al6061 alloy

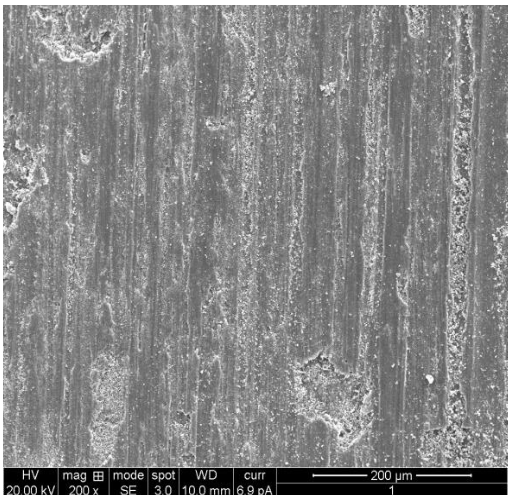

Fig (b) Al6061+ 2% SiC +1% Gr

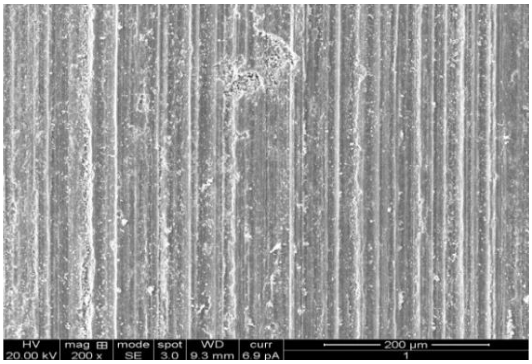

Fig (c) Al6061+ 4% SiC +1% Gr

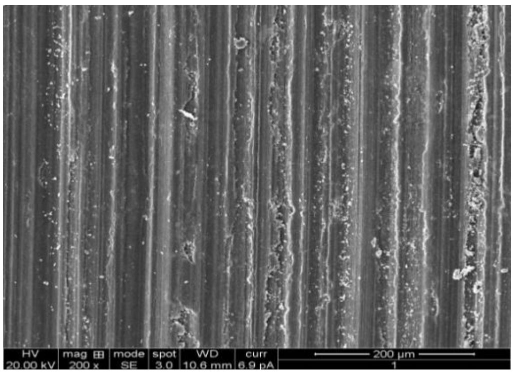

Fig (d) Al6061+ 8% SiC +1% Gr

Fig 9. SEM images of worn surfaces of uncoated reinforcement composites (40 N, 0.84m/sec)

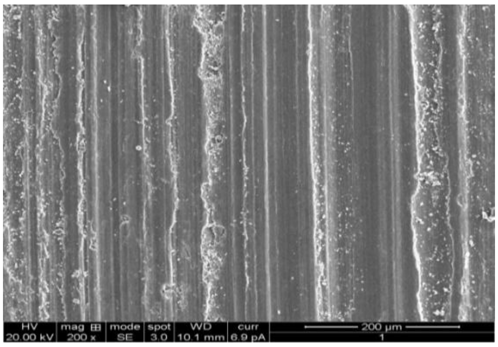

Fig (a) Al6061+ Cu - 2% SiC + Cu - 1% Gr

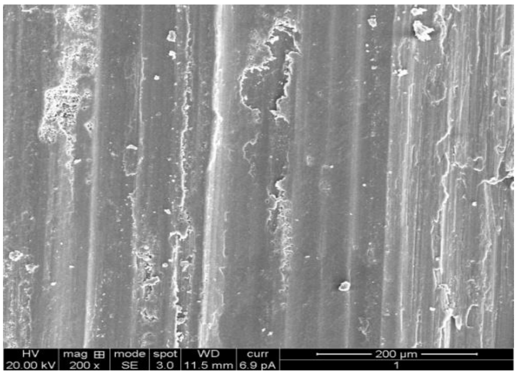

Fig (b) Al6061+ Cu - 4% SiC + Cu - 1% Gr

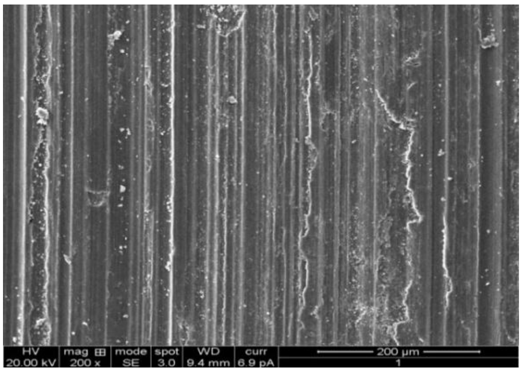

Fig (c) Al6061+ Cu - 8% SiC + Cu - 1% Gr

Fig 10. SEM images of worn surfaces of Cu coated reinforcements composite (40 N, 0.84m/sec).

IV. CONCLUSIONS

1) Hybrid composite manufactured with Cu coated reinforcements shows increased wear resistance as compared to the uncoated reinforcements because of improved wettability and possibly formation of Al_2Cu which hardens the composites.
2) Cu coated reinforcements in hybrid composites showed reduced coefficient of friction when compared with that having uncoated reinforcements
3) Due to the wetting of SiC particles and graphite powders by copper coating , high interfacial bonding strength was achieved which is a key factor in improving wear behavior .
4) SEM observation of wear surfaces of specimens containing Cu coated reinforcements revealed that worn surfaces were smooth and uniform and was incorporated with mechanically mixed layers.

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