MICROSTRUCTURE AND TRIBOLOGICAL BEHAVIOUR OF ALUMINIUM REINFORCED WITH TUNGSTEN CARBIDE PARTICULATE AND FLYASH METAL MATRIX COMPOSITES

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Abstract

Metal Matrix Composites are formed by combination of two or more materials (at least one of the materials is metal) having dissimilar characteristics. In this present investigation, Aluminium (Al 6061) as base matrix metal and Tungsten Carbide (WC) particulate, Fly ash as reinforcements. Fabrication of MMCs was done by stir-casting process. The Tungsten Carbide particulate was added in proportions of 1%, 2%, and 3% and Fly ash was added in proportions of 2%, 4%, and 6% on mass fraction basis to the molten metal. The different combination sets of composites were prepared. The tribological property of Al metal matrix composites, reinforced with WC and fly ash particles is presented. Sliding tests were performed on a pin-on-disk apparatus under different contact loads. It was found that the reinforced WC and fly ash particles could effectively reduce the wear, especially under higher normal loading conditions. In order to further understand the wear mechanisms, the worn surfaces were examined under the scanning electron microscope.

Keywords: *Aluminium metal matrix composite, Tungsten Carbide, Fly ash, Stir-casting, Wear, SEM*

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1. INTRODUCTION

Metal matrix composites (MMCs), like most composite materials, provide enhanced properties over monolithic materials, such as higher strength, stiffness, hardness and weight savings. Aluminium based metal matrix composites are concentrating more for engineering applications since it is the class of light weight and high performance aluminium centric materials system.

Al6061 is the form of aluminium alloy containing magnesium and silicon as major alloying elements, commonly used for aerospace, marine applications, cycling and automotive applications and to make gas cylinders. Al6061 is heat treatable, can be easily welded, with very good corrosion resistance and finishing characteristics. It has medium strength, hardness.

Particulate composites are widely used in composites development because they are cheap and of manufacturing ease. Particulate reinforced MMCs have recently found special interest because of their specific strength and specific stiffness at room or elevated temperatures. Ceramic particles or fibers are commonly used as reinforcement. The basic reason of metals reinforced with hard ceramic particles or fibers are improved properties than its original material like strength, stiffness, wear resistance etc. It can also improve strength to weight ratio of the composites.

Fabrication of composites is commonly done by the stir-casting among the different processing techniques available, because it is simplest and cheapest form, references [8][9][10].

In recent days, considerable work has been done on tungsten carbide reinforced metal matrix composites as well as fly ash reinforced metal matrix composites.

The tungsten carbide is used as reinforcement in Al6061 matrix composites with different weight percentages, references [1][2][3]. The fabrication is done by stir casting process. Wear resistance increases with increase in WC content, in reference [2].

In references [4][5][6][7], fly ash is used as reinforcement in aluminium composites. Fabrication is done by stir-casting method. It was found that as increase in fly ash content, resulted in increase in wear resistance, reference [7].

2. EXPERIMENTAL DETAILS

Aluminium alloy (Al6061) is taken as base matrix metal, tungsten carbide (WC) particulate of 2-3µm size and fly ash are taken as reinforcements. WC was taken in 1%, 2%, and 3% on mass fraction and fly ash was taken 2%, 4%, and 6% on mass fraction.

2.1 Composite Fabrication

Fabrication of composites is done by stir-casting method. Al6061 alloy ingots are kept in crucible and melt in electric resistance furnace at 850˚C. The melt was degassed by adding solid dry hexachloroethane (C_2Cl_6), called degasser. The stirring setup is brought near the furnace; stirrer is dipped inside crucible and stirred at 500rpm. The calculated amount of the preheated reinforcement particles of WC and fly ash were added slowly into the melt. As the impeller rotates it generates a vortex that draws the reinforcement particle into the melt from the surface. The stirring action was carried out about 10-15min. After by removing stirrer setup, the mixed melt is poured to the required preheated metallic mould of 22mm diameter and 220mm length. The molten metal is made to solidify and the prepared casting is removed from the mould.

