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Mechanical properties of Al-SiC Nano Composites fabricated by Friction Stir Processing

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Abstract. Aluminium metal matrix composites finds its application in aerospace, automobile, and energy industry owing to their excellent mechanical properties such as low density high strength, light weight, high strength-to-weight ratio and fatigue and corrosion resistances. Further the addition of nano size particles improves mechanical properties of the composites. The present work is focused on the mechanical performances of aluminium SiC nano composites. Instead of making bulk composites, the surface layers on the substrate improve the mechanical properties. For the fabrication of such surface composite layer, the new modification technique, friction stir processing (FSP) is used. FSP technique is used to produce defect-free surface composite with a good bonding and uniform distribution of reinforcement particles within an aluminium matrix. Various process parameters such as rotational speed, transverse feed, and volume fraction of nano SiC, on mechanical properties is investigated. The mechanical properties such as micro hardness and flexural strength were measured using micro hardness tester and universal tensile testing machine respectively.. In addition to that the morphology of the specimen is examined through scanning electron microscope to study them in detail.
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1. Introduction

In the modern era, a material with high strength is a basic requirement for various engineering applications. In order to satisfy these needs, composite materials have found a wide range of applications in various industrial components and structures because of their improved mechanical properties. Among various types of composites materials available, metal matrix composites plays a vital role in terms of high strength or stiffness, low density, good corrosion as well as fatigue resistance. For further improving the mechanical properties of such composites, the widely practiced method is the incorporation of either micron/Nano-sized inorganic particle in the metal matrix. Most of the properties improvement by incorporation of such nano particles in aluminium metal matrix composites fabricated by friction stir processing route is not fully explored yet.

Most of the research in composites materials start early in 1960, but addition of nano particles to increase its mechanical and wear properties comes to picture in the beginning of 21st century. Both mechanical and tribological properties are reported in the literature. Some of the work done in the last decade is summarized. In another work, Zhao et al (2015) studied the effect of friction stir processing with B4C particles on the microstructure and mechanical properties of 6061 aluminium alloy. In their research, Optical microscopy, scanning election microscopy, and energy-dispersive X-ray analysis were used to study the microstructure and the distribution of B4Cp. Shahi et al (2014) studied the influence of the rotational and traverse speed of the tool as well as the number of FSP passes on the in situ formation of Al3Ni in aluminium matrix. From the research they found that six passes of FSP showed the highest hardness, which was almost twice of that of the base metal. Liu et al. (2013) fabricated aluminium matrix composites reinforced by multi-walled carbon nanotubes via FSP. They reported that the maximum ultimate tensile of composite was improved about two times compared with as-received aluminium. Dolatkhah et al. (2012) produced metal matrix composite on surface of 5052 aluminium sheets by means of 5-μm and 50-nm SiC particles using FSP. They noticed that hardness value of fabricated composite was improved up to 55% and wear rate was reduced about 9.7 times comparing with as-received 5052 aluminium. Barmouz et al. (2011) used FSP to fabricate copper- SiC composites by varying the volume fraction and size of the SiC particle. They studied the microstructure and mechanical properties of the composites and concluded that Cu/SiC composite will be very attractive to surface composites manufacturers. Asadi et al. (2010) used FSP for modifying the mechanical properties and microstructure of AZ91/SiC composite. They considered the rotational and traverse speeds, tool penetration depth and tilt angle on the formation of defects such as cracks, tunnelling cavity and also on sticking of matrix material to the tool. From the result they concluded that FSP is an effective process to fabricate SiC/AZ91 composite layer with uniform distribution of SiC particles, good interfacial integrity and significant grain refinement. Puviyarasan et al. (2015) used FSP to produce composites reinforced with B4C particles. The result indicates that the composites fabricated using optimal process parameters exhibit a higher tensile strength (174 MPa) and microhardness (183 HV). After a thorough literature survey it was found that out friction stir processing route alter the microstructure which enhances the mechanical properties of the composites. This makes this composites one of the most important composite materials used in many industries, such as aerospace, construction, transportation, as well as for medical and military applications. Taking this into consideration, the present work is focussed on studying the mechanical properties such as micro hardness and flexural properties of Al-SiC nano composites.

2. Materials &Methods

2.1. Fabrication of Composites

Aluminium 6061 is used as the base metal. Nano SiC of size 60-90nm is used as the reinforcement which is purchased from U.S. Nanoresearch. The friction Stir Processing Set-up is shown in the figure1. A Hardened H13 steel with and without pin is used as tool for the FSP. Firstly a groove is made on the al 6061 alloy of 5mm width and 4 mm depth. The groove is filled with Nano SiC particles. Secondly a pin-less tool is allowed to go-through the groove to avoid scattering of the Nano SiC particles. Then a pin tool of shoulder 15mm, pin of 5mm diameter and 5 mm long is pressed along the groove for fabrication of the surface composites. The experiment is done for a rotational speed of 1000rpm and transverse feed of 30mm/min. The experiments were done by varying the number of passes from 1 to 3.

