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Wear Characterization of Al/ B4C surface composite produced by TIG arc process

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Abstract : Aluminium based surface composites were fabricated by TIG arc process. B_4C mirco and nano particles were filled separately on the grooves of Aluminum substrate and modified the surfaces with different TIG arc speeds. The modified composite surface was characterized by optical microscope, Scanning Electron microscope and X-ray diffraction. The microhardness and wear properties of the composite surface were evaluated. The results of this study revealed that the newly formed nano composite surface enhances the hardness and wear characteristics. The wear worn-out surfaces of the composite surface were analyzed through SEM studies in order to understand the wear mechanisms.

Keywords: TIG arc surface, Aluminium, B_4C, Hardness, Wear resistance

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I. INTRODUCTION

Aluminium alloys having good strength-to-weight ratio, low density, better mechanical properties and excellent corrosive properties, but poor in wear resistance [1-2]. The Aluminium based surface composites replacing with Aluminium alloys due to high elastic modulus and improved wear resistance [3-5]. The varies surface modification methods are cladding, thermal spray, laser, sintering, electron beam irradiation, coating etc [6-8]. Znamirowski et al., (2004) [9] have studied the effect of ceramic particles on the substrate by plasma spraying technique. Seong-Hun Choo et al., (1999) [10] fabricated Steel/TiC surface composite by electron beam irradiation technique and studied the effects of flux during surfacing. The optimum flux value of 10 to 20% addition during surfacing gives better dispersion of TiC particles in the composite without agglomeration. The hardness of modified surface was improved 3 to 4 times more than unaltered original substrate. Dubourg et al., [11] (2002) added copper and iron powders on the Aluminium substrate to enhanced the mechanical properties of the surface by laser cladding technique. Majid Tavoosi and Sajad Arjmand (2017) [12] deposited Aluminium on Titanium subtract through TIG cladding process and produced Al/Al_3Ti surface composite coating in order to improve hardness and corrosive resistance.

Alireza Ardeshiri et al., [13] (2017) have pasted mixture of 30wt%Fe+70wt%Si powders in the Al2618 alloy and modified the surface by TIG arc technique. The hard-intermetallic compounds such as $Al_{13}Fe_4$, Fe_5Si_3, Al_8Fe_2Si, and Al_5FeSi were formed. The microhardness of the composite layer was 3 to 4 times higher than the base alloy due to presence of TiC hard particles. These processes create excellent bond between the substrate and the composite layer. The hardness of the alloyed surface was very high (210Hv) and the base alloy hardness was 60Hv. The wear rate of the alloyed surface was half of the untreated surface.

Sh. Zangeneh et al., [14] (2017) studied the effect of surface melting in Co-28Cr-5Mo-0.3C cast alloy using TIG arc welding process. $M_{23}C_6$ carbides were formed in the range of nano scale during solidification which leads to improvement of hardness of the surface. A. Monfared et al., [15] (2013) produced Ti/TiC surface composite by TIG arc method and studied the effect of different current intensity and welding travel speeds of the TIG arc process on mechanical and wear properties of the surface composites. Microhardness (1100Hv) of the surface composite fabricated at lower heat input value of $232.1Jmm^{-1}$ was 7 times higher than base material due to increase in higher volume contentment (32.4%) of TiC particles in the composite surface. The TIG process produced thick and hard surface composite with good metallurgical bonding. Various researchers are reported for surface modification by using TIG arc source [16-19]. TIG arc surfacing method is cost effective process with significant advantages such as simple method of operation and lower price [20]. Recent years B_4C has been extensively used in fabrication of surface composites. B_4C reinforcements has excellent properties such as high hardness, low density, high melting point and good thermal stability. Owing to their specific properties, it finds in distinct high wear resistance applications [21]. In this study B_4C micro nano reinforcements are added on the Aluminium subtract and modified by the TIG arc method. Optical, SEM, micro hardness and wear properties of the composite surface were studied.

II. MATERIALS AND METHODS

In this study 8mm thick Al5083-O plate with a chemical composition of 4.1%Mg, 0.06%Cr, 0.5%Mn, 0.19%Fe, 0.02%Zn, 0.2%Si, 0.04%Ti (all in weight %) and rest Aluminum was used. The B_4C micro particles size of 30µm and B_4C nano particles average size of 30-60nm was used. The SEM micrograph of the B_4C particles is depicted in Fig. 1. To produce surface composites 1mm width and 2.5mm depth groove was created in middle of the plate. B_4C particles were mixed with acetone in the form of slurry and tightly packed inside the groove in order to prevent the escape of the particles from the groove by the flow of shielding gas. Then the prepared plate was dried at 50^{o}C temperature for 30 min. TIG arc surfacing process was fabricated on the straight polarity of pulse DC TIG arc welding machine. The process parameters are listed in the Table No.1.

Table No. 1 TIG arc surfacing process parameters

S No.	Operation parameters	
1	Electrode	Zirconated Tungsten Electrode
2	Shielding Gas	99.95 argon
3	Electrode diameter	2.4 mm
4	Gas flow rate	7L/min
5	Current	130A
6	Voltage	12
7	Speed	1.25 mm/sec, 2.5 mm/sec & 3 mm/sec
8	Nozzle to plate distance	5 mm

TIG arc surfacing experimental setup is shown in Fig. Metallographic and microhardness specimens were taken from the cross section of the modified region and examined through Optical and Scanning Electron Microscope (SEM) (Hitachi S3700). Standard metallographic procedure was followed and modified Poulton's reagent [22] (30 ml HCl, 40 ml HNO_3, 2.5 ml HF, 12g CrO_3, and 42.5 ml H_2O) was used to study microstructure. To identify the presence of inter metallic phases in the composite region XRD (BRUKER D8 ADVANCE) was used. The microhardness of the surface composite and base alloy were examined through Micro hardness tester (Leica VM Auto) at a load of 100g with dwell time of 10s. Dry sliding wear test was carried on the pin on disc tribometer (make DUