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Investigation on the Effect of Coating for the Scratch Resistance of Aluminium Matrix Composite Reinforced with SiC Particles

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Abstract

The requirements of the current engineering industry cannot be met by conventional materials. The opportunity to make composite materials comes from combining two or more different, chemically non-reactive, and easily producible elements to satisfy the demand of the ever changing requirements. An impressive strength to weight ratio and improved mechanical properties attracted many researchers. In this investigation, aluminium 6065 with SiC particles of various concentrations are prepared by stir casting method. The effects of Ni-Cr coating on SiC particle reinforced aluminium composite on the scratch resistance was investigated for constant loading of 30N. The friction coefficient and scratch morphology of the aluminium matrix composites were also studied using scratch tests. It is observed that the higher the particle content offers more resistance for the scratch when compared to lesser concentrations of the particles in the matrix material. The coating offers more resistance for the scratch in comparison with un coated specimens.

Keywords **—Aluminium Matrix Composites, Ni-Cr Coating, Scratch Test**

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1.INTRODUCTION

Metal matrix composites are metals reinforced with other metal, ceramic or organic com- pounds. They are made by dispersing the reinforcements in the metal matrix. Reinforcements are usuallydone to improve the properties of the base metal like strength, stiffness, conductivity, etc.Aluminium and its alloys have attracted most attention as base metal in metal matrix composites [1]. Aluminium MMCs are widely used in aircraft, aerospace, auto- mobiles and various other fields [2]. The reinforcements should be stable in the given working tem- perature and non-reactive too. The most commonly used reinforcements are Silicon Carbide (SiC) and Aluminium Oxide (Al2O3). SiC reinforcement in- creases the tensile strength, hardness, density and wear resistance ofAl and its alloys [3]

MMCs are no exception to the coating application in a variety of industries, including aerospace. Although aluminium alloys have great bulk mechanical qualities, their surfaces are prone to wear and corrosion, rendering them unsuitable for many applications. The 7075-T6 aluminium alloy was tested for rotating bending and 3 percent NaCl solution using a WC–10Co–4Cr cermet [4].Some literature with their findings are concluded that the coating significantly impacts the substrate's fatigue strength, making it a feasible fatigue option. Electrolytic hard chrome plating (EHC) and chromic acid anodizing (CAA) have been widely utilized to improve the surface characteristics of metals [5–10]. However, the use of hexavalent chromium in these treatments is well-known and is governed by solid international health and environmental laws [11-14].

EHC plating benefits both ferrous and non-ferrous surfaces, significantly reducing fatigue for the aeronautic and aerospace industries. Various coating compositions with substrate and their finding on the different behaviors have been tabulated. Puchi-Cabrera and co-workers [15] the presence of the coating dramatically boosts the substrate fatigue resistance, indicating that it may be a significant option for electrolytic hard chromium plating for aerospace industry. Based on the optimum changing pressure applied to the coated system, the final fatigue fracture may be caused by the joint action of huge cracks propagating from the substrate–coating interface as determined by fractographic specimens' analysis. The absence of grit blasting before HVOF deposition does impact the coated system functioning, and it also precludes the introduction of extra acute stress concentrators that could lead to fatigue fracture formation. The findings are discussed, and the necessary conclusions are being drawn. The impact of treatments and coatings on carbon/graphite, alumina (Al_2O_3), and silicon carbide (SiC), reinforcements on the characteristics and interface structure of aluminum alloy matrix composites. By alloying with the matrix, metallic coatings improved reinforcement wettability and altered matrix alloy composition. Ceramic coatings act on the diffusion barrier thus minimizing the interfacial reaction between the matrix and reinforcement.The exterior damages to surfaces of the components may happen throughout the processes of manufacturing, repairing, and providing services owing to accidents like the fall of tools or scratches by sharp objects. One of the most dangerous surface flaws is the scratch caused by accidents. Study [16] reported that a small scratch can significantly reduce the fatigue life of aluminum alloys. Many factors associated with the scratch may influence the fatigue performance These factors can be classified as, morphology and configuration of the scratch, residual stresses around the scratch, and microstructure characteristics of the material in the vicinity the scratch.[17]. Nishimura et al. [18] conducted torsional fatigue tests and rotating bending fatigue tests on specimens with scratches, and pointed out that when the direction of a scratch is perpendicular to the maximum principal stress, the fatigue performance is degraded most.

2. Materials and experimentation

Among many materials, aluminum suits most applications because of its agility to take different forms, light weight, low melting temperature, good mechanical properties, availability, and ease of handling.

