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Characterization and Mechanical Properties of Nano-sized TiB_2 reinforced Al6061-T6 surface composite

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Abstract

Microstructure and mechanical properties of Al-TiB_2 nano surface composite fabricated by Friction Stir Processing (FSP) were studied. Al6061-T6-TiB_2 composite with 24% volumetric fraction of TiB_2 was prepared using FSP. Microstructural analysis confirmed the uniform distribution of TiB_2 particles of 35nm size in the aluminium matrix after FSP. Characterization of base metal, composite and TiB_2 was done through OM, SEM, XRD and EDS. The phases present in base metal, namely Al phase and Mg_2Si phase are confirmed by optical microscope(OM), scanning electron microscope(SEM) and X-ray diffraction (XRD). The newly formed phase of Al-Ti in the composite was also confirmed by XRD. Microhardness test results show FSP of Al6061-T6 alloy with 24% TiB_2 displays more hardness than base metal.

1. Introduction

Aluminium alloys are commonly used in aircraft, defense, automobiles, space and marine applications due to its benefits like good strength to weight ratios, availability, thermal conductivity and better corrosion properties. But, studies show that aluminium alloys show inferior tribological properties [1]. Aluminium Metal Matrix Composites became more prominent and received good attention due to its properties like high temperature withstanding capabilities, wear resistance [2]. Also, the fabrication of the MMCs is relatively less costly. Thermal spraying and laser beam techniques were utilized to prepare surface composites [3]. These processes involve very high temperatures where unwanted phases may form due to the reactions between the parent alloy and reinforcements. Also, the presence of the ceramic particles in the metallic matrix makes the matrix brittle [4]. Hence, instead of bulk reinforcement of ceramic particles into the alloy, if the ceramic is limited to the surface, it could improve the wear and erosion. Recent research has modelled and demonstrated that, for a fixed concentration, smaller particles usually produce stronger and harder composites Many other techniques were used for the fabrication of metal matrix composite namely laser cladding technology, ion implantation technology, plasma spraying technology etc., But they too have their own imperfections [5-6]. Friction stir processing (FSP) is best suited for preparation of surface composites and surface modification. FSP involves a pre-heat-treated tool with typically a shoulder and pin. It is plunged into the surface of material, which when rotated at high speeds creates frictional heat high enough to melt the alloy below the pin and disperses reinforcements in the metal matrix causing uniform Surface composite. Tool rotational speed is the most important process parameter in FSP which has greater influence in uniform distribution of reinforcement particles, grain refinement and heat input during the process. Many researchers have given their valuable contributions in preparing surface composites by the use of FSP technique with various reinforcement particles like SiC, Al_2O_3, Al_3Ti on the surface of Aluminum alloy 6061-T6 [7-10]. MMCs prepared by addition of single or mixture of two or more different types of particles with certain volume fractions into the parent alloy. These Hybrid surface composites shown even more promising results in terms of wear resistance [11]. TiB_2 is also ceramic powder which have better properties than SiC, Al_2O_3. However, much literature was not available on the wear behavior of 6061 Al alloy with TiB_2 as surface composite. The objective of the present investigation was to enhance the wear resistance of 6061 Al alloy by dispersion of TiB_2 particulates on the surface using FSP technique. Homogeneous dispersion of TiB_2 particles on a surface of aluminium alloy 6061-T6 through FSP technique. The distribution of reinforcement particles has been observed to optimize the FSP parameters, by scanning electron microscope.

2. Materials Used

6061 -T6 Aluminium alloy plate with 6.3 mm thickness was utilized as the metal matrix for making the surface composite. The composition of aluminum alloy 6061-T6 is shown in Table 1. The plates were cut into rectangular pieces with dimensions 280mm x 140 mm x6.3 mm. Ball milled TiB_2(35nm) particles were used as reinforcements. Square groove was cut with dimensions of 1.5 mm x3.4 mm, width and depth on the rectangular alloy plate perpendicular to the tool pin in the advancing side as shown in Fig 2.1 . The FSPed surface composite is denoted as Al6061-T6/TiB_2-24%.

