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Tensilel Properties of AA6061-T6/SiC_p Surface Metal Matrix Composite Produced By Friction Stir Processing

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Abstract - In this experiment, Friction stir process (FSP) was attempted to incorporate micron-sized SiC particles 20µm in average size into the commercially AA6061-T6 to form surface particulate metal matrix composite. Microstructure observations were carried out by scanning electron microscope (SEM) in the nugget zone. Mechanical properties include micro hardness behavior and tensile properties were evaluated. From the results, SEM microstructure shows that the SiC particles are uniformly distributed in nugget zone without any defect. The micro hardness of nugget zone with SiC particles is higher than the as-received Al alloy. Tensile properties of the FSPed composite were reduced as compared to the as-received Al alloy.

Keywords- *Friction stir processing, Aluminum alloy 6061-T6, SiC particles, Micro hardness, Tensile properties.*

I. INTRODUCTION

Friction stir processing is a recent technology for surface modification and developing surface and bulk reinforcement MMCs and it's an adaptation of friction stir welding and based on the concept of friction stirring. The stirring action and frictional heat generated by the FSP tool can be used to distribute ceramic particles as reinforcement on the surface of light metals like aluminum, copper and magnesium alloys. Therefore, the friction stir process can be used as a generic process to modify the microstructure and change the composition, at selective locations. At this time, FSP is the only solid-state processing technique that has these unique capabilities. The SiC particles were uniformly distributed and excellent bonding obtained between SiC_p and base metal. The composite exhibited high microhardness compared to untreated material [1]. The reinforcement particles (SiC, Al_2O_3 or their mixture) were distributed almost homogenously over the nugget zone by FSP without any defects except small some voids forming around the Al_2O_3 particles. The hybrid composites containing 20% Al_2O_3 + 80% SiC exhibited superior wear resistance was reported by Essam R.I. et al [2]. Mohesn Barmouz was demonstrated that the microcomposite produced via FSP exhibited enhanced wear resistance and higher average friction coefficient in comparison with pure copper and it was shown that MMC layer produced by FSP had lower strength and elongation than pure copper while a remarkable elongation was observed for FSPed specimen without SiC particles [3]. The SiC may react with molten aluminum to form brittle Al_4C_3 carbide [4, 5] and bonding problem between the SiC_p and base metal in normal fusion process. Considering this problem, friction stir processing (FSP) seems to be a good technique for successful fabrication of MMCs.

Aluminum and its alloys mostly used in automotive and aerospace industries because of its low density and high strength to weight ratio [6]. Metal-matrix composites (MMCs) are represent a new class of structural materials as conventional metals and alloys approach their developmental limits and with proper processing, the reinforcement of a metal matrix with various particulate reinforcements can yield MMC with significantly improved properties (e.g. lower density, higher specific modulus and higher specific yield strength)[7]. The addition of ceramic reinforcements (SiC) raised performance limits of the Aluminum alloy 6061and however the presence of reinforcements in matrix makes it brittle. In this regard, it may however be noted that wear is a surface dependent degradation mode, which may be improved by a suitable surface modification and/or composition. Hence, instead of bulk reinforcement, if the ceramic particles would be added, it could improve the wear resistance [8-9]. M.Barmouz was reported that increasing the volume fraction or the decreasing the reinforcement particle size enhances the tensile strength, wear resistance and lower the percentage of elongation [10].

In the present work, SiC particles were dispersed in to AA6061-T6 via FSP and in order to reveal properties like microstructure, microhardness and tensile properties, compared with as-received Al alloy.

