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Characterization and Mechanical Properties of hybrid SiC+Al_2O_3 reinforced Al6061-T6 surface composite

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ABSTRACT:
Friction stir processing (FSP) was used for the fabrication of Al 6061 with SiC, Al_2O_3 nano composites for surface applications. The influence of rotational speed on mechanical properties of fabricated Aluminium alloy based surface hybrid composites through FSP was studied. The dispersion of SiC and Al_2O_3 on the fabricated surface hybrid composite was investigated by Optical Microscope. The uniform distribution of reinforcement particles (SiC and Al_2O_3) at the nugget zone was observed in all the microstructures of surface hybrid composite. The change in the properties (grain size) of the fabricated surface hybrid composite at Stir Zone (SZ), Thermo-mechanically affected zone (TMAZ) and Heat affected zone (HAZ) was observed. The increase in rotational speed resulted decrease in microhardness. The higher microhardness value in Al- SiC, Al_2O_3 surface hybrid composite is exhibited due to the presence and pinning effect of hard SiC and Al_2O_3 particles. The observed mechanical properties have been correlated with microstructures.

I. INTRODUCTION

Aluminium alloy 6061-T6 is widely utilized in aircraft, defense, automobiles and marine areas due to their good strength, light weight and better corrosion properties. Though hardness and wear properties are not up to the mark [1,2]. In addition, Aluminium based alloys become brittle by the addition of reinforcements such as SiC and Al2O3 ceramic particles if dispersed throughout the matrix [3]. A proper technique can be employed to refine the microstructure and homogeneous dispersion of reinforcements on metallic surface as since wear is a surface deprivation property [4]. Dispersion of reinforcement particles on metal surface and the control of its dispersal are more difficult to attain by conventional surface modification techniques [5]. Guptha et al. [6] and Mabhali et al. [7] reported that the thermal spraying and laser beam techniques were utilized to prepare surface composites, in which it degrades the properties due to formation of unfavourable phases. These techniques are operated at higher temperatures and it is difficult to avoid the reaction between the reinforcements and the matrix, which forms a detrimental phase. Therefore, a process can be employed which is operated at below melting temperature of matrix for the fabrication of surface composites which can be used to avoid the above-mentioned complications. Considering the above problems, FSP is best suited for preparation of surface composites and surface modification. In FSP a rotating tool with shoulder and pin is plunged into the surface of material, which creates frictional heat and dynamic mixing of material area underneath the tool [8], it leads to incorporation and/or dispersion of the reinforcement particles in the matrix material such as Aluminium alloys, Magnesium alloys and Copper [9–11]. Devaraju et al. [12] achieved homogeneous dispersion of SiC particles (20 lm average size) on a surface of Aluminium alloy 6061-T6 via FSP. Hybrid composites are prepared by reinforcing with a mixture of two or more different type of particles which combines the individual properties of each type of particle. Essam et al. [13] fabricated Al-1050-H24/(20%Al2O3 + 80%SiC) hybrid composite via FSP and exhibited high hardness and superior wear resistance than the matrix material. However, it has not been found and yet no result was reported for improvement of wear and mechanical properties by the addition of mixture of SiC and Al2O3 particles as refinements on the surface of Aluminium alloy 6061-T6 via FSP. The optimization of rotational speed and volume percentage of reinforcements for improving the wear properties of Aluminium alloy 6061-T6/ (SiC + Al2O3) surface hybrid composites was not reported. Taguchi method is a systematic methodology intended for design and analysis of experiments to improve the quality characteristics [14–16]. Nowadays, it has become a very popular practical tool for improving the quality of output without increasing the cost of experimentation by reducing the number of experiments. Mallaiah et al. [17] optimized mechanical properties of TIG welded Ferritic Stainless steels by using Taguchi method. The objective of present investigation is to study the influence of reinforcement particles and mechanical properties of Aluminium alloy 6061-T6/(SiC + Al2O3) surface hybrid composites fabricated via FSP and to obtain the optimum combinations using Taguchi method.

II. MATERIALS USED

6061 -T6 Aluminium alloy plate with 6.3 mm thickness was utilized as the metal matrix for making the surface composites. The composition of Aluminium alloy 6061-T6 is shown in Table1. The plates were cut into rectangular pieces with dimensions 280mm x 140 mm x6.3 mm. SiC + Al_2O_3 particles with various volume fractions were used as reinforcements. Square grooves were cut with dimensions of 0.5mm x3.4 mm, 1 mm x3.4 mm and 1.5 mm x3.4 mm width and depth each were cut on the rectangular alloy plates perpendicular to the tool pin in the advancing side as shown in Fig 2.1. The three FSPed surface composites selected out of a total of 9 with different volume fractions are denoted as Al6061/(SiC+Al_2O_3)– 8/2 %, Al6061/(SiC+Al_2O_3)– 6/3 % , Al6061/(SiC+Al_2O_3)– 4/4 % respectively.