The casted composites were sectioned and made to prepare dry wear testing specimens as per ASTM standards.

2.2 Wear Test

The specimens were prepared and dry slide wear testing was carried out as per ASTM G99 standard in Ducom pin on disc wear test apparatus. The specimen pin dia. is 6mm. Disc track dia. is 70mm and the specimen pins were rotated against a polished steel disc EN31 hardened to 60HRc. The tests were conducted for 15 min. each under different normal loading conditions, i.e. 5N, 10N, 15N and the sliding velocity is 1m/s.

Fig-1: Wear test specimens

Fig-2: Ducom pin on disc wear test machine

3. RESULTS AND DISCUSSION

3.1 Wear Properties

Table-1 shows the variation of wear of the composites with the different weight fractions of tungsten carbide and fly ash particles. It can be noted that the wear resistance increased with an increase in the weight percentage of tungsten carbide and fly ash. It is observed that lesser wear resistance at unreinforced Al6061 alloy and higher wear resistance at reinforcement of WC-3% wt. and fly ash- 6% wt. This is due to the reinforcement particles imparts the load carrying capacity to the matrix. The highest volume loss is distinct for unreinforced matrix alloy and linearly the volume loss decreased by increasing the percentage of reinforcements. The wear resistance is considerably improved due to the addition of tungsten carbide (WC) particles. Also presence of fly ash strengthen the matrix hence more wear resistance is observed and therefore volume of wear debris increase with increasing normal load resulting in greater wear volume loss.

Table-1: The wear test results.

Volume loss (mm^3)				
Serial No.	**Reinforcement content (%)**	**Normal Load**		
		5N	**10N**	**15N**
1	WC-0% and flyash-0%	2.4881	3.9584	4.7783
2	WC-1% and flyash-2%	2.1771	3.2233	4.2129
3	WC-1% and flyash-4%	2.0640	3.1667	4.1563
4	WC-1% and flyash-6%	1.9792	3.1102	4.1281
5	WC-2% and flyash-2%	1.7530	2.9971	4.0998
6	WC-2% and flyash-4%	1.6965	2.9405	4.0432
7	WC-2% and flyash-6%	1.5551	2.5730	3.9584
8	WC-3% and flyash-2%	1.4420	2.4599	2.7143
9	WC-3% and flyash-4%	1.3572	2.2902	2.4316
10	WC-3% and flyash-6%	1.1875	1.3572	1.6399

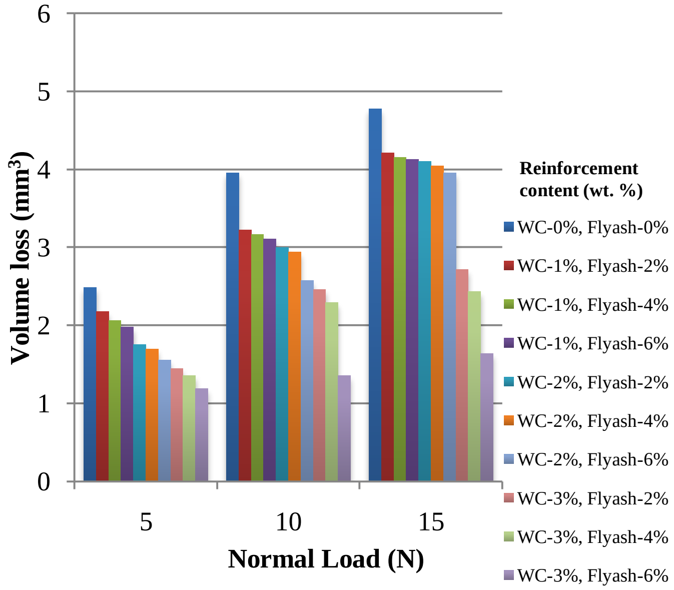

Chart-1: Graph of Volume loss (mm^3) v/s Normal load (N)

