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INFLUENCE OF SIC NANO PARTICLES ON MICROSTRUCTURE AND MECHANICAL PROPERTIES OF 6061/SIC$_P$ ALUMINUM ALLOY NANO COMPOSITES VIA FRICTION STIR PROCESSING

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ABSTRACT

The current work is to accentuate the influence of volume percentage (vol.%) of nano-sized particles (SiC: average size is 35 nm) on microstructure and mechanical behaviour of 6061-T6 Al alloy surface nano composite prepared via Friction stir process (FSP). The microstructure of the fabricated surface nanocomposites is examined using optical microscopy (OM) and scanning electron microscope (SEM) for distribution of SiCnanoreinforcement particles on the Aluminum alloy substrate and fracture features. It was observed that increase in volume percentage of SiCparticles, the microhardness is increased up to further increment it decreases to 70 Hv and it is lower than as-received Aluminum alloy's microhardness (104 Hv). It is seen that the increasing of volume percentage of SiCparticles, increases the tensile properties. It is also observed that at 4.5 volume percentage higher tensile properties exhibited as compared with the 1.5 and 3.0 vol. %. The observed wear and mechanical properties are interrelated with microstructure and fractography.

Keywords*—6061 Aluminum alloy; Surface nano composites; Microstructure; Tensile properties; Fractography*

I. INTRODUCTION

Aluminum alloy 6061-T6 is extensively using in aircraft, defence, automobiles and marine areas due to their good strength, light weight and better corrosion properties. But, it revealed inferior mechanical and tribological properties in extensive usage [1]. Aluminum matrix composites (AMCs) which are produced by reinforcing Aluminum alloys with particles like SiC, Al_2O_3 andTiB_2 etc., are the new generation materials. These AMCs exhibit higher properties than parent alloy such as stiffness, improved tribological characteristics and high strength. Further these properties can be enhanced by using nano scale ceramic materials [2-4]. Distribution of nano reinforcement particles on Al alloy surface and its control is complex to achieve in conventional surface modification methods [4-5]. Earlier researches [6-7] reported that thermal spraying and laser beam techniques were utilized to prepare surface composites, in which it degrades the properties due to creation of unfavorable phases. These techniques operate at higher temperatures and impossible to avoid the reaction between the reinforcements and the matrix, which forms detrimental phase. Considering these problems, Friction stir processing (FSP) is the best technique suited for preparation of surface composites and surface modification [8-13]. The current corresponding author [14-15] was achieved in homogeneous dispersion of TiB_2 particles (35 nm average size) on a surface of Aluminum alloy 6061-T6 via FSP. This investigation is aimed to fabricate and study the influence of volume percentage of nano sized SiC (average size is 35 nm) reinforcement particles on microstructural and mechanical behaviour of 6061-T6 Al alloy surface nano-composites by using FSP.

II. EXPERIMENTAL PROCEDURE

The base material employed in this study is 6 mm thick Aluminum alloy 6061-T6. The chemical composition of the base material is given in Table 1.

Table 1 Chemical composition of Aluminum alloy 6061-T6 (Wt. %)

Element	Mg	Si	Cu	Zn	Ti	Mn	Cr	Al
Amount (Wt %)	0.85	0.68	0.22	0.07	0.05	0.32	0.06	Balance