2.1 Stir casting method

Stir casting is recognized as a low-cost method for creating aluminium metal matrix composites (AMMCs). Its benefits include being simple to use, adaptable, and suitable for mass production. This technique allows for the production of incredibly huge components and is the most economical of all AMMC manufacturing techniques. The stir casting process setup are shown in figure 1 below. There is no chemical contact between the matrix alloy and the reinforcement. A critical trait that defines the quality of bonding between constituents is good wettability, which has a significant impact on the characteristics of composite materials. [19,20].

Wettability and reduced porosity were increased by preheating the reinforcement particles , which allowed moisture to escape and resulted in the sound casting. The preheating of the mould, according to the researchers, has a good effect on the final casting. The ultimate mechanical and microstructure properties of the composites are influenced by a number of factors. For a casting to be structurally robust, the stirrer speed, stirring period, and pouring temperature are all crucial factors. [19].

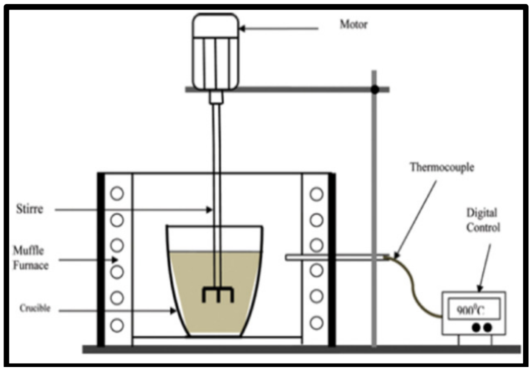

Figure 1: Stir casting arrangement

Tests are conducted for constant normal load and ramp load using the diamond indentor on the digitally controlled scratch tester. DUCOM Scratch tester TR-101 model as shown in figure 2 is used for generating scratch on the surface of the composite. Different loading types such as constant load and ramp load with different intensities have been analyzed. Diamond indentor with 45^{o}angle is used for the test. Below figure 2 shows the computerized scratch testing machine

Figure 2: DUCOM Scratch tester TR-101

The specimens are fixed on the table with attachments, after fixing the specimen, types of loads and intensity, stroke length, off set distance can be selected. After parameters are set, the indentor will move above the specimen. The scratch will be initiated and the traction force v/s stroke length graph will be shown on the display provided. After the scratch, the camera captures the high definition image of the scratch and stored for the analysis. For each specimen the above steps are repeated until all specimens are being tested against scratch resistance

Scratch test was carried out for reinforcement concentration of 8%weigth and coating thickness of 100 and 200 microns . Constant load of 30N and the stroke length of 10mm is considered for the testing. From the result it was observed that at the initial stage the scratch resistance increases and reaches constant value. The traction force increases initially up to certain length of the stroke and is remained constant throughout the stroke. From the scratch test it was observed that the effort required to produce the scratch on the specimen reduced with the increase in the coating thickness. It is observed that the coating materials are deformed to allow the indenter to more with minimum resistances.

3. Results and discussions

3.1 Effect of constant load on 8% SiC particle concentration without coating

To investigate the effect of the constant load, 30N is applied to the indentor, the traction force required to make scratch on the surface is shown in the figure 3. The difference between the traction force and the normal load is the force required by the indenter to overcome the resistance of the material for the scratch to be developed on the surface of the material

Initially high resistance is offered by the material this can be observed in the graph up to 0.8 mm the rise in the traction force required. As the material deformed, it flows outwards to make a way for the scratch to be developed, this reduces the force required to overcome the resistance of the deformed material and maintains the constant traction force around 10N throughout the 10 mm stroke length.

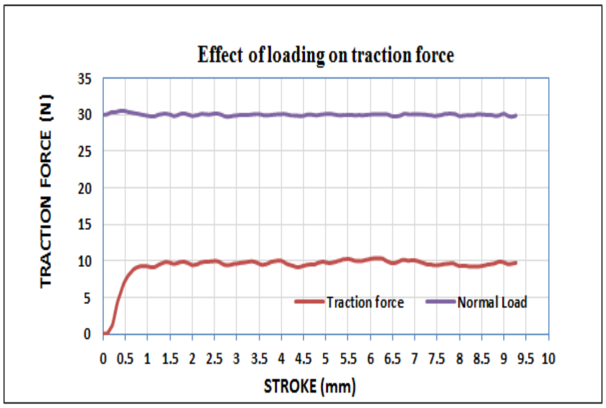

Figure 3: Effect of 30N constant load on scratch resistance of 8% SiC particle: Traction force

Initially high resistance is offered by the material this can be observed in the graph up to 0.8 mm the rise in the traction force required. As the material deformed, it flows outwards to make a way for the scratch to be developed, this reduces the force required to overcome the resistance of the deformed material and maintains the constant traction force around 10N throughout the 10 mm stroke length.

