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Abrasive wear Behaviour of TiB2 Fabricated Aluminum 6061 ☆

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Abstract

The usage of Aluminum has been growing rapidly during past few decades due to its inbuilt variety of properties viz., high strength stiffness to weight ratio, good formability, good corrosion resistance, and recycling potential. The research interest is more on the abrasive behavior of Aluminum 6061 composites as the automotive industry is looking forward for the properties of rigidness, not subject to fracture or deformations. This paper focuses on abrasive wear behavior of Al 6061 composites. The Al 6061-T6 sheet which is fabricated after friction stir process with TiB2 is subjected to abrasive testing performed on pin-on-disc. Various samples are subjected for testing on pin-on-disc, at high temperatures, with parameters viz. sliding speed, load applied. The increase in addition of the TiB2 filler leads to a non-sticky property with Al 6061 which leads in decrease in strength, is observed. The results are based on weight loss method when subjected to pin-on-disc. The various parameters are discussed and compared with several experimental results, which has shown that the composites having more percentage of non-metals are good at wear resistance than the composites having less percentage of non-metals. By adding TiB2 in to the metal which leads to increase in wear resistance has been observed in the results.

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Keywords: Al 6061; TiB2 MMC; abrasive wear testing; wear resistance.

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1. Introduction:

Aluminium alloys are prominently utilized in aircraft, defence, automobiles and marine applications due to its advantages like good strength to weight ratios, availability and better corrosion properties. But, research shows that aluminium alloys exhibit 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 techniques 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 are to the surface, it could improve the wear and erosion. 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 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, Al2O3, Al3Ti 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].TiB2 is also ceramic powder which have better properties than SiC ,Al2O3. However much literature was not available on the wear behaviour of 6061 Al alloy with TiB2 as surface composite. The objective of the present investigation was to enhance the wear resistance of 6061 Al alloy by dispersion of TiB2 particulates on the surface using FSP technique. Homogeneous dispersion of TiB2 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 AND EXPERIMENTAL PROCEDURES:

6061 -T6 Aluminium alloy plate with 4mm 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 100mm x 70mm x4mm. Tib2 particles with various volume fractions were used as reinforcements. A square groove was cut with dimensions of 2mm x2mm width and Depth each were cut on the rectangular Alloy plates perpendicular to the tool pin in the advancing side. The three FSPed surface composites with different volume fractions are denoted as Al/TiB2-5%, Al/TiB2-10%, Al/TiB2-15%.

Table 1 Chemical composition of aluminum 6061-T6 alloy (mass fraction, %)

Contents	Mg	Si	Cu	Zn	Ti	Mn	Cr	Al
%	0.85	0.66	0.23	0.07	0.05	0.30	0.06	Bal

The tool used for FSP was fabricated with H13 tool steel with a shoulder diameter of 18 mm, screwed taper profile pin diameter of 6 mm and height of 3.5 mm. The reinforcement particles of TiB2 powder were packed in the grooves of the samples. The tool rotational speed of 1000 rpm, transverse speed of 50 mm/min, axial force of 5 KN and tool onward tilt angle of 1.5°along the center line were used. After successful FSP, dispersion of reinforcement particles in the surface composite were captured by using Scanning Electron Microscope (TESCAN make). Microhardness 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. For wear tests, Prismatic pins of 6 mm diameter were cut from the stir zone, with the axis of the pin normal to the FSP direction. Experiments were done using a pin-on-disc tribometer (Make: Ducom)as per ASTM standard G99-05 under dry sliding Conditions with sliding velocity of 3 m/s, normal force of 40 N and sliding distance of 4000 m. The disc was made of EN31 steel with 100mm diameter.

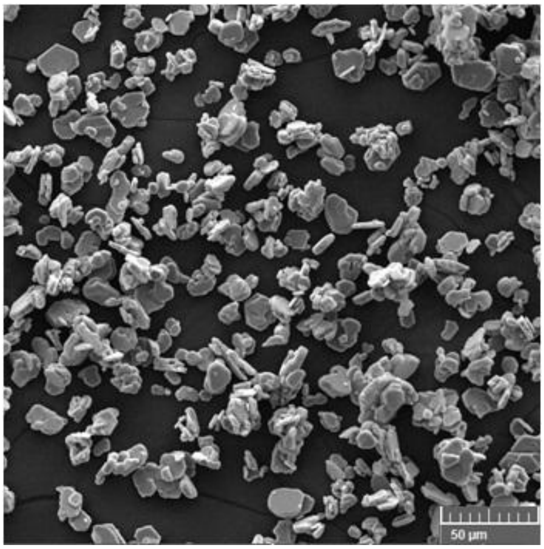

Fig 1.: TiB2 reinforcement Particles

3. Results and discussions:

Friction stir processed Surface composites of 6061-T6 alloy TiB2 were fabricated successfully. The macroscopic view of the FSPed surface of the Al/TiB2-10% was shown in Fig. 2. The surface was smooth without any defects such as voids and cracks and improper mixing.