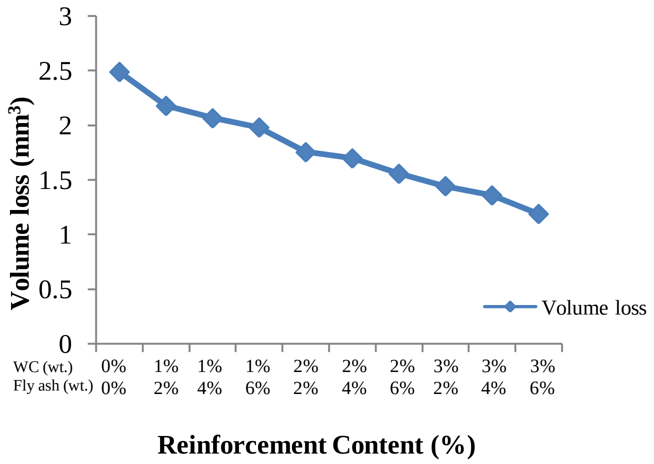

Chart-2: Graph of volume loss (mm$^{3)}$ v/s reinforcement content (wt. %) at 5N load

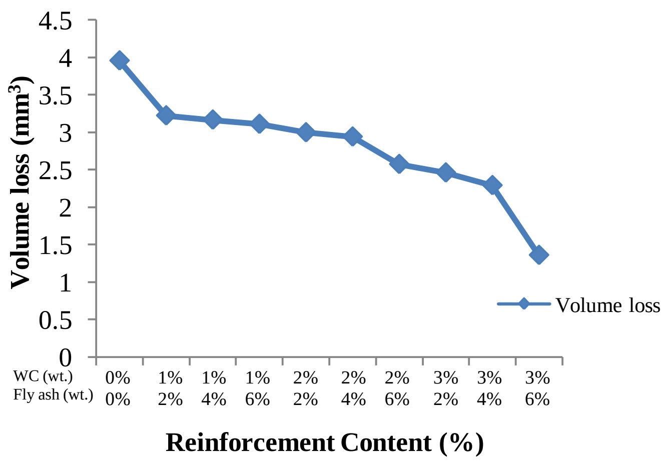

Chart-3: Graph of volume loss (mm$^{3)}$ v/s reinforcement content (wt. %) at 10N load

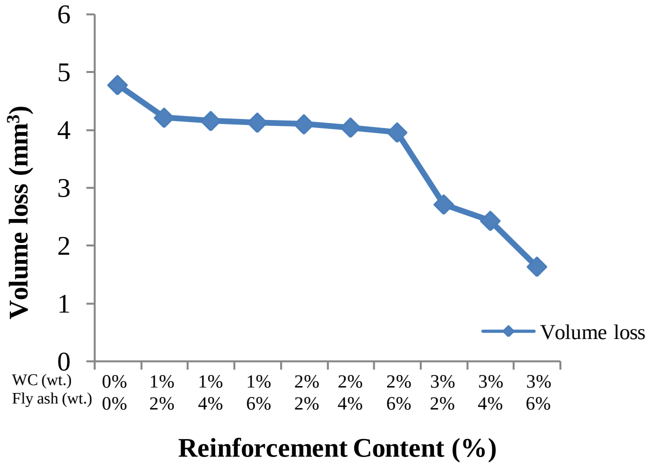

Chart-4: Graph of volume loss (mm$^{3)}$ v/s reinforcement content (wt. %) at 15N load

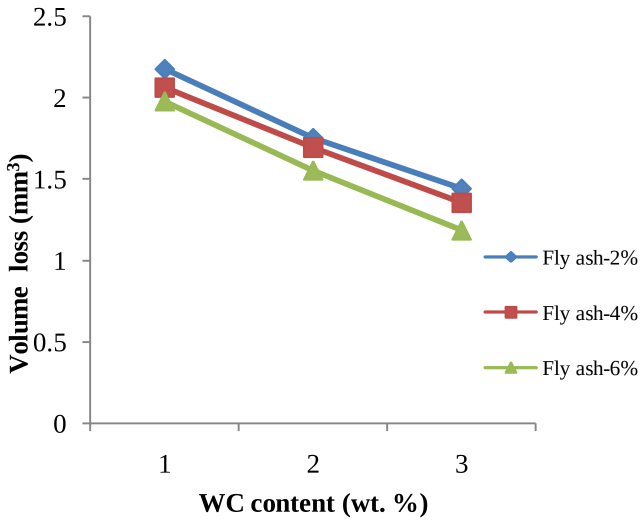

Chart-5: Graph of volume loss (mm$^{3)}$ v/s WC content (wt. %) with varying fly ash content (wt. %) at 5N load