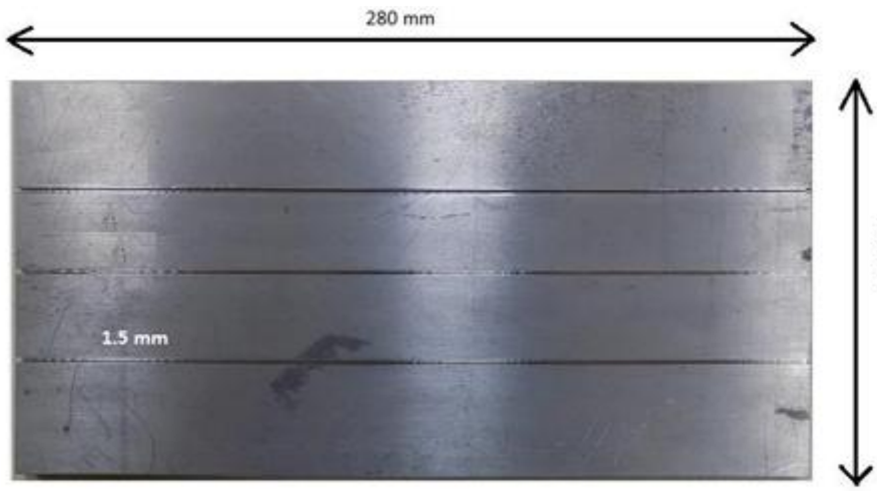

Fig. 2.1 Aluminium Plate after Preparation

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 TiB_2 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 .

Well-polished samples were scanned in the 2Θ range of 20° to 120° with the scanning speed of 0.119366°/sec and 0.0167113° step size using a X-ray diffractometer (Make: PANalyTiB2al, Model- X'pert powder Cu Kα radiation (λ = 1.54056 A°) operating at 45 kV and 30 mA. The indexing of the XRD patterns obtained for these samples were carried out by comparing with the standard patterns of the phase reported in the literature (JCPDS cards).

3. RESULTS AND DISCUSSION

3.1 Microstructure Analysis

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.

Fig. 3.3 Shows the Optical microscope images of 24% TiB_2 composite.It represents the SEM images of Al-6061/TiB_2 – 24 %. The distribution of TiB_2 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.