II. EXPERIMENTAL PROCEDURE

In this experiment, commercial SiC particles (average size: 20μm) and Aluminum alloy 6061-T6 rolled plate (thickness: 4mm) were used and chemical constitution is shown in Table 1. The SEM image of as-received SiC_p is shows in Fig.7. A groove was prepared at the edge of pin in the advancing side, which were 3mm width and 3mm depth. The groove was 2mm away from the center line and plate with groove as shown in Fig.1. The FSP tool was made of H13 tool steel and had a cylindrical shape shoulder (□24mm) and a screwed taper pin profile (□8 mm) as shown in Fig.2. In the beginning of the FSP, the groove was covered with a modified FSP tool that only had a shoulder and no probe to prevent the SiC particles from being displaced out of the groove during process. Then the tool penetrated into the plate until the shoulder's head face reached 0.25mm under upper surface. The rotational speed of tool was 1400rpm and the travelling speed was 40mm/min along the center line. The tool tilt forward angle of 2.5^0 was used. The process is carried out on a vertical milling machine (VMM) (Make HMT FM-2, 10hp, 3000rpm) and tool arbor as shown in Fig.3 & 4. FSPed composite picture is shown in Fig.5. For testing, specimens were cut from the region under the tool shoulder (stir zone) by using wire cut EDM. The distribution of the dispersed SiC_p was observed by SEM. The micro hardness was measured as per IS: 1501-2002 test method. Tensile testes of as-received Al alloy and the FSPed composite were determined at room temperature. Fig. 6 shows the schematic diagram of the tensile test specimens. Tensile test specimens were machined to the depth that FSP was applied.

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TABLE I. TYPICAL CHEMICAL COMPOSITION OF ALUMINUM ALLOY 6061-T6

Element	Al	Mg	Si	Fe	Cu	Zn	Ti	Mn	Cr	Others
Amount (Wt %)	Bal	0.8-1.2	0.4-0.8	Max. 0.7	0.15-0.40	Max. 0.25	Max. 0.15	Max. 0.15	0.04-0.35	0.05

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Fig.1 Picture of as-received Al alloy with groove