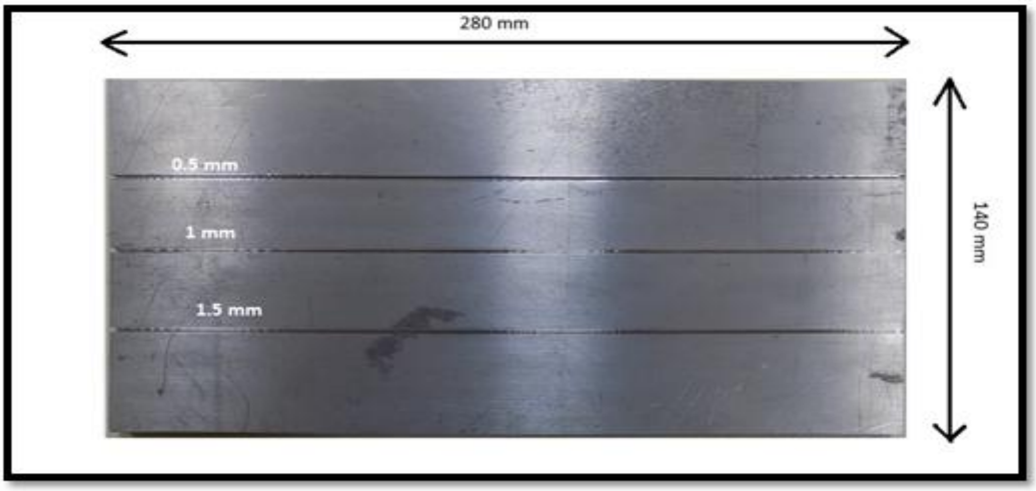


Fig. 2.1 Aluminium Plate after Preparation

Table 1: Chemical composition of Aluminium 6061 - T6 alloy (massfraction, %)

Contents	Mg	Si	Cu	Zn	Ti	Mn	Cr	Al
%	0.85	0.66	0.23	0.07	0.05	0.3	0.06	Bal

The tool used for FSP was fabricated with H13 tool steel with a shoulder diameter of 24 mm, screwed taper profile pin diameter of 8 mm to 3mm and height of 3.7 mm as shown in Fig 1.2. The reinforcement particles of SiC+Al_2O_3 powder were packed in the grooves of the samples. The tool rotational speeds of 1120rpm traverse speed of 40 mm/min, axial force of 10 KN and tool onward tilt angle of 2°along the center line were used. After successful FSP, samples were characterized using Optical microscope (Make: Quasmo) and Scanning Electron Microscope (Make: TESCAN , Model : Vega 3) . The SEM-EDX is carried out to analyze the chemical composition of Al-TiB_2 surface. Micro hardness tests were carried out using Vickers digital microhardness tester (Make: Shimazdu) using 100 g load for 15 s. Reading were taken on the cross section of the samples along a line which is below 2mm from the surface of the sample.

Fig. 2.2 Tool Profile of H13 Tool Steel used for FSP.

III. RESULTS AND DISCUSSION

3.1 Microstructure

Fig. 3.1 is the Optical microscope obtained image of Al-6061-T6 base metal. Two distinct phases, namely Al phase and Mg_2Si phase are observed. Mg_2Si phase presence is due to the relatively more content (weight %) of magnesium in Al 6061 alloy. Fig. 3.2 shows the SEM images of the base metal. The distribution of hybrid reinforcement particles of (SiC + Al_2O_3) in different zones i.e., SZ (Stir Zone), TMAZ (Thermo-Mechanically Affected Zone), HAZ (Heat Affected Zone) is found to be uniform and no obvious micro-porosity defect can be observed. In the SZ, dynamic recrystallization is found to occur. In the TMAZ, grains are equiaxed and elongated along the tool rotational direction. In the HAZ grain size is found to be increased.