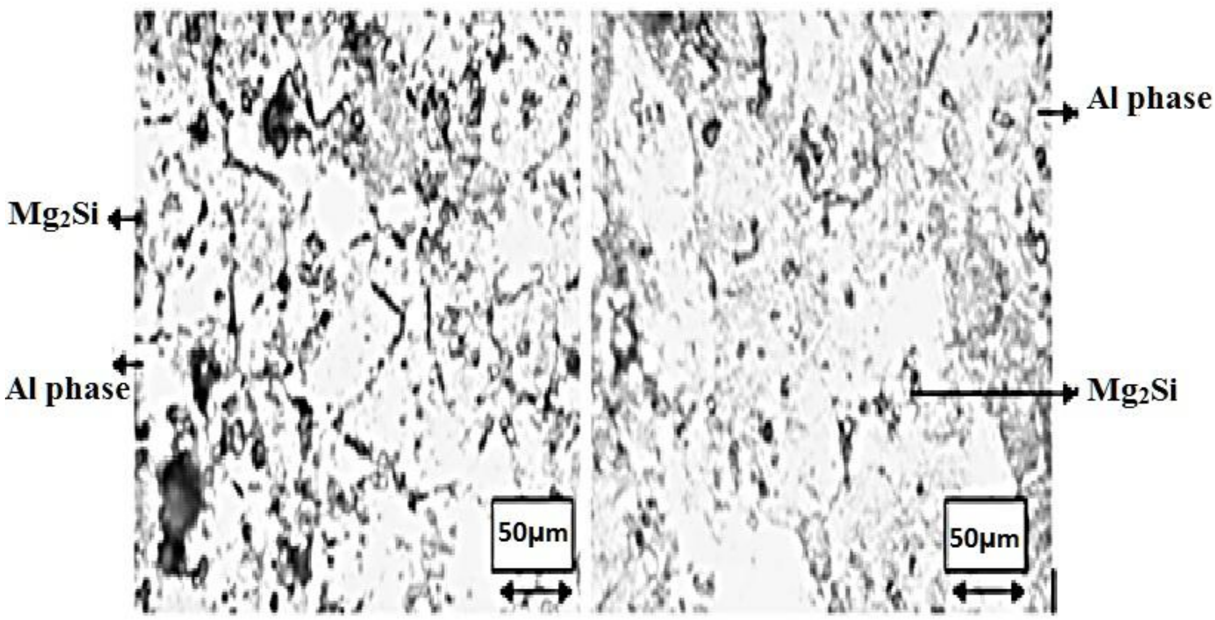

Fig. 3.1 Optical microscope image of Al-6061-T6 base metal

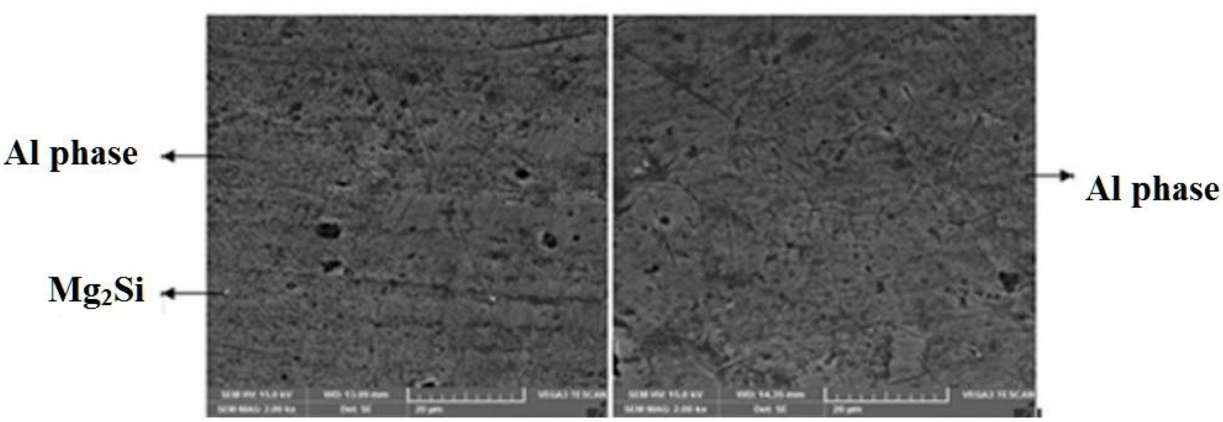

Fig. 3.2 SEM micrograph of Al6061 in as received condition at (a) 2000X (b) 5000X.

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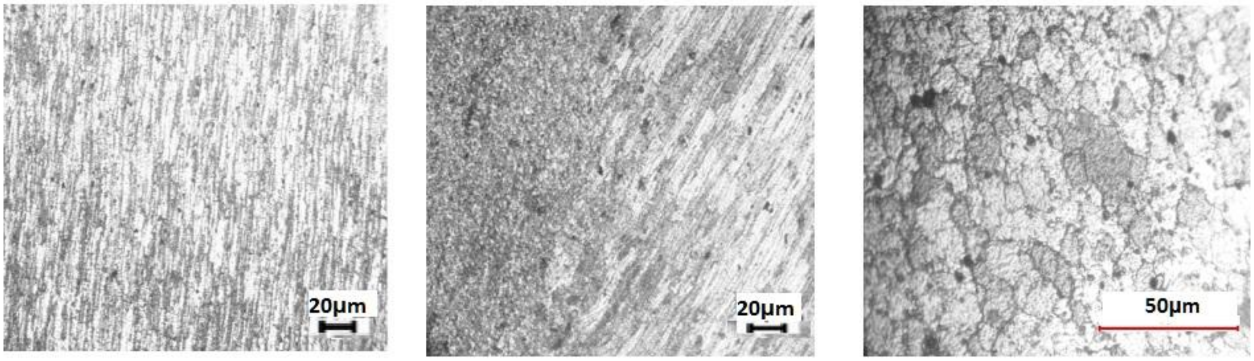
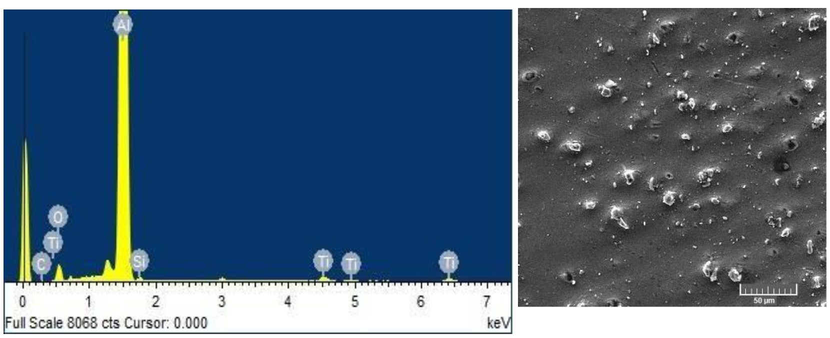


Fig. 3.3 Optical micrograph of Al6061-TiB2 (24% vol) surface composite at 1120 rpm and 40 mm/min. (a) HAZ at 10X, (b) TMAZ at 10X, (c) Nugget at 100X.

