IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

Impact Factor: 5.731

Volume 6, Issue 2, June 2021

Influence of Loading Parameter on the Scratch Resistance of Aluminium Matrix Composite with SiC Particle Reinforcements

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Abstract: *The advent of developing newer materials gives ways to composite materials. The unique properties such as strength to weight ratio and improved mechanical properties attracted many researchers. In this investigation, aluminium 6065 with silicon carbide particles of various concentrations are prepared by stir casting method. The effects of particle content (8 to 12wt %), for constant loading of 30 N on the scratch resistance of the composites were investigated. 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. Experiments are being conducted for various particle contents and appropriate conclusions are being made.*

Keywords: Aluminium Matrix Composites, SiC particle, Scratch Test

I. INTRODUCTION

The aircraft, aerospace, and automotive sectors frequently use aluminium matrix composites (AMCs) reinforced with ceramic particles due to their high stiffness, strength-to-weight ratio, low coefficient of thermal expansion, and exceptional wear resistance [1]. Excellent casting qualities make aluminium alloy a popular choice for complicated geometries. These cast components are subjected to cyclic loading in engineering practice, which may cause fatigue failure [2]. Al/TiB_2 nano-composites were created using the powder metallurgy method by first pressing aluminium powder with varying TiB_2 volume ratios, and then sintering them between 620 °C and 690 °C [3-5]. Haghighi et al[6] considered Al-5 by vol% and Al_2O_3 by equal channel angular pressing and extrusion and compared the physical and mechanical properties. Studies are conducted on preparing the AMCs reinforced by two sizes of alumina particles by hot forward extrusion and wet attrition milling processes [7].

Duirs R L et al. [8] evaluated the fracture toughness of constituent phases by means of a scratch test with an increasing force. The phase was not considered due to the escalating level of pressure. This approach distinguished the shift from ductile to brittle abrasion based on the onset of lateral cracking. It was observed that the ratio of fracture hardness to toughness determined to investigate whether the material was ductile or brittle.In numerous scratch investigations, abrasive materials (quartz and alumina) were utilized instead of the usual diamond indentor to simulate abrasive wear in dual-phase alloys. Further studies on the use of diamond indentors and AI_2O_3 in scratch experiments on Co-based alloys to investigate the mechanisms for removing the material are being investigated[9].

The cohesion or adhesion bond strength of thin and thick coatings can be evaluated in the laboratory using a variety of test procedures.[10]. However, each one has its own set of advantages and limitations. The scratch test is easy to use and doesn't need any further specimen preparation, despite the fact that it is not as accurate as other techniques. Scratch testing is a remarkable tool for optimizing plasma spraying settings. It has been used for a while to figure out how well a coating adheres to its base. [11]. The adhesion and failure processes of thin layers (20 m) have previously been investigated by scratching the coating's surface. The faults introduced during composite processing can reduce fatigue

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performance and cause early failure. Thus, a method for quantitatively evaluating these flaws that takes into account, both safety and economics needs be developed [12].

II. 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. The following table 1 shows the composition of the aluminium 6065 alloy

Table 1: Composition of 6065-Aluminium alloy [7]

%Al	%Bi	%Si	%Fe	%Cu	%Zn
94.4-98.5	0.5-1.2	0.4-0.8	0-0.7	0.15-0.4	0-0.25

2.1 Stir Casting Method

Stir casting is widely regarded as a low-cost approach for fabricating aluminium metal matrix composites (AMMCs) in the commercial world. Its advantages are its ease of use, adaptability, and suitability for large-scale production. This method is the most cost-effective of all the AMMC manufacturing methods, and it enables the fabrication of extremely large components. The following figure 1 shows the arrangements of the stir casting process. Between the reinforcement and the matrix alloy, there is no chemical interaction. Good wettability is a critical property that defines the quality of bonding between constituents, as a result, has a substantial impact on the properties of composite materials [13,14].

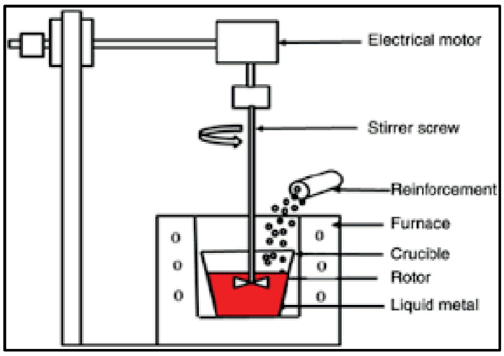

Figure 1: Stir casting arrangement

Preheating the reinforcements improved good wettability and less porosity, allowing moisture to escape and produce the sound casting. The researchers observe that preheating the molds positively impacts the final casting. Many variables influence the composites' final mechanical and microstructure properties. The stirrer speed, stirring time, and pouring temperature plays a vital role in producing a structurally sound casting [15]. 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 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. 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