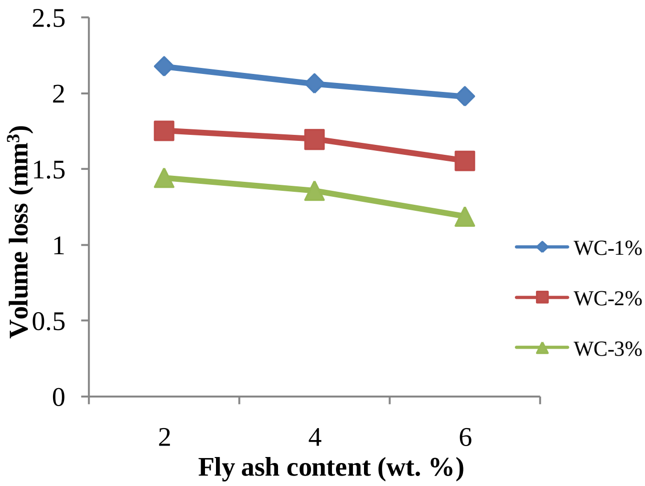

Chart-6: Graph of volume loss (mm$^{3)}$ v/s fly ash content (wt. %) with varying WC content (wt. %) at 5N load

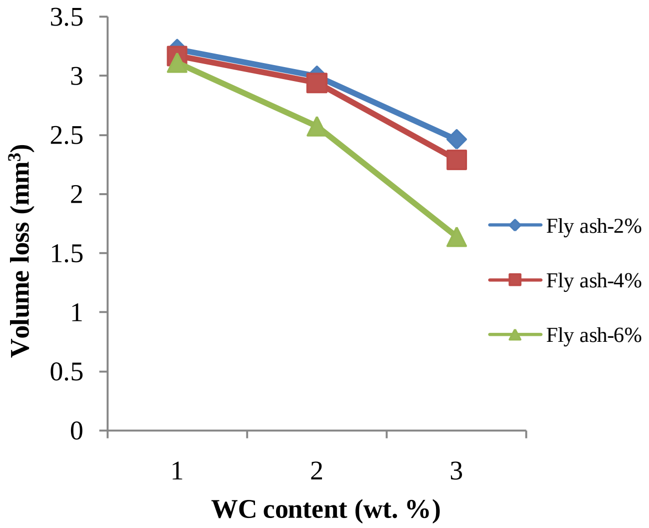

Chart-7: Graph of volume loss (mm^{3}) v/s WC content (wt. %) with varying fly ash content (wt. %) at 10N load

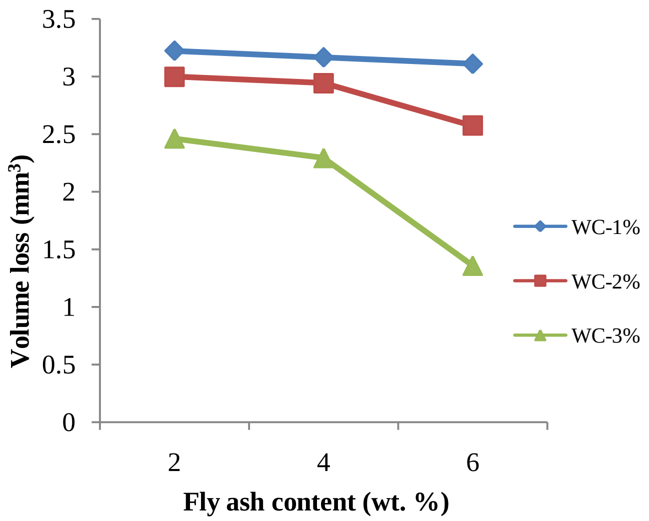

Chart-8: Graph of volume loss (mm^{3}) v/s fly ash content (wt. %) with varying WC content (wt. %) at 10N load