Table 1. Composition of Al6061

COMPONENT	Al	Cr	Cu	Fe	Mg	Mn	Si	Ti	Zn
WEIGHT %	98.6	0.35	0.4	0.7	1.2	0.15	0.8	0.15	0.25

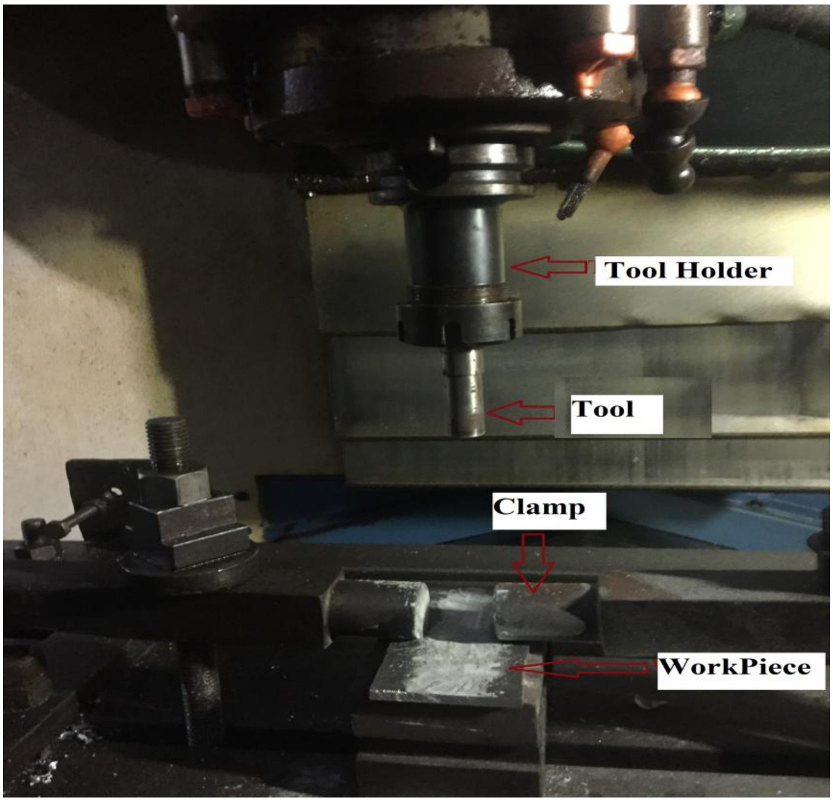

Figure 1. Friction Stir Processing Set-up

2.2 Mechanical Testing

The composite material thus fabricated will be cut into required dimension for mechanical testing. Mechanical properties such as flexural test and micro hardness test are conducted as per ASTM standards. In order to perform the flexural test the different composite specimen is tested in the universal testing. Microhardness of the specimens was measured on the cross section of the specimen perpendicular to the processing direction using Vickers micro hardness tester. The effects of nano SiC on the mechanical properties are studied in terms of its microstructure, the nature of failure, the increase in strength of the composites.

3.Results and discussion

3.1.Morphological and structural characterization

Figure 1-3 shows the microstructure of the fabrication composites using scanning electron microscope. From the figure 2a, it is found that the Nano SiC particles were distributed evenly throughout the matrix for three passes which is not so in one and two passes. In figure 2b and 2c, it is noticed that the particles are agglomerated at one particular places and proper even distribution is not seen.