III. RESULTS AND DISCUSSIONS

The specimens prepared by stir casting technique is being utilized to for scratch testing under standard loading conditions and at room temperature

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3.1 Effect of Constant Load on 8% SiC Particle Concentration

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 2.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

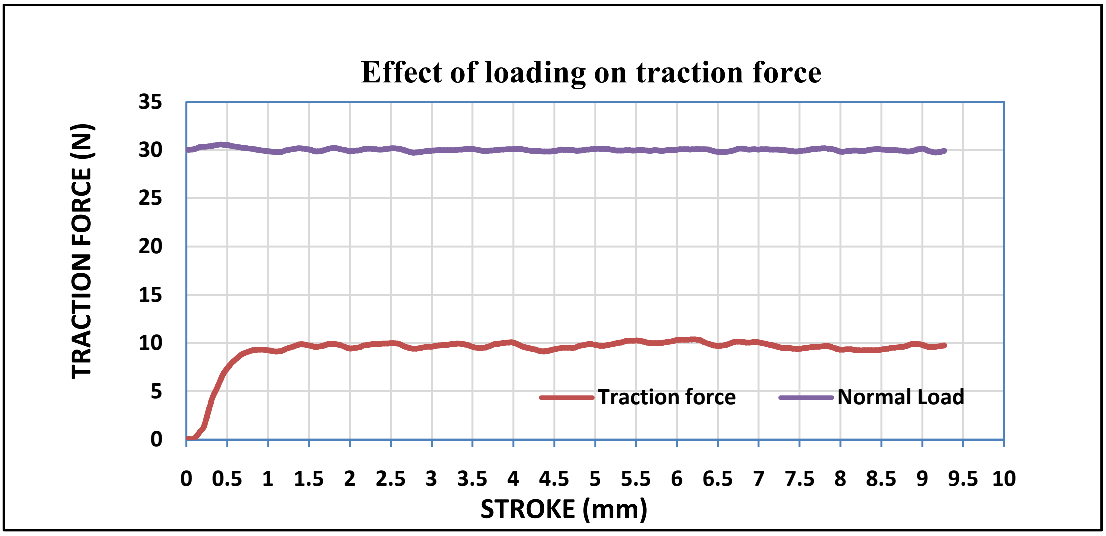

Figure 2: Effect of 30N constant load on scratch resistance of 8% SiC particle: Traction force

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 can be observed from the graph, similarlymany 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.

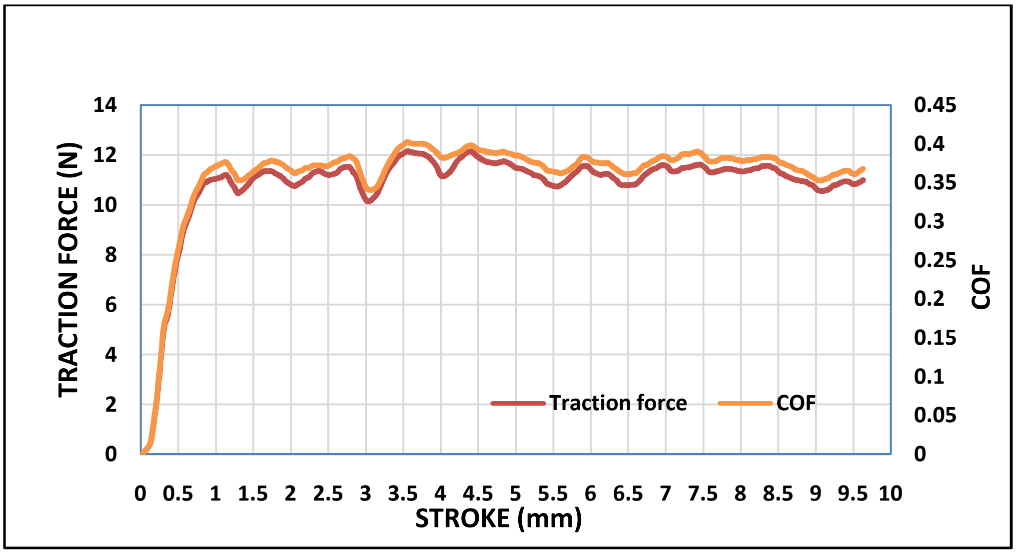

Figure 3: Effect of 30N constant load on scratch resistance of 8% SiC particle: COF & Traction force

DOI: 10.48175/IJARSCT-6576

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 as observed from the above graph. It is also due to the material is undisturbed it indicates the resistance offered by the composite for the scratch to progress.

3.2 Effect of Constant Load on 10% SiC Particle Concentration

To analyze 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 5. Initially high resistance is offered by the material, this can be observed in the graph up to 0.7 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.