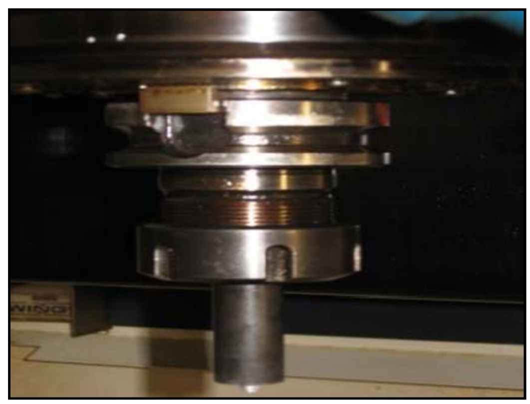

Fig.3 Picture of VMM arbor

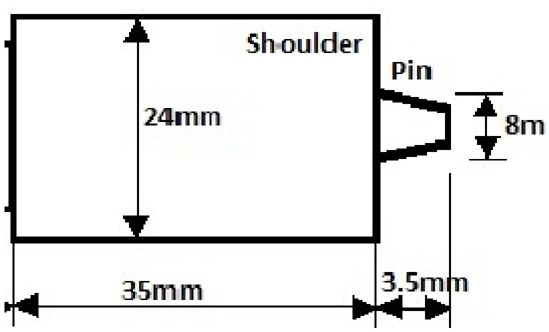

Fig.2 Schematic diagrame of FSP tool

Fig.4 Picture of Vertical milling machine

Fig. 5 Image of FSPed AA6061-T6/SiC_p

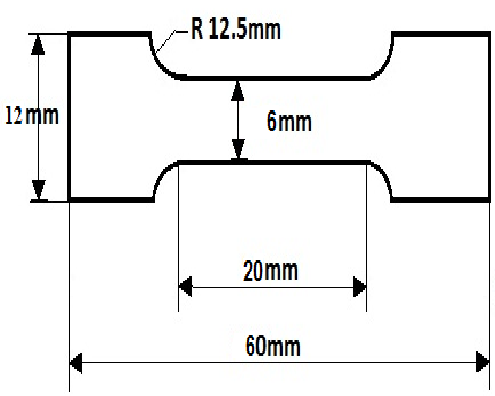

Fig.6 Schematic diagram of tensile test specimen

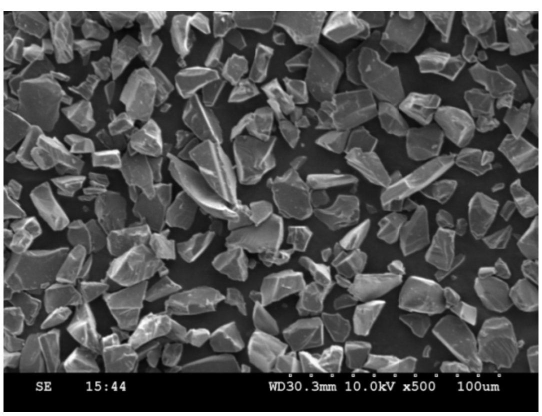

Fig.7 SEM image of as-received SiC particles

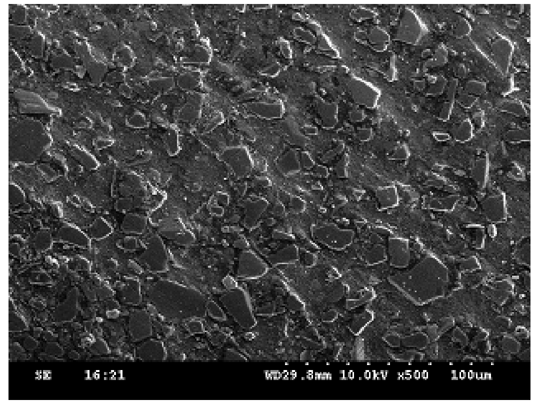

Fig.8 SEM microstructure of FSPed composite

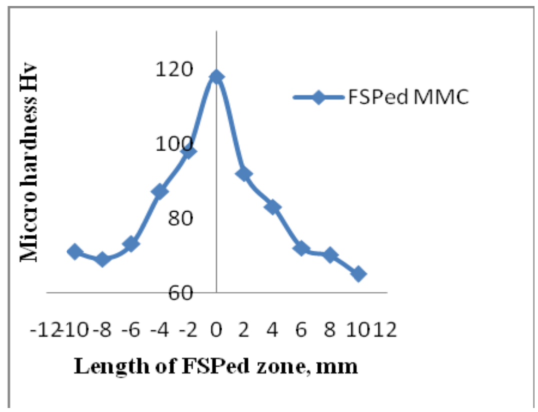

Fig.9 Micro hardness profile of the FSPed composite

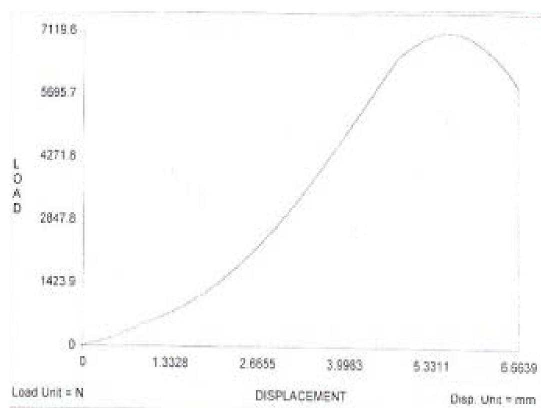

Fig.10 Graph between load vs. Displacement of As-received Al alloy

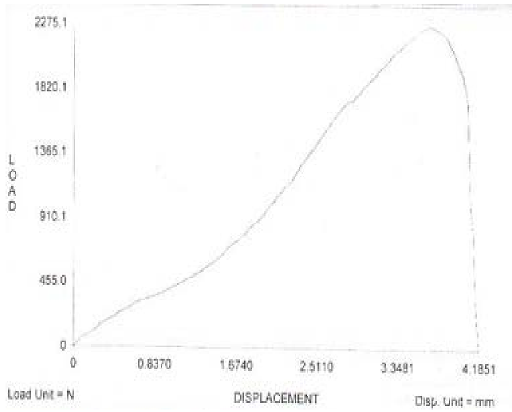

Fig.11 Graph between load vs. Displacement of FSPed composite

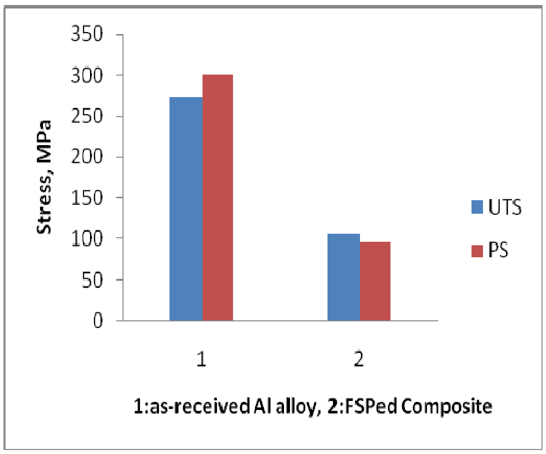

Fig.12 Stress values of As-received Al alloy&FSPed composite

III. RESULTS AND DISCUSSIONS

1) Microstructure:

After the Aluminum alloy 6061-T6/SiC_p was fabricated by FSP, microstructure at cross-section of stir zone was observed by SEM (the parameters are 1400rpm and 40mm/min) and microstructures are shown in Fig.8. In such higher rotational speed and lower travel speed enough heat input was produced and the tool also supplied shear force to make the SiCp flow and disperse in stir zone. It is seen that the reinforcement particles distributed more widely and uniformly in the nugget zone, without any defect by applying single pass FSP. This was due to the stirring action generated by the rotated tool. There is no reaction between SiC_p and the base metal because of FSP is a solid-state process, and peak temperature during process was below the melting point of base materials. The reinforced particles were easily wrapped by softening metal and rotated with the FSP tool; it is difficult to travel like the same move with softening base metal. So the particles are not easy to disperse in larger region.

B. Microhardness:

Microhardness behavior of the composite metal over the length of FSPed zone as shown in Fig.9 and the microhardness of the FSPed Aluminum alloy 6061-T6/SiC_p of the nugget zone is higher than that of the as-received Al alloy. It is considered that higher value was obtained due to the pinning effect and presence of hard SiC particles. At lower traverse speed SiC particles were separated well and consequently an intense pinning effect occurs in stir zone leading to a further enhancement of microhardness values.