The nano sized reinforcement particles such as SiC is used at different volume percentages (vol. %) such as 1.5, 3 and 4.5. A square groove was made with dimensions of 1 mm width and 1 mm deep tangent to the pin in the advancing side and which is 1 mm far away from the centre line of the tool rotation on the Aluminum alloy 6061-T6 plate. The schematic diagram of Aluminum alloy plate for FSP as shown in Fig.1.The H13 tool steel having screwed taper pin profile with shoulder diameter of 24 mm, pin diameter of 8 mm and 3.5 mm height was used. The groove opening initially closed by means of the tool which is having shoulder without pin to avoid the escapement of reinforcement particles from groove while processing. The tool rotational speed of 900 rpm, tool travelling speed of 40 mm/min, axial force 5 KN and tool onward tilt angle of 2^0 along the centre line were used in FSP. The FSP is carried out on a Vertical milling machine (Make HMT FM-2, 10 hp, 3000 rpm). The experimental setup is shown in Fig. 2. The schematic sketch of selection of samples for testing is shown in Fig.3. After FSP, microstructural observations were carried out at the cross section of NZ of surface nano composites normal to the FSP direction, mechanically polished and etched with Keller's reagent (2 ml HF, 3 ml HCl, 20 ml HNO_3 and 175 ml H_2O) by employing optical microscope (OM). Microhardness tests were carried out at the cross section of NZ of surface nano composites normal to the FSP direction, samples with a load of 15 g and duration of 15 sec using a Vickers digital microhardness tester. The tensile specimens were taken from the surface composites normal to the FSP direction and made as per ASTM: E8/E8M-011 standard by wire cut Electrical discharge machining to the required dimensions. The Scanning electron microscope (SEM) is also utilized for fractography analysis.

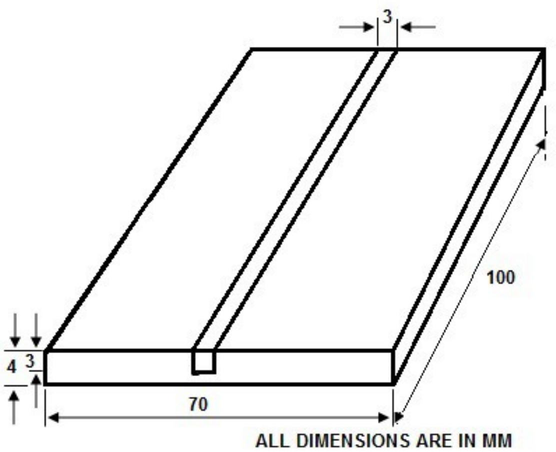

Fig. 1 Schematic sketch of Aluminum alloy plate for FSP

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Fig.2 Experimental setup of FSP

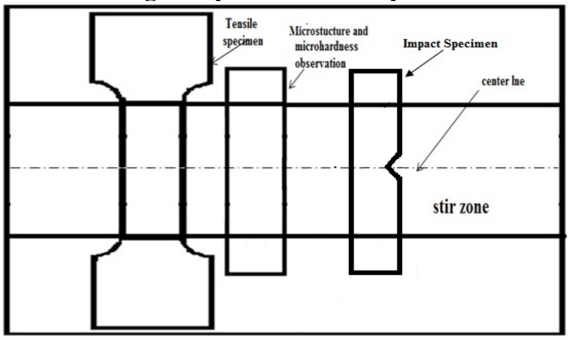

Fig. 3 Schematic sketch of selection of samples for testing

III. Results and Discussions

The surface nano composite was successfully fabricated via FSP. The surface nano composite is shown in Fig.4. It is revealed that there are no imperfections such as cracks, voids on the surface. It is also revealed that the top surface appears as smooth and fine quality with almost no depressions.