3.2 EDS Analysis

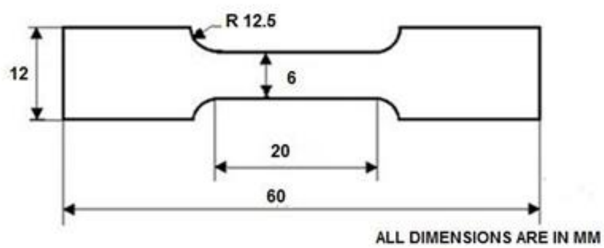
The SEM-EDS is carried out to analyze the chemical composition of Al-TiB_2 surface composites and the results were presented in Fig. 3.4 the EDS spectrum illuminates that the surface composites are rich in Al. It shows that there is a loss of Mg and Si content during FSP.

Fig.3.4 EDS analysis of Al-TiB_2 surface composite



Element	Weight%	Atomic%
C K	12.58	23.74
Mg K	0.57	0.53
Al K	78.39	65.86
Si K	0.91	0.74
Ti K	1.65	0.78
Totals	100.00	

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.



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

Fig. 3.5 Tensile test of base metal

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 TiB_2 surface composites shown higher hardness than the base metal (70 HV). However, Specimen no.5 with Al/TiB_2 24%, showed highest hardness value (121 Hv) as shown in Fig. 3.6. The percentage

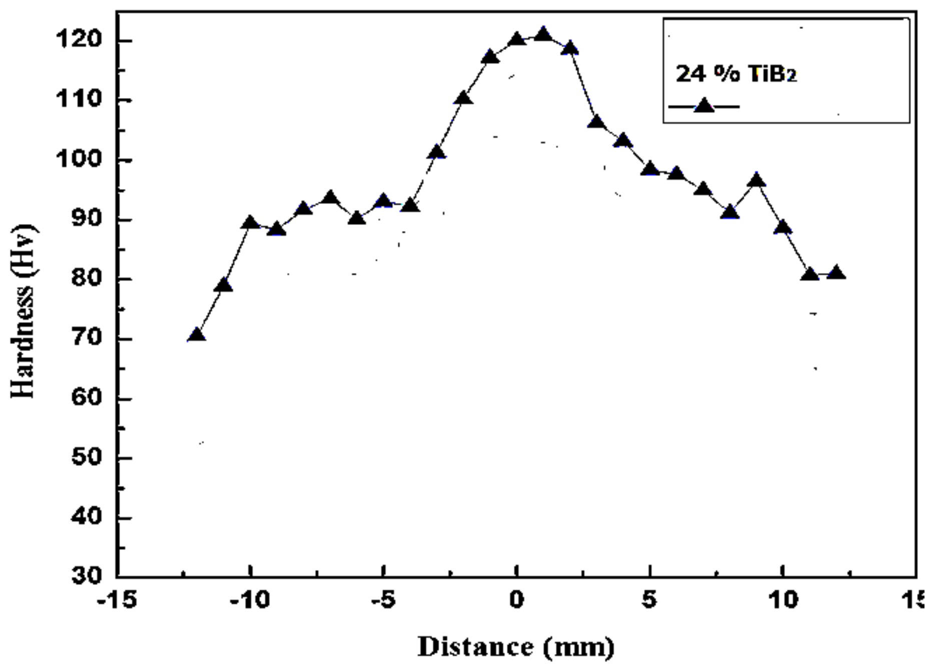


Fig. 3.6 Vickers microhardness of Al-6061/TiB_2 24% composite.

increase from base metal hardness to composite harness is thus 72.8% This may be due to dynamic mixing of TiB_2 particles into the softening Al 6061T6 matrix, causing its uniform mixture in the nugget zone, termed as Orowan strengthening. Severe grain refinement in the weld zone has happened in Al/TiB2 24%, in which TiB_2 acted as a perfect harder phase.