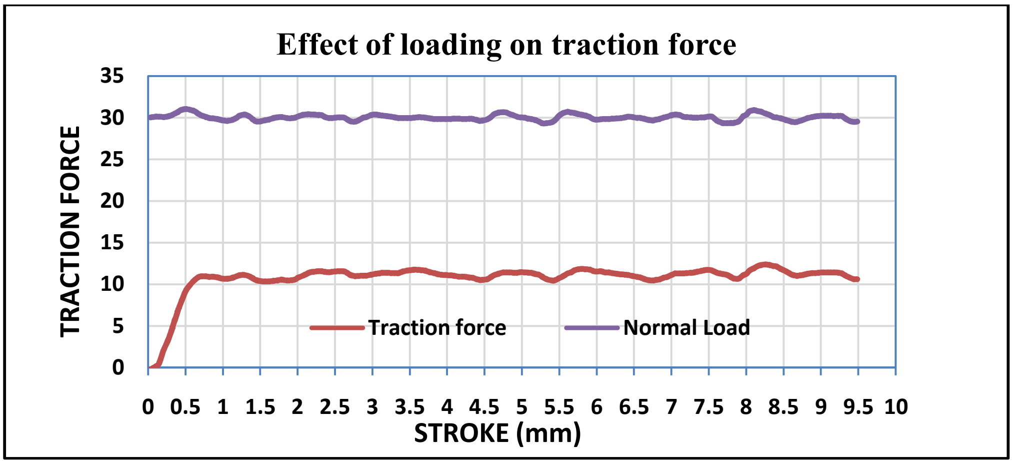

Figure 4: Effect of 30N constant load on scratch resistance of 10% SiC particle:Traction force

It is further observed in the figure 4, at nearly 8.2 mm stroke there is a peak in the traction force this is reflected on the image of the scratch below the graph. Similarly, many such peaks nearly at 1.25, 5.75 mm are observed on the graphs, this shows the particle resistance for the scratch. This also indicates the particles have distributed throughout the length of the stroke

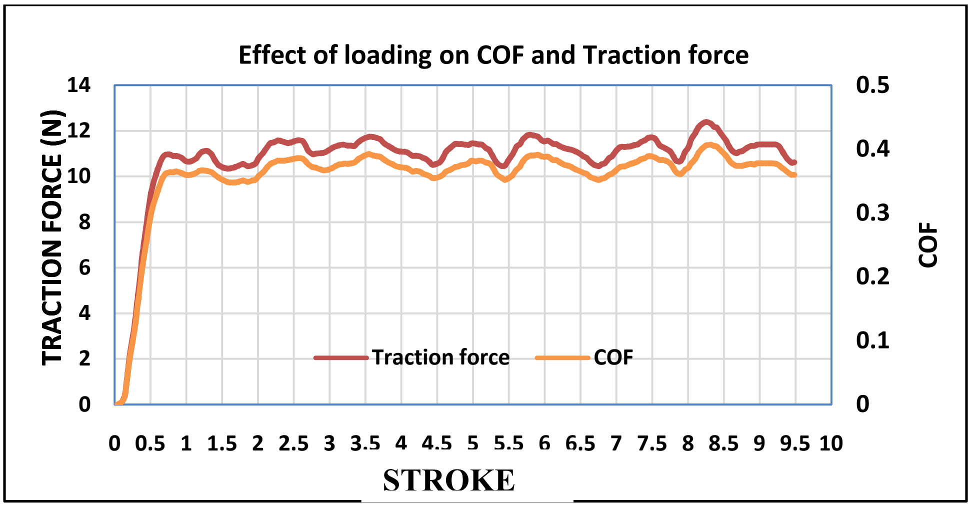

Figure 5: Effect of 30N constant load on scratch resistance of 10% SiC particle:COF & traction force

For the above testing, 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 8.2 mm stroke length where the particles have obstructed the movement of the indenter,

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the COF has increased as observed from the figure 5. It is the result of the un uniformly distributed material, this causes resistance by the composite for the scratch to progress.

3.3 Effect of Constant Load on 12% SiC Particle Concentration

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 6. 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.