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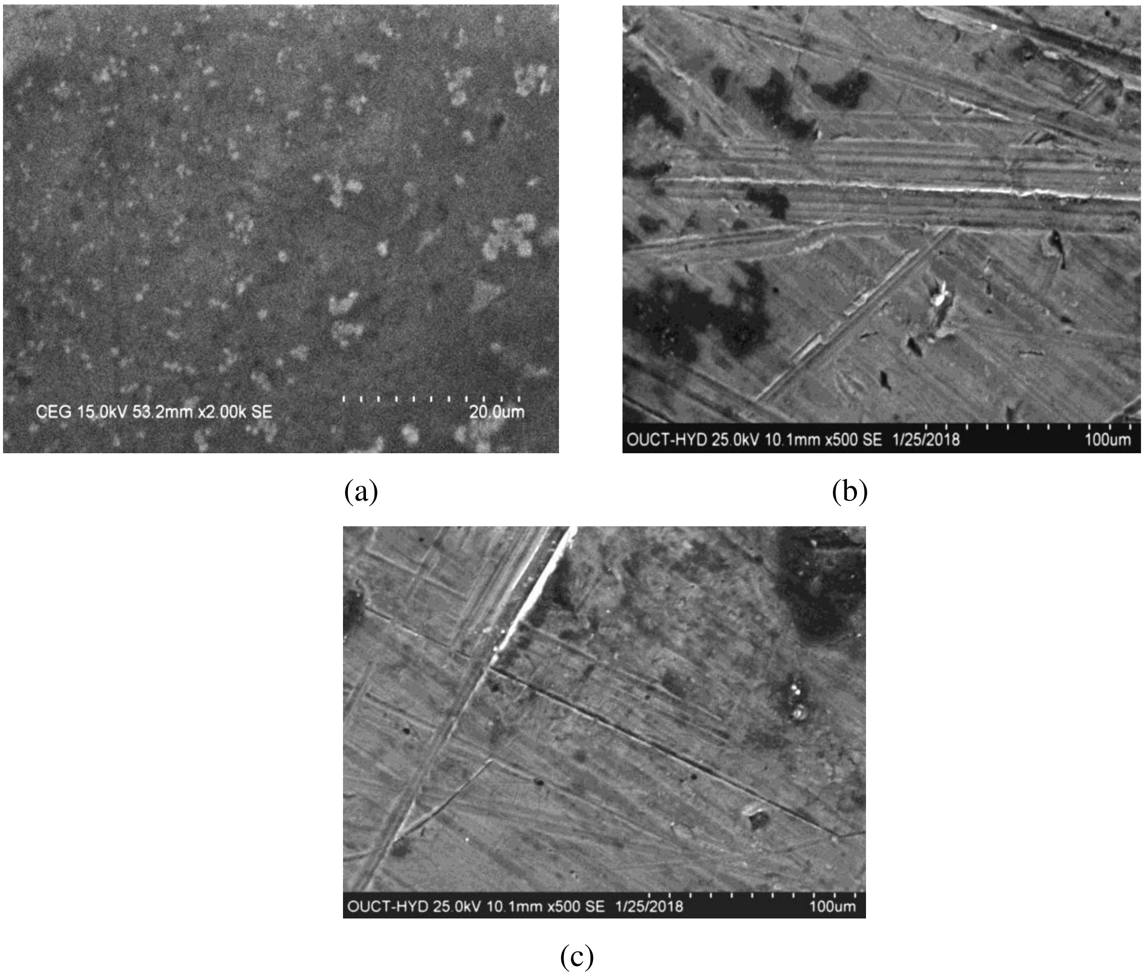

Figure 2.SEM image FSPed specimen (a) Three Pass (b) Two Pass (c) One Pass.

3.2. Microhardness

Figure 3 shows the effect of number of pass on microhardness of FSPed specimen. From the figure, it is inferred that three number of pass results in higher microhardness and the microhardness decreases with decreasing the number of passes. At three pass, grain refinement, better bonding and even distribution of particles occurs which results in the enhancement of microhardness as compared to two and single pass. Also the increase in microhardness for all specimens follows the same trend which is similar to the results obtained by Yuvaraj et al. (2017).

