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Evaluation of Wear Properties of AL2024 Reinforced with Tungsten Carbide Particulate Metal Matrix Composites

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ABSTRACT

Stir cast technique is basically employed in the fabrication of tungsten carbide (WC) reinforced Aluminium (AA) 2024 alloyed AMCs, As it is pronounced for low cost and homogeneous distribution of reinforcement particle in AA 2024 alloy. The use of WC particles in an alloy of AA 2024 ranges from 1wt. % to 5 wt. % in the step of 1 wt. % to prepare composites. As WC is famous for its hardness, which intern shows wear resistant behavior hence it is used as cutting tool material and coating material. Use of such hard and wear resistant particles attributes in improving the properties of soft AA- 2024 alloy, also high tough nature of AA alloy with soft nature give suitable cushioning effect to hard reinforcement. The effect of addition of WC on tribological behavior of WC-AA 2024 composite was investigated by machining the prepared composites to ASTM standard.

Key words: AA-2024 alloy, Friction, SEM of Worned surface, Tungsten Carbide (WC), Wear.

I.INTRODUCTION

Fuel saving is one of the biggest challenge in present day fuel crisis. The use of light weight and high performance aluminium alloy in automotive and air craft application can save the fuel hence such materials are used in the production of suspension, heat shields, steering system, heat exchanger, driveline, radiators etc. [1].Present day industrial application demands high thermal conductive, less dense and corrosion resistance behavior made to choose an alternate material for ferrous material which is an aluminium and its alloy [2], but it has a limited usage in the field of wear related applications as it has poor tribo-logical performance. Researchers have been attempting to develop materials with improved wear and mechanical properties [3]. Composites prepared out of Aluminium alloy reinforced with ceramic particles results in achieving low density, stiffer, high hardness, ductility, good dimensional stability, and other properties [4]. Also the use of hard ceramic particles in AMCs leads to high wear resistance and high strength to weight ratio [5, 6] .Tungsten Carbide (WC) is an attractive ceramic reinforcement which exhibits higher hardness and thermal stability as its melting temperature is 3058K. The use of WC shows superior nature of wear and corrosion resistance nature due to the formation of 6B transition metal carbide makes it as appropriate choice for reinforcement [7]. Residual porosity, segregation of particles and poor bonding strength are the common problems associated with forming techniques [8].The present investigation focuses the significant improvement in tribological properties of AA2024 alloy based composites. The use of hard WC particles in an alloy influences its wear behavior by minimizing the wear loss more effectively when compared to base alloy [9, 10] when the specimen is subjected to wear at different loading condition. The presence of such hard particles in a AMC helps in pushing the seizure on the higher loading at constant velocity of sliding.

II.MATERIALS AND EXPERIMENTAL PROCEDURES

In this study, AMC was developed by using AA 2024 as primary alloy phase and WC reinforcement particle as secondary phase. The use of WC in a composite will have the size of 60µ. Stir casting technique is one of the liquid metallurgical techniques adopted in preparing composites because of its economic nature. During the process, the base alloy was melted to a temperature of 660^0C and the temperature was further increased to a temperature from 750^0C to 800^0C then the pre heated WC to the temperature of 400^0C was added to the melt for different composition of WC in the proportion 0, 1,2,3,4 and 5wt% [11, 12]. The proper mixture was poured into a permanent mould cavity of standard size 12 mm diameters and 250 mm length by proper stirring to a speed of 450rpm using mechanical stirrer. After solidification these specimens are machined to suit the requirement of ASTM as shown in Figure (1) and wear test was performed for different loading condition followed by SEM analysis for worn out surface to identify the superior properties of AA-WC composites.