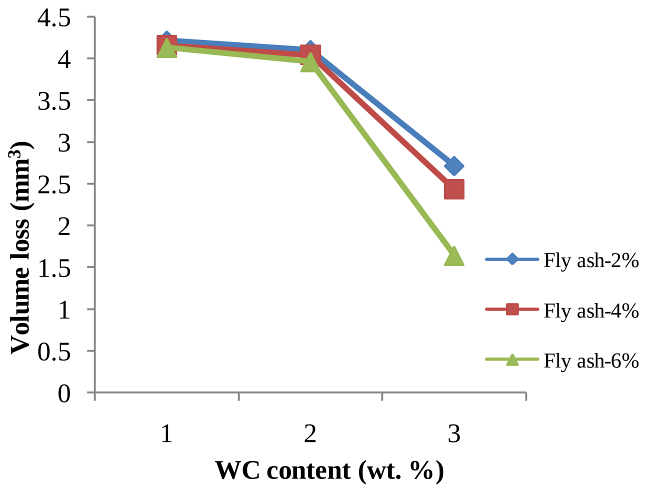

Chart-9: Graph of volume loss (mm^{3}) v/s WC content (wt. %) with varying fly ash content (wt. %) at 15N load

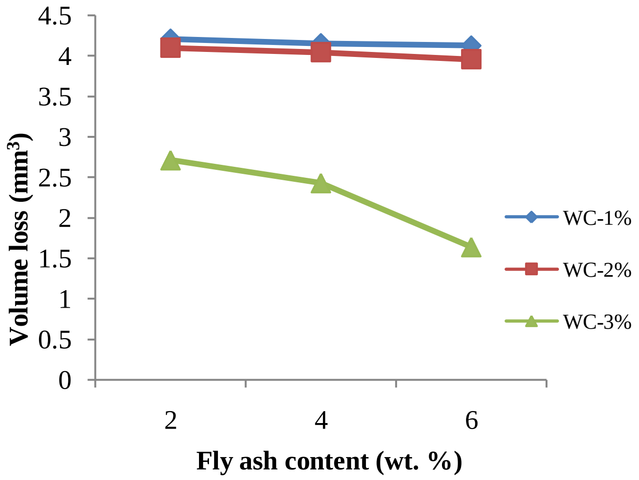

Chart-10: Graph of volume loss (mm^{3}) v/s fly ash content (wt. %) with varying WC content (wt. %) at 15N load

3.2 Microstructure

As the microstructure plays an important role in the overall performance of a composite and the physical properties depend on the microstructure, reinforcement particle size, shape and distribution in the alloy, prepared samples were examined using a Scanning Electron Microscope (SEM) to study the worn surfaces of composites. The micrographs of worn surfaces of composites can be seen below.

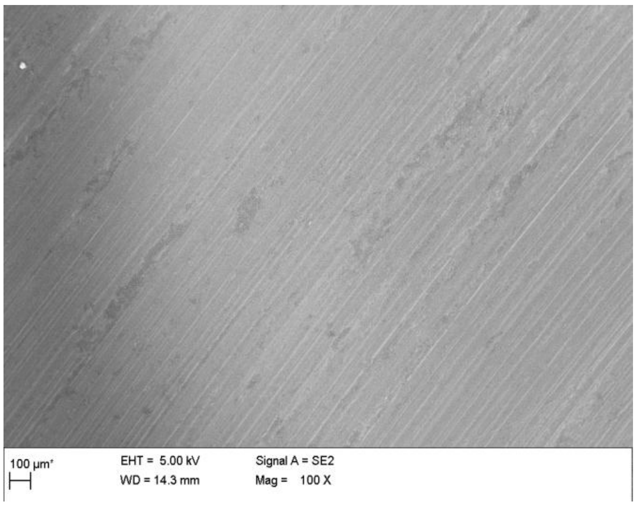

Fig-3: SEM micrograph of worn surface of Al6061+WC2%+fly ash6% at 5N normal load and sliding velocity 1m/s