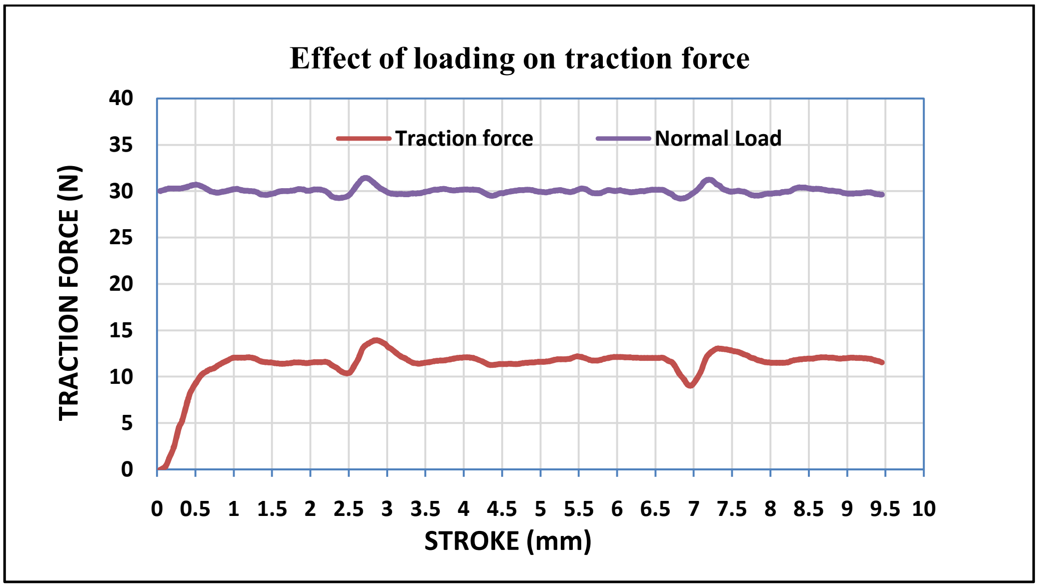

Figure 6: Effect of 30N constant load on scratch resistance of 12% SiC particle: Traction force

Initially high resistance is offered by the material this can be observed in the graph up to 1.1 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 to 14N throughout the 10 mm stroke length.

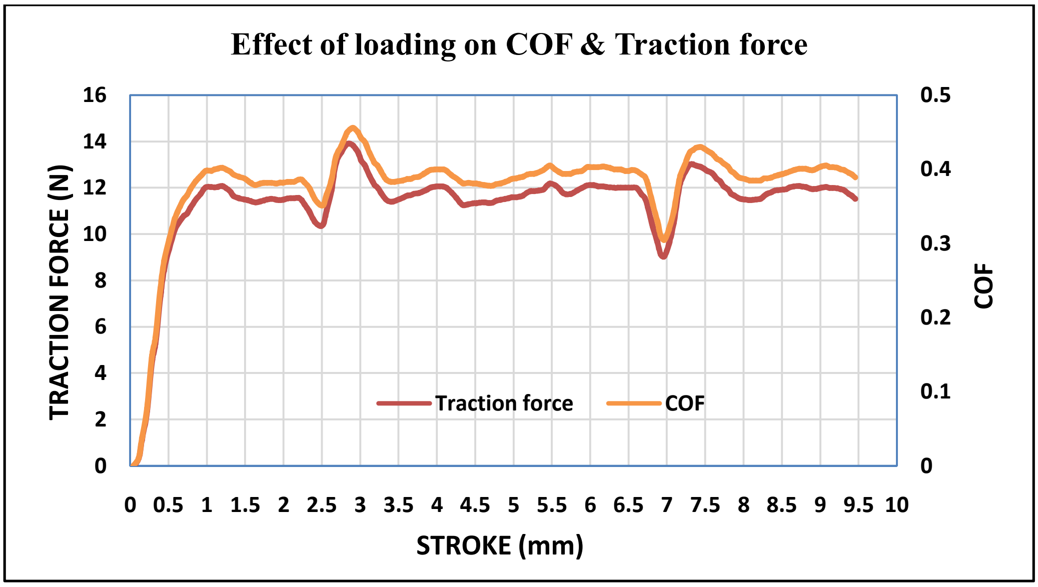

Figure 7: Effect of 30N constant load on scratch resistance of 12% SiC particle:COF & traction force

It is further observed that at nearly 3.0 mm stroke there is a peak in the traction. Similarly at 7.0 mm there is a valley to indicate the particle is removed and the load required is very less Hence the valley to show less force is required to overcome the scratch resistance is observed. Many such miner peaks on the graphs shows 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 indicate the extra force required by the indenter to overcome the resistance of the particle in the track of the indenter.

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 3 mm stroke length where the particles have obstructed the movement of the indenter, the COF has increased d as observed from the figure 7. It is also shown in the image that at 7.0 mm the removal of clustered particle has less resistance to offer and hence the value is reduced. The trend of variation of COF shows that the particles are being distributed evenly through the length of travel of the indentor. The corresponding variations in the values are being seen in the above graph.

IV. CONCLUSION: THE PRESENT STUDY SHOWS

(1) Aluminum matrix composites reinforced with in SiC particles were successfully fabricated by stir casting method

(2) Increase in the particle concentration increases the traction force for the given particle size. This can be attributed primarily to the ununiformed distribution of the particles which causes clusters and requires more force to produce the scratch.

(3) For a constant load of 30N throughout the length of travel the traction force is increased initially and remains constant. This indicates that initial resistance is increased and then remains constant due to constant load.

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