Figure1 AL2024/WC composite Wear specimens

Figure 2 Pin on Disc wear testing machine

Wear test- Pin on disc method is employed to check the wear behavior of composites as shown in Figure (2). The specimen under goes sliding wear test has to be forced against SiC abrasive paper of 220, 320, 400 of grit and it is attached to the pin on disc machine, exactly perpendicular to the rotating disc. An applied load of 10N, 30N and 50N were applied for each specimen with varying percentage of WC [4]. Initially the pinned specimen was weighed using standard weighing machine. The prepared pinned samples with varying % of WC composites were subjected to above test to analyze the effect of applied load and varying % of WC. For statistical purposes, three runs were performed with different samples for each wear condition using new abrasive papers in each case. The samples were ultrasonically cleaned in methanol, then dried at 60^0C for about 30seconds and weighted in order to calculate the weight loss of the specimens in each interval of the test. The micro structure study of the worned samples was performed by scanning electron microscopy (SEM).

III.RESULTS AND DISCUSSION

Table 1 is a result of wear in grams of AA 2024-WC composites with varying percentage of WC when it is subjected to different loading condition. Each test samples are tested to a constant speed of 300rpm with a sliding distance of 1.5Km. The prepared composites are subjected to wear test by varying load and summarized and discussed below. From the wear test results in table(1) the wear rate was expected to be decreased with the addition of WC from AA 2024-0wt% WC to 3wt% WC [8], after that the increase in wear rate was predominated due to brittle nature of composite ie for 4% WC and 5% WC.

The wear rate of alloy and prepared composites also influenced by applied load. Increase in wear rate with an increase of load at constant speed in prepared composite and base AA 2024 alloy. Similar observation was reported in the influence of particle size on wear rate of fly ash in A-380 Aluminium matrix composites [13]. The increase in applied load results in adhesive wear followed due to plastic deformation with increase of specific load [14].

Load (N)	0% WC	1% WC	2% WC	3% WC	4% WC	5% WC
10	0.00031	0.00026	0.00022	0.00021	0.00035	0.00035
30	0.00053	0.00048	0.00044	0.00042	0.00066	0.00065
50	0.00076	0.00069	0.00066	0.00064	0.00093	0.00092

Table 1 Wear loss grams of AA2024-WC composites subjected to dry sliding wear

3.1 Effect of ploughing component of friction on composites.

Figure (3) shows wear loss as a function of WC content in AA 2024 matrix. The plot shows that volume loss decreases with an addition of WC percentage. From the result it is clear that lesser percentage of WC in a matrix exposed the softer surface during sliding action, as a result easy removal of particles from sliding surface was more effective through ploughing action causing surface roughness, volume loss and irregularities on the surface. Due to the sliding action of soft material, polished surface was expected in the initial stage. But it will not last for a long period because the surface layers are removed continuously with excessive temperature developed due to friction causing surface roughness again.

The friction between two sliding surface develops excessive temperature which removes soft material due to surface roughness forms irregular pattern. The soft surface is more expected in the composite if the WC content is less there by increases and volume loss of material. When the wear load is increased, the corresponding increase in volume loss is observed in AA 2024 alloy and AA- WC composites.