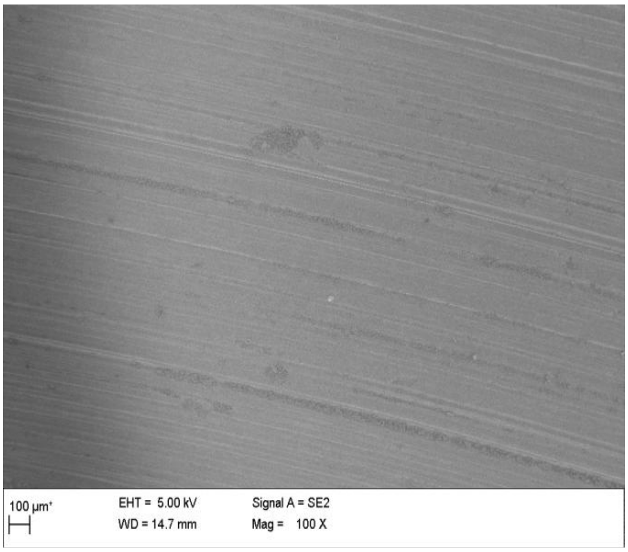

Fig-4: SEM micrograph worn surface of Al6061+WC2%+fly ash6% at 10N normal load and sliding velocity 1m/s

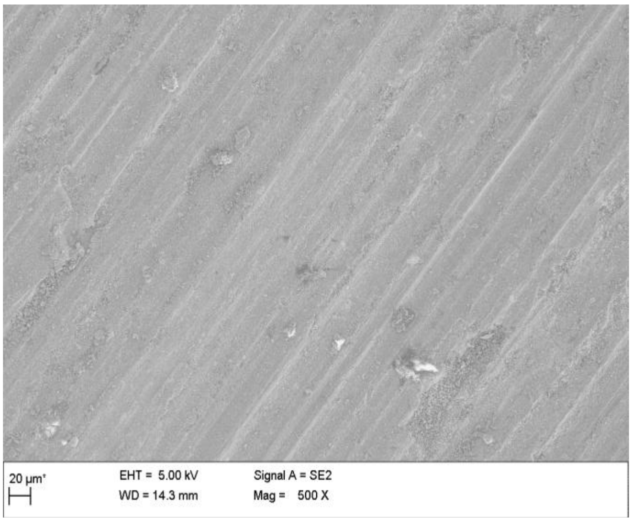

Fig-5: SEM micrograph of worn surface of Al6061+WC 2%+fly ash 6% at 15 N normal load and sliding velocity 1m/s

From fig-3, 4 and 5, it is observed that the sliding wear surface is quite smooth and resulting from adhesive wear. There is no serious material removal observed. In a magnified view, local matrix micro-cracks may occur, which were probably caused by the ‘‘fatigue wear’’ of adhesive contact.

4. CONCLUSION

Al6061 matrix composites were easily and economically fabricated by stir-casting method with tungsten carbide and fly ash particulates as reinforcements.

From dry slide wear test results, wear volume loss of composites increased with increase in normal load and volume loss decreased with increase in reinforced content in all normal loads.

The wear resistance is increased with increase in the addition of reinforced content. It is observed that lesser wear resistance at unreinforced Al6061 alloy and higher wear resistance at reinforcement of WC-3% wt. and fly ash- 6% wt.

The enhancement effect of tungsten carbide reinforcement is more compared to fly ash reinforcement in wear resistance property.

From SEM micrograph studies, it highlights that the sliding wear surface is smoother and no serious particle removal observed. Addition of reinforcement in weight fraction increased that the worn surfaces gradually changes from fine scratches to distinct microgrooves.

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