Fig. 2 Macrograph of FSP zone of Al/TiB2 10% surface composite

3.1 EDAX results:

The particles of TiB2 were observed to be dispersed uniformly within the NZ due to the existence of dynamic stirring of the rotating tool during the FSP as in Fig 3. It was observed that some reinforcement particles are smaller in size than the as-received particles. This is because the tool provides a shear and circumferential force to break the reinforcement particles in the NZ.

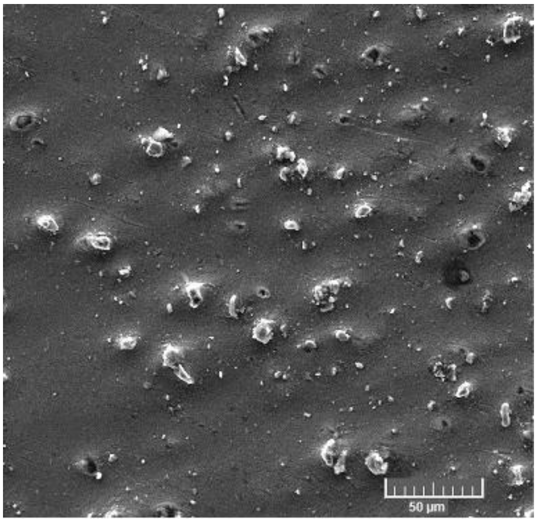

Fig. 3: Dispersion of TiB2 particles in 6061 matrix

The EDAX spectrum of the prepared Al-TiB2 composite was shown in Fig. 4. The peaks of Al, Ti are clearly visible in the Fig. 4b . The percentage of Ti shown in as-received alloy was almost nil (0.05%), but in Al-TiB2 surface composite, it was 1.51%. It confirms that, the presence of reinforcement particles (TiB2) and its dispersion in the Alloy matrix.

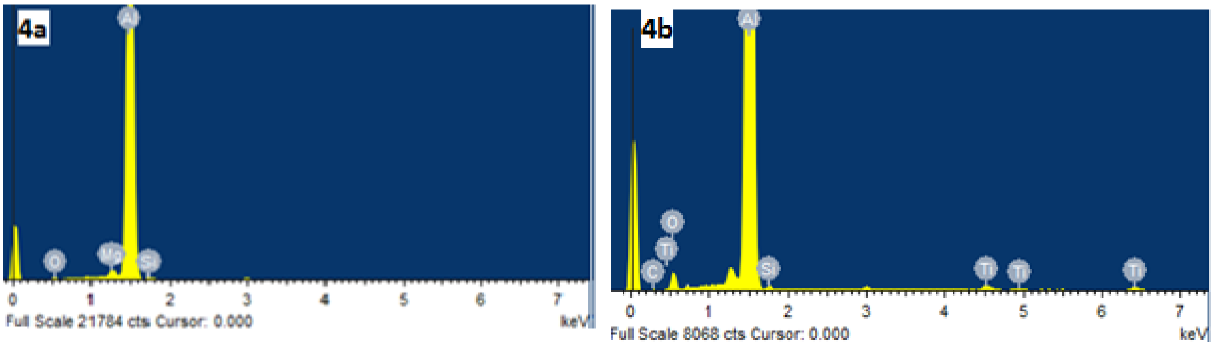

Fig. 4. EDAX analysis of : (a) Al-6061 as received alloy and (b) Al-TiB2 surface composite

3.2 Microhardness

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 [4]. The hardness for all the specimens of FSPed 6061-T6 Al alloy with TiB2 surface composites shown higher hardness than the base metal (103.5 HV). However, Specimen no.2 with Al/TiB2 10% , showed highest hardness value (135 HV) compared to Al/TiB2 5% , and Al/TiB2 15% , (129.5 HV) as shown in Fig. 5 .This may be due to dynamic mixing of TiB2 particles into the softening Al 6061T6 matrix, causing its uniform mixture in the nugget zone, termed as Orowan strengthening [12]. Severe grain refinement in the weld zone has happened in Al/TiB2 10%, in which TiB2 acted as a perfect harder phase.