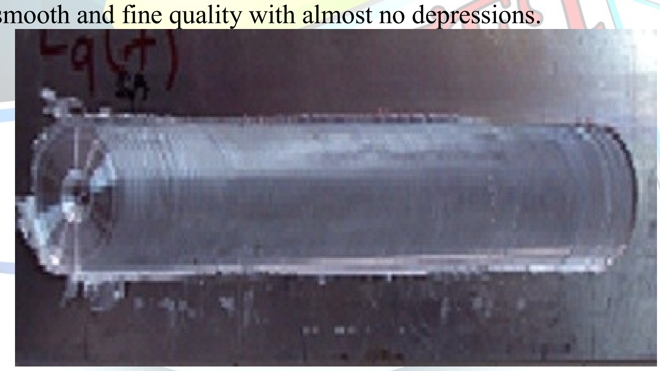

Fig.4 Macrograph of FSP zone of surface nano composite

A. Microstructural studies

The friction stirred zones were characteristically about the size of the rotating pin, namely width and depth of 8 mm and 4 mm respectively. The optical micrographs of Al-SiC surface nano composites and as-received Al alloy are shown in Fig.5. It is observed that the nano-size SiC particles were found to be distributed within this zone due to the occurrence of dynamic stirring during the FSP. It is also observed that the SiC nano particles were dispersed uniformly in the nugget zone (NZ) at 4.5 vol. % as compared to other 1.5 vol. % and 3 vol. % of Al/SiC surface nano composites made by FSP due to rotating tool gives sufficient heat generation and circumferential force to distribute the reinforcement particles to flow in wider area [13-15].

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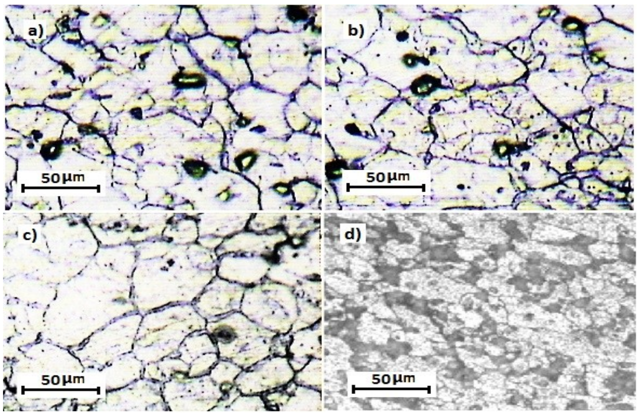

Fig. 5 Optical microstructures of Al/SiCsurface nano composites
a) 1.5 vol. %,b) 3 vol. %, c) 4.5 vol. % & d) As-received Al alloy

B. Microhardness

Microhardness survey of Al- SiC-1.5 vol. %, Al- SiC-3 vol. % and Al- SiC-4.5 vol. % surface nano composites and as-received Al alloy is shown in Fig.6. Mainly, the microhardness value depends on the presence and uniform distribution of SiCparticles. It is observed that increase in volume percentage of SiC, microhardness decreases and which is lower than as-received Aluminum alloy (104 Hv). The SiC particles exhibit pronounced effect on microhardness of nugget. In fact, if they are agglomerated they can act as preferred nucleation sites via particle stimulate nucleation (PSN) mechanism for the formation of new grains during dynamic recrystallization. This results in extensive small grains. After the recrystallization and in the grain growth stage, the individual SiC particles suppress grain coarsening by impeding the boundaries and resulting in finer grains, i.e., Zener effect. On the other hand, these ceramic particles have high hardness themselves which exhibit strong resistance to dislocation motion. Therefore, the produced nanocomposite exhibited high levels of hardness and strength [12-15].

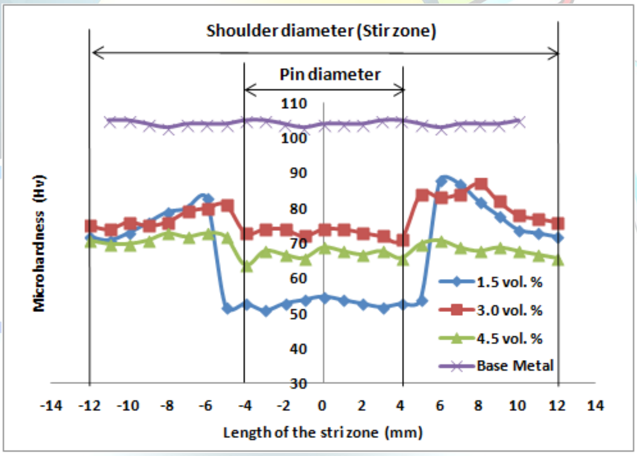

Fig.6. Microhardness survey of Al/SiCsurface nano composites and as-received Al alloy