3.4 XRD Analysis

The XRD pattern of the FSP Al6061-TiB2 composite for different volume fraction of TiB2 is shown in Fig. 3.7 . The XRD pattern was indicating the presence of Mg_2Si and AlTi phases formed during friction stir processing. The reason for the formation of above mentioned phases can be attributed to the generation of high temperatures during friction stir processing and rotation of the tool pin may cause intimate contact between the different elements and provide favourable conditions for the necessary reaction. This gives the support to microstructural observation.

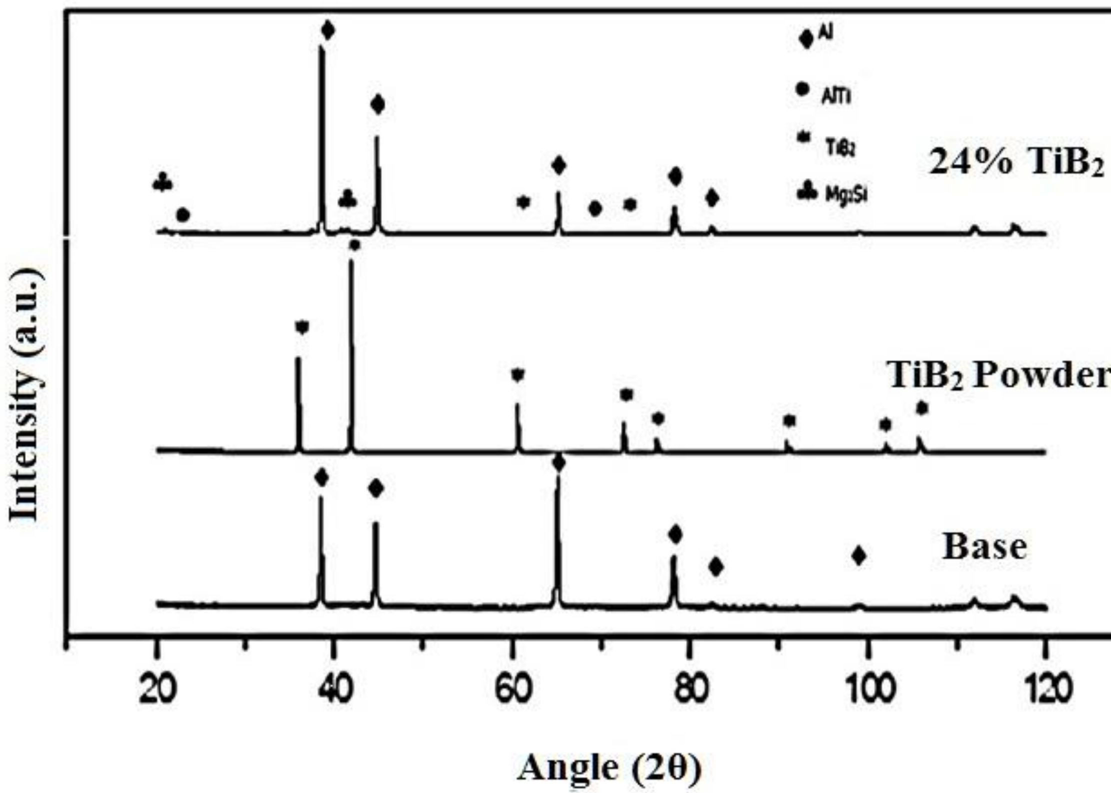


Fig. 3.7 Comparative XRD plot of AA6061-TiB2 composites.

4. Conclusions

The nanocomposite surface layer by reinforcing TiB2 particles on Aluminum 6061-T6 Alloy via FSP successfully fabricated. Effect of nano-sized reinforcement particles such as TiB2 (average size is 35 nm) on microstructure, micro-hardness of Aluminum 6061-T6 alloy based nano surface composite fabricated via FSP, its XRD and EDS were studied and the following conclusions are to be obtained.

1) The TiB_2 particles are uniformly distributed in the composite as confirmed in the microstructures.
2) The phases present in the composite is confirmed by the XRD and the TiB_2 causes the creation of a new phase Al-Ti in the matrix.
3) In the SZ dynamic recrystallization was observed, equiaxed grains were found in the TMAZ and grain growth was observed in the HAZ.
4) Microhardness of the composite (121 Hv) was increased by 72.8% as compared to base metal (70 Hv) in the SZ.

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