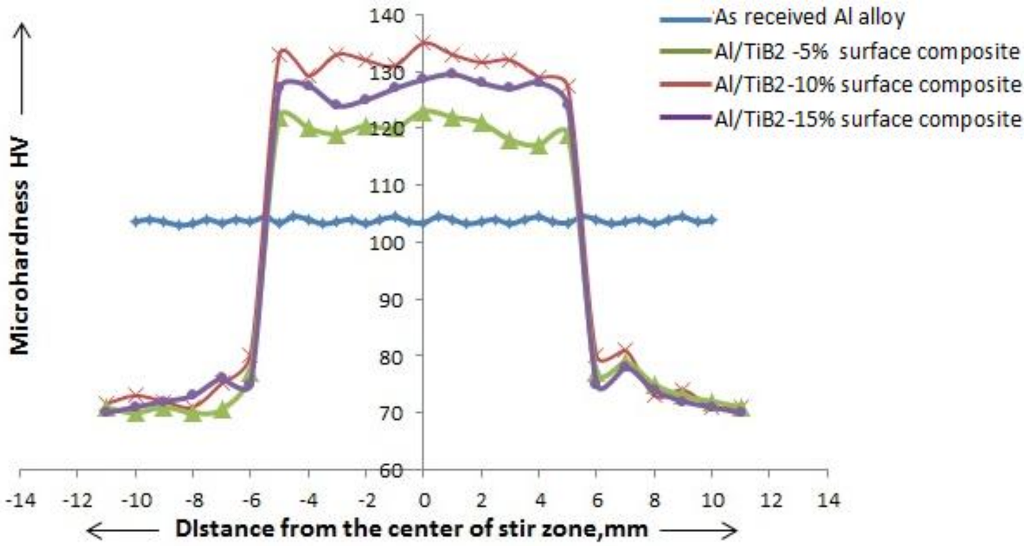

Fig. 5: Microhardness profiles of Al-TiB2 surface composites

3.3 Wear Behaviour:

During sliding of wear specimen, it was observed that the TiB2 particles are pulled out from pin tip and were trapped between its body and steel disc. Jun Qu Et Al [13] suggested that abrasive type of wear in surface composites by the use of Al2O3 and SiC reinforcements showed better wear properties than as received alloys in which adhesive wear is predominant. Similarly , these TiB2 debris particles which are pulled out of the surface acted as load bearing particles which converted the adhesive mode of wear of the composite to abrasive wear mode Hence, the wear rate of all the composites showed lower than that of as- received alloy by a good magnitude. Also the fine dispersion of TiB2 particles in the metal matrix increased the hardness of the weld. This might have also influenced the decrease of wear rate of the composite [14-15]. Wear rate of each specimen with respect to sliding distance was shown in Fig. 6, which gives the comparison of wear volume loss of surface composites with respect to as received alloy. Volume loss due to wear in all the specimens increased with sliding distance but they are considerably low when compared to as received alloy. Surface composite Al/TiB2 -10% sample showed better wear results than all the three composites. The SEM micrographs of the worn morphology of Al–TiB2/5%, Al–TiB2/10%, Al–TiB2/15%, surface composites and as-received aluminum alloy are shown in Fig. 7. It indicates the adhesion type wear in as received alloy (Fig. 7a), abrasion mode of wear in particles (Fig. 7b, 7c and 7d).The worn surfaces of the surface composites after FSP also possess parallel grooves/scratches like pattern. The reinforcement debris from the grooves forms a spherical type of particles, which gives a rolling effect to the sliding wear sample (Fig. 7c). In Fig 7d, though the volume fraction of reinforcement particles are high, wear rate is also observed to be high, which might be attributed due to the improper mixing, clustering of reinforcement particles in the alloy matrix during FSP [16].