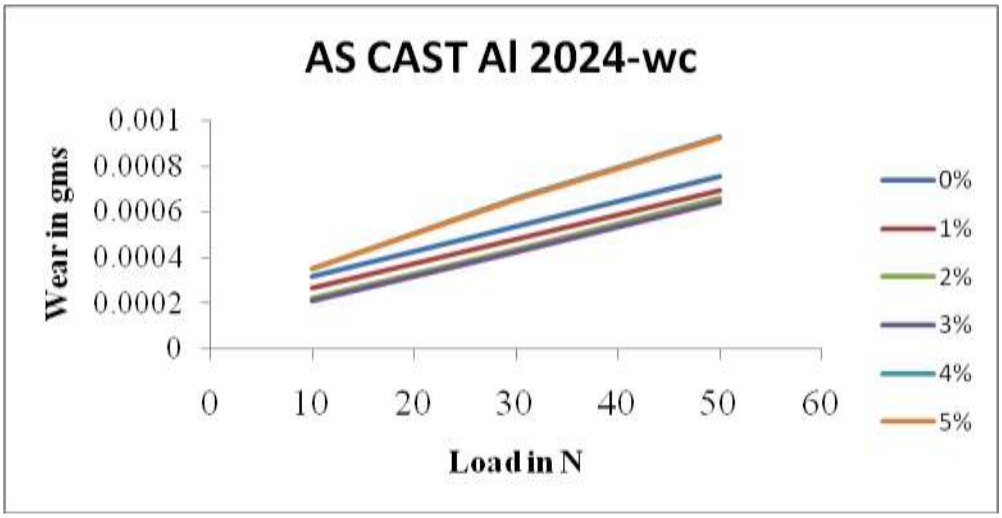
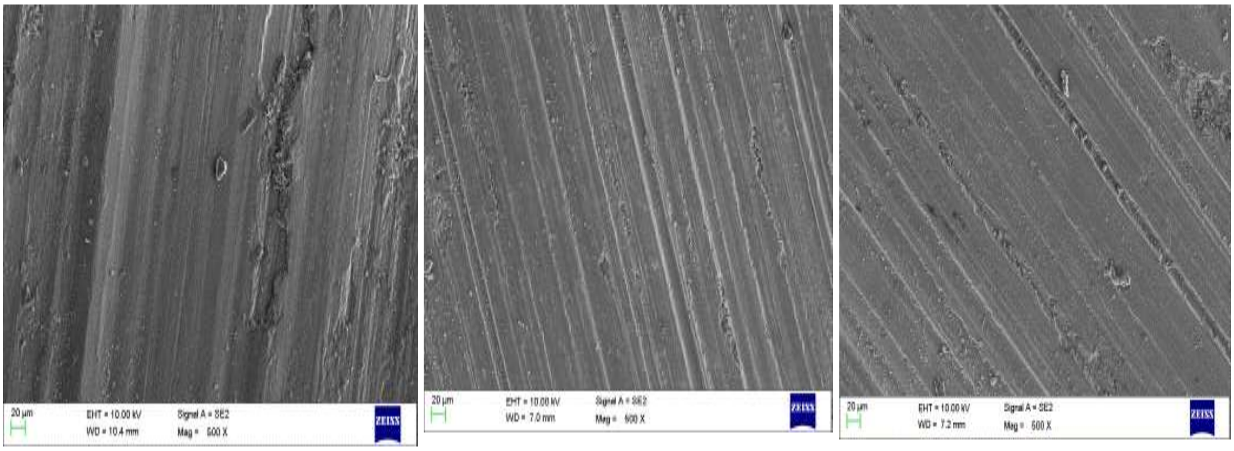


Figure 3 Applied Load (Newton) V/s Weight loss in grams for varying percentage of WC



A. Applied load of 10N on AA 2024/3% WC composite sample

B. Applied load of 30N on AA 2024/3% WC composite sample

C. Applied load of 50N on AA 2024/3% WC composite sample

Figure 4 SEM of Wear surfaces of AA-2024 with 3% WC composite subjected to different loading conditions.

A close up by SEM on micro structures (Figure 4) is a SEM structure of AA 2024 alloy with 3wt % WC composite subjected to wear with loads of 10N, 30N and 50N revealed the presence of WC which was observed as round isolated precipitates. The WC particles used in MMC reduces the wearing effect. Due to the casting of AA2024 with WC composites, the inter metallic particulates get dissolved in matrix medium leading to modification of grain structure there-by improving wear properties. From the figure it is evident that increase in the load results in increased wear rate which was shown in figure as more plowing of surface, due to the presence of hard carbide particles forcing the aluminium surface to plow.

IV.CONCLUSION

- The SEM of Al2024 composites produced by stir casting method showed that the better uniform distribution of WC in the matrix metal.
- The reduction in wear rate was observed with the addition of WC during dry sliding process.
- The SEM study cleared the surface behavior which has rougher worn surface in case MMCs compared to base alloy, this infers the abrasive wear happened during the wear process due to hard WC particles exposed on the worn surface.
- SEM structure also showed the three modes of wear which are adhesion, abrasion and delamination. Abrasive wear is expected under low load condition. Adhesive and delamination wear results due to high load.
- The composite with 3%WC is best for high load applications.
- From the microstructure of the specimens it is seen that damage of composite with 3% WC is very low compared to Base alloy. Therefore it is recommended that the composite with 3%WC is the best for engineering applications composite.

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