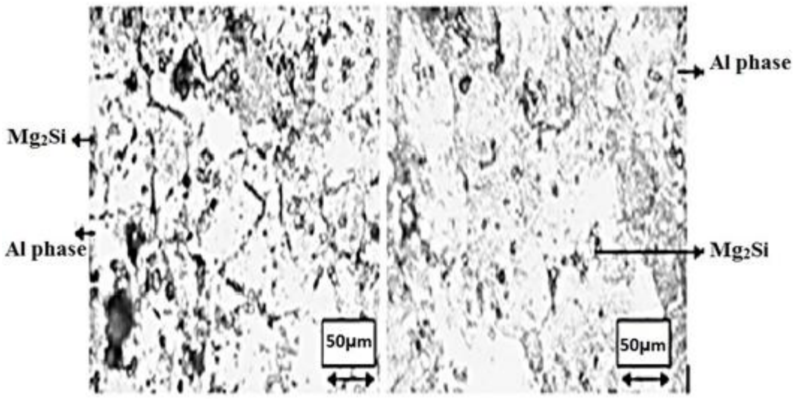


Fig. 3.1 Optical microscope image of Al-6061-T6 base metal

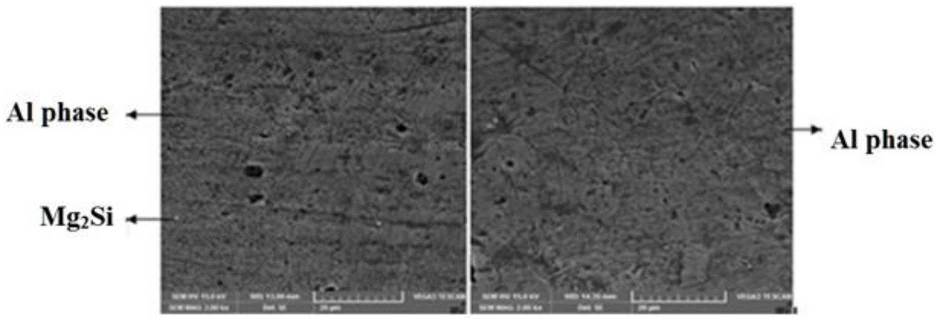
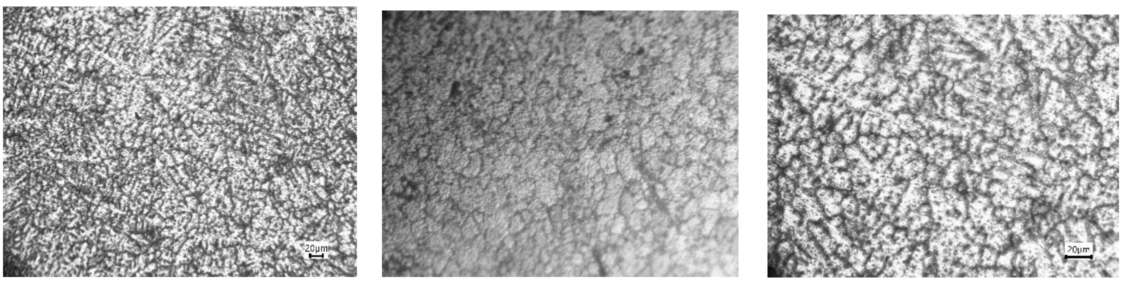


Fig. 3.2 SEM micrograph of Al6061 in as received condition at (a) 2000X (b) 5000X.

Fig 3.3 a) 8% SiC/2% Al_2O_3 b) 6%SiC/3%Al_2O_3 c) 4% SiC/4%Al_2O_3



3.2 EDS

The SEM-EDS is carried out to analyze the chemical composition of Al-SiC+Al_2O_3 surface composites and the results were presented in Fig. 3.4 the EDS spectrum illuminates that the surface composites are rich in Al. It shows that there is a loss of Mg and Si content during FSP.