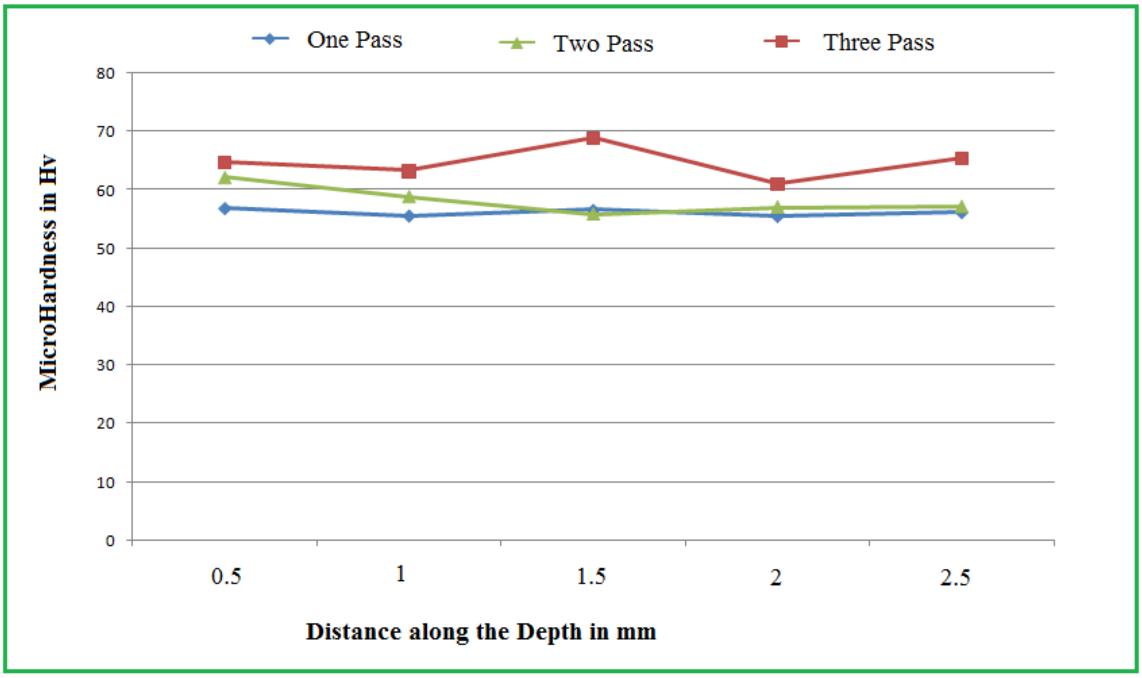

Figure 3. Microhardness values of the FSPed Specimen

3.3 Flexural Strength

The increase in flexural strength of the composites improves the crack expansion and also limits the deformation of the composites. The effect of number of passes on flexural strength of FSPed specimen is shown in the figure 2. It is depicted from the figure tat the flexural strength of all FSPed specimen increases with respect to the base alloy. Further the increase in flexural strength is found to high for three pass specimen compared to the other which indicates a better bonding and grain refinement during the FSP operation.

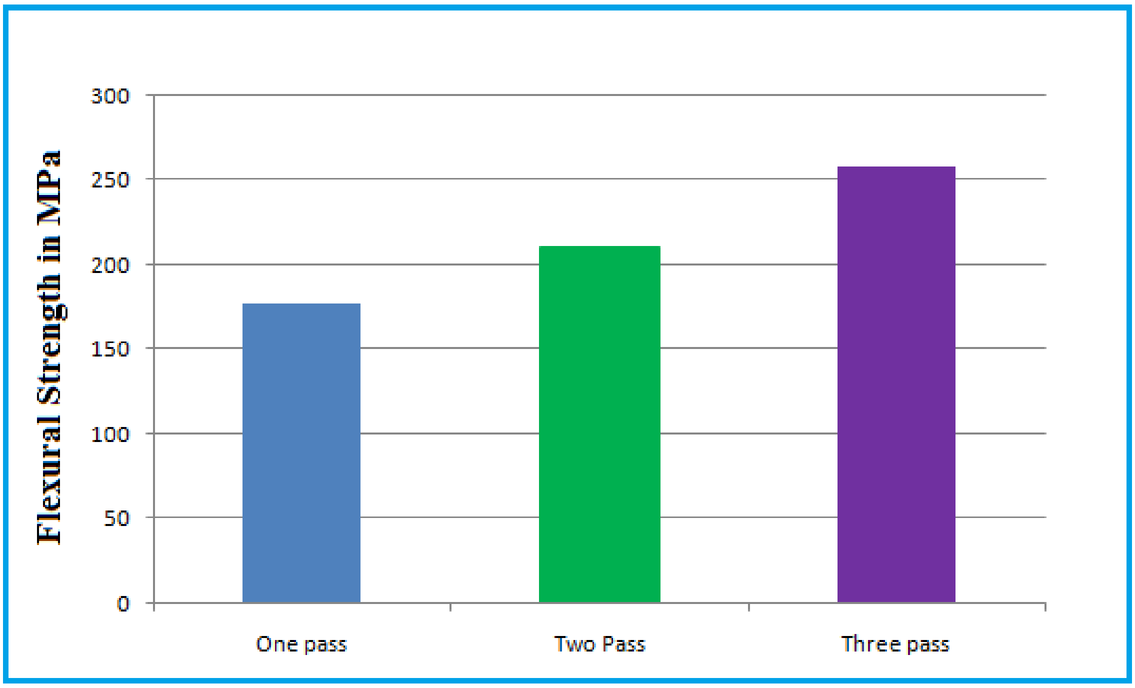

Figure 4. Flexural Strength values of the FSPed Specimen

4.Conclusions

From the study the following conclusion are arrived.

- The composites are successfully fabricated by FSP operation
- The microstructure of the composites shows even distributed nano SiC particles at three pass.
- The hardness and flexural strength of the composites increases for all fabricated composite specimen further three numbers of passes of FSPed specimen shows a better microhardenss and flexural strength.

5.References

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