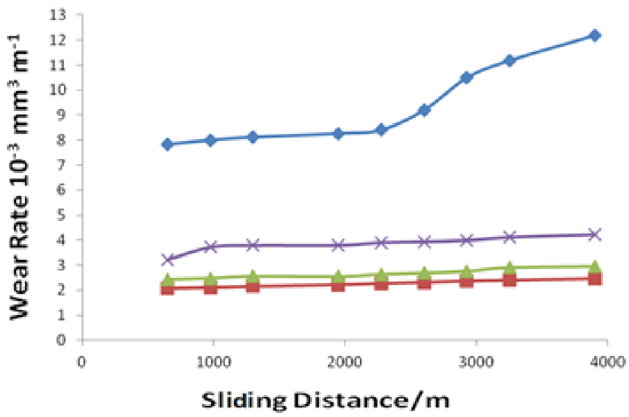

Fig.6: Wear Rate of Surface composites with respect to as-received alloy

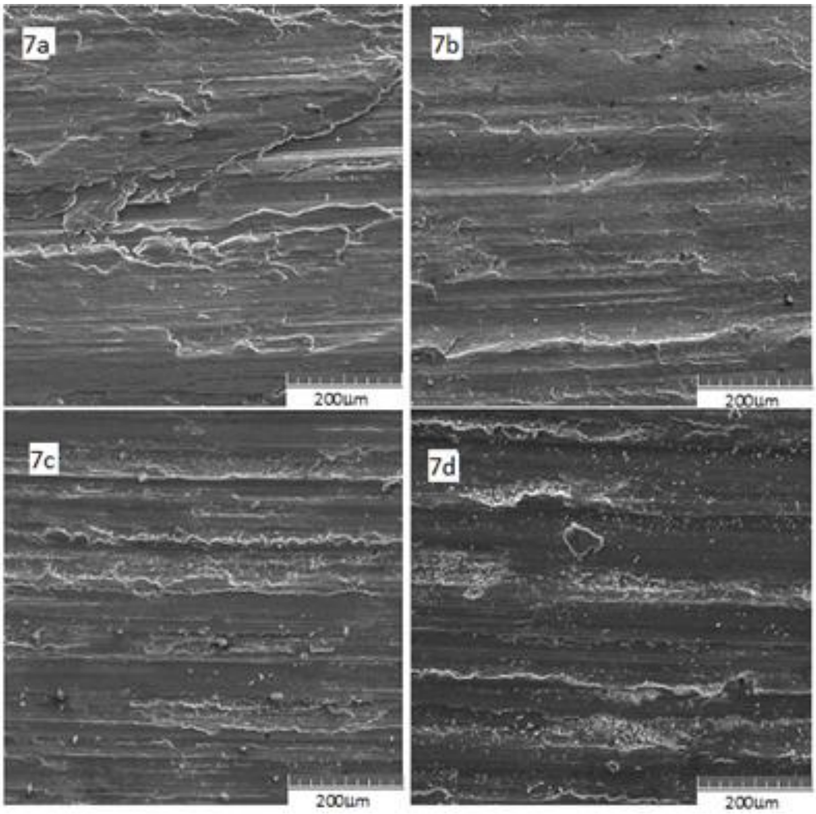

Fig. 7: Worn morphology of the samples of as-received alloy (7a), Al/TiB2-5%(7b), Al/TiB2-10% (7c), Al/TiB2-15% (7d)

EDAX of the wear sample of surface composite was shown in Fig 8.It was observed that the wear specimen pin surface containing reinforcement particles drag the iron particles from the steel disc, forming transfer layers rich in iron and iron oxide. The iron rich film also contributes to the wear resistance of the composite [17].

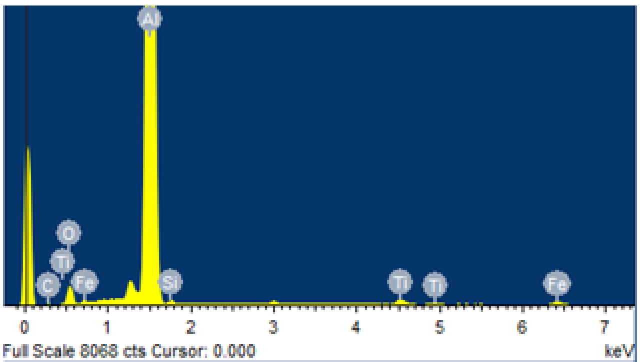

Fig.8 : EDAX of worn surface of the composite showing the presence of iron

4. Conclusions:

1. Surface composites with uniform distribution of TiB2 inside the nugget zone was achieved by FSP.

2. The hardness values of all the surface composites showed superior results than as received alloy. Al/TiB2-10%

composite showed best hardness among the three composite. The increase in hardness is attributed due to the presence of hard reinforcement particles.

3. Wear rate of the composites were observed to be less compared to that of parent alloyAl-6061, where TiB2 reinforcements acted as load bearing particles which resisted the normal wear behaviour in the sample.

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