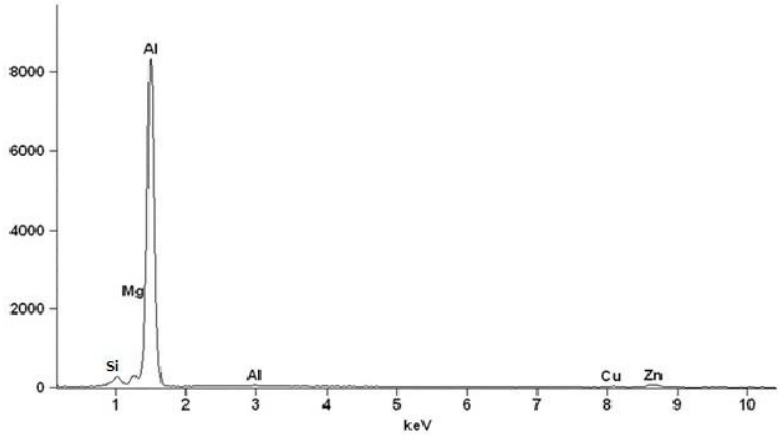


Fig.3.4 a) EDS analysis of Al-TiB_2 surface composite

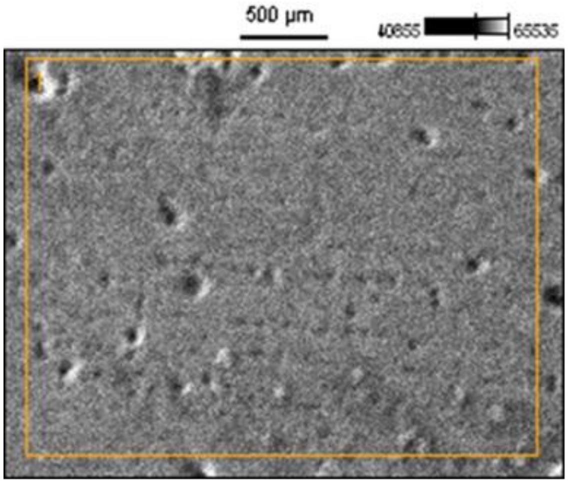


Fig.3.4 b) SEM analysis of the ds piece

Table 2 : Elemental analysis report from EDAX (Weight %) for as received material

Location	Mg-K	Al-K	Cu-K	Si-K
Point 1	1.97	90.2	1.96	5.87

The tensile specimen was taken from the base metal and made as per ASTM: E8/E8M-11 standard by using Wire cut Electrical Discharge Machining to the required dimensions. The schematic sketch of tensile specimen is shown in Fig. 3.5. The tensile test is carried out on a computer controlled universal testing machine at a cross head speed of 0.5 mm/min.

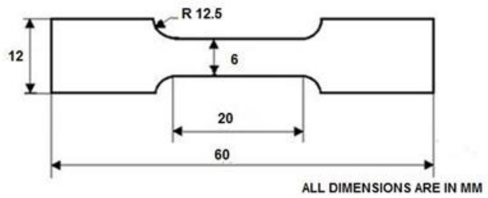


Fig. 3.5 Tensile test of base metal

Material	Microhardness (Hv)	Ultimate Tensile Strength (MPa)	Yield Strength (MPa)	Elongation (%)
Al 6061-T6 Alloy	70	290	169	11

3.3 Micro hardness

The microhardness value of a surface composite depends on how best the reinforcing particles distributed in the metal matrix. The better uniform distribution, the best will be the hardness attained. The hardness for all the specimens of FSPed 6061-T6 Al alloy with SiC + Al_2O_3 surface composites shown higher hardness than the base metal (70 HV). However, Specimen no.2 with SiC + Al_2O_3, showed highest hardness value(123 Hv) as shown in Fig. 3.6. The percentage increase from base metal hardness to composite harness is thus 75.7%

This may be due to dynamic mixing of SiC + Al_2O_3 particles into the softening Al 6061T6 matrix, causing its uniform mixture in the nugget zone, termed as Orowan strengthening[9]. Severe grain refinement in the weld zone has happened in Al-SiC + Al_2O_3, in which SiC acted as a perfect harder phase. The hardness values were increased due to the presence and pinning effect of SiC and Al_2O_3 particles.

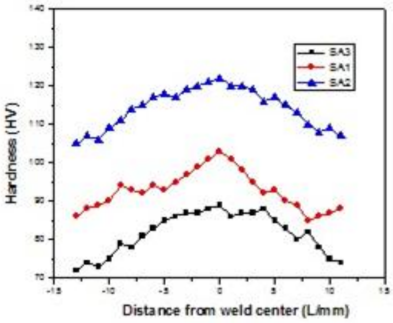


Fig. 3.6 Vickers microhardness of Al-6061 /SiC + Al_2O_3 composites

IV. CONCLUSIONS

The nanocomposite surface layer by reinforcing hybrid SiC + Al_2O_3particles on Aluminium 6061-T6 Alloy via FSP successfully fabricated. Effect of nano-sized reinforcement particles such as SiC + Al_2O_3 (20 µm) on microstructure, micro-hardness of Aluminium 6061-T6 alloy based surface composite fabricated via FSP, its hardness and EDS were studied and the following conclusions are obtained:

1) The SiC + Al_2O_3 particles are uniformly distributed in the composite as confirmed in the microstructures.
2) In the SZ dynamic recrystallization was observed, equiaxed grains were found in the TMAZ and grain growth was observed in the HAZ.
3) The 6%SiC+3%Al_2O_3 showed the best hardness of the three composites, this is because of the optimal formation of grain boundaries due to presence and pining effect of hard SiC particles and the lubricant nature of Al_2O_3 .
   Microhardness of the composite was increased by 75.7 in the best sample %

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