It is further observed in the figure 3, at nearly 4.15 mm stroke there is a peak in the traction force, which is illustrated in the above image, similarly many such peaks on the graphs show the particle resistance for the scratch. This also indicates the particles have distributed throughout the length of the stroke, the value of the traction force indicates the extra force required to overcome the resistance of the particle in the track of the indentor for the tested composite specimen

During testing of the above specimen, coefficient of friction (COF) has been recorded. This value represents the amount of friction offered for the movement of the diamond indenter in the surface. COF is the representation of friction it is observed that at the same place at nearly 4.15 mm stroke length where the particles have obstructed the movement of the indenter, the COF has increased d as observed from the figure 4.

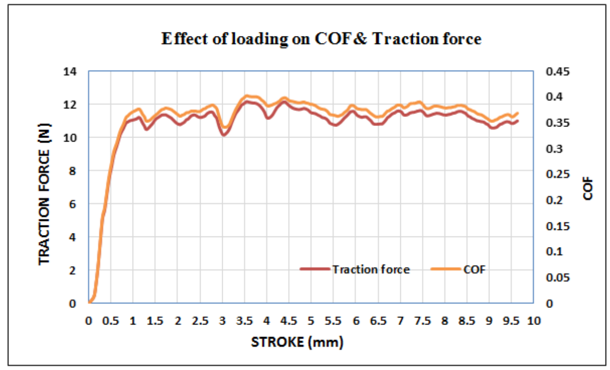

Figure 4: Effect of 30N constant load on scratch resistance of 8% SiC particle: COF & Traction force

It is also observed that the material is undisturbed it indicates the resistance offered by the composite for the scratch to progress.

3.4 Effect of coating on scratch resistance for 8% SiC with constant load

Tests were further conducted for nickel chromium coating for 100, 200 microns thickness. Similar loading parameters were considered, and the results were shown in figure 5. The traction force for without coating and with coating for varying thickness are plotted. It is observed that, coating is well adhered to the substrate, and it has not pealed out. It is the strong bonding between the substrate and the coating which allows better surface characteristics of the coated specimen. The traction force required for 100-micron thickness is much lower than the uncoated specimen as the depth of penetration is not enough to scratch thorough the surface and in to the substrate. The increases in the coating thickness had shown that the material offers less resistance for the scratch

It is observed from the above figure 5 that the constant traction force is increased from 0 to 11.2 N and maintained the steady average value of around 11-12 N

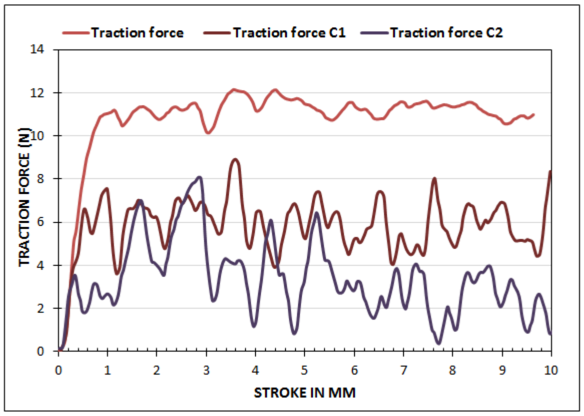

Figure 5: Effect of 100, 200-micron coating thickness on scratch resistance for 8% SiC

. The variations of peaks and valleys over the entire length of travel of the indenter indicate that the particles have uniformly distributed over the entire surface of the composite specimen. Similarly, the 100 microns coating thickness coating is experiencing traction load in a range of 4-7 N the difference between the normal loads the traction force is the resistance offered by the coating material.The hard particle coating resisted less in compared to uncoated specimen. It is noticed that the indenter has plastically deformed the coating particle and the surface cracks on the scratch path The width of the scratch measured is around 170 microns and the indenter moves with less resistance on the coating material.

For 200 microns coating it is observed that the deformation of the coated particles is reduced further as the hardness is increased. This requires less traction load to be applied on the surface of the coating for producing the scratch. Further observation revealed that indenter has made less penetration in the coating surface that less force is applied on the 200-micron coating in comparison with 100 microns coated specimens. The scratch direction and the plastic deformation of the particles have shown the resistance offered by the particles for the scratch

4. Conclusions

1. Aluminum matrix composites reinforced with 8%wt. SiC particles were successfully fabricated by stir casting method

2. Under the present scratch test conditions, coating of Ni-Cr has reduced the force for the scratch as the harder particles have less friction for the movement and more uniform partical distribution..

3. Increasing in the coating thickness from 100 to 200 microns, has further reduced the traction resistance for the scratch formation. This is mainly because better surface characteristics and better wettability between initial coating and the final coating

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