C. Tensile properties:

Tensile test was performed at room temperature in order to determine the tensile properties including yield strength and ultimate strength of the specimens FSPed composite and as-received Al alloy at rotational and traverse speeds of 1400 rpm and 40 mm/min. The graph between load vs. displacement of FSPed composite and as-received Al alloy are shown in Fig.10&11. Fig. 12 shows the comparisons of tensile properties of both FSPed and As-received Al alloy. It is seen that proof stress (PS) and ultimate tensile strength (UTS) of the specimen FSPed composite decreased in comparison with as-received Al alloy. According to the mentioned results in microhardness behavior, this phenomenon could be because of remarkable annealing softening which occurred during FSP. It is also observed that yield strength and ultimate strength of the specimen FSPed composite with SiC particles were reduced as compared to the As-received Al alloy which may be concluded as the presence of hard SiC particles that enhances the hardness and consequently reduces the elongation of specimen. Moreover, the presence of SiC particles could restrict the grain boundary sliding. We postulate that in order to improve the strength and elongation of FSPed composite, one could use the post FSPed heat treatment and this subject will be discussed thoroughly in our future investigations.

V. CONCLUSIONS

The SiC particles dispersed AA 6061-T6 was successfully fabricated by the FSP and in order to reveal properties like microstructure and tensile properties, compared with as-received Al alloy. The SiC particles were uniformly distributed inside the nugget zone without any defect. The micro hardness of nugget zone with SiC particles is more compare to as-received Al alloy. Tensile properties are yield strength and ultimate strength of the specimen FSPed composite with SiC particles were reduced as compared to the as-received due to presence of hard SiC particles that enhances the hardness and consequently reduces the elongation of specimen.

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