C. Tensile properties& Fractography

Comparison of Tensile properties of Al/SiCsurface nano composites & as-received Al alloy is shown in Fig.7.It is seen that all the tensile properties of Al surface nano composites were decreased as compared with the as-received Al alloy. This is due to the presence of reinforcement particles could restrict the grain boundary sliding, dislocations and also the weak interfacial bond between the reinforcement particles and the matrix, finally leading to deterioration of the tensile properties [15]. The SEM fractography of Al- SiC-1.5vol. %, Al-SiC-*3* vol. % and Al-SiC-4.5 vol. % surface nano composites and as-received Al alloy is shown in Fig.8. The appearance of fracture surface of as-received Aluminum alloy includes dimple and voids which demonstrates the ductile fracture (Fig.8 d). It is also observed that the pulling out of the reinforcement particles and small dimples were seen in the fracture surface of Al- SiC-1.5vol. %, Al-SiC-*3* vol. % and Al-SiC-*4.5* vol. %surface nano composites. These observations further confirm the mentioned reasons for low UTS, YS and %EL of all the surface composites [11-14].

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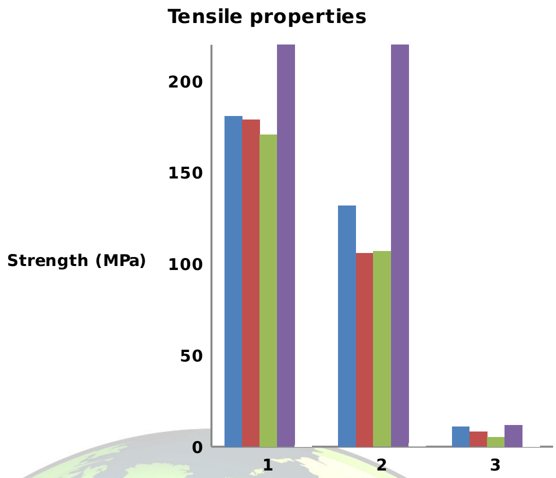

Fig.7. Comparison of Tensile properties of Al/SiCsurface nano composites & d) As-received Al alloy

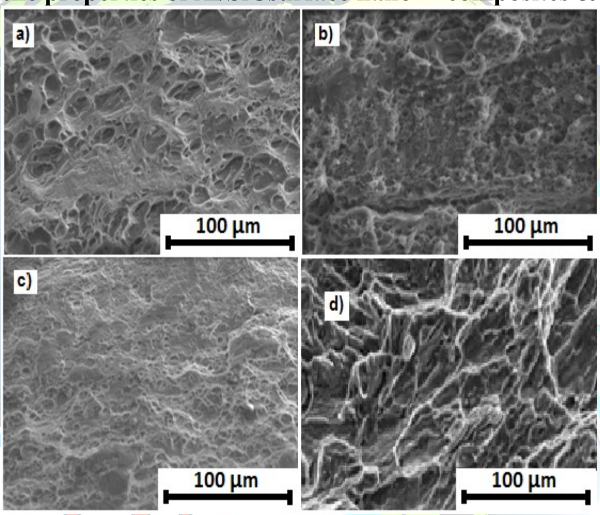

Fig.8. Fracture features of Al/SiCsurface nano composites a) 1.5 vol. %,b) 3 vol. %, c) 4.5 vol. % & d) As-received Al alloy

IV. CONCLUSIONS

The nano composite surface layer by reinforcing SiC particles on 6061-T6 Aluminum Alloy via FSP successfully fabricated. Effect of nano sized reinforcement particles such as SiC (average size is 35 nm) on microstructure and mechanical properties of 6061-T6 Aluminum alloy based surface nano composites fabricated via FSP was studied and the following conclusions are to be obtained.

- The friction stirred zones were characteristically about the size of the rotating pin, namely width and depth of 8 mm and 4 mm respectively.
- It is observed that increase in volume percentage of SiC, microhardness decreases.
- It is seen that all the tensile properties of Al surface nano composites were decreased as compared with the as-received Al alloy.
- It is seen that at 4.5 volume percentage higher tensile properties exhibited better tensile properties as compared with the 1.5 vol. % and 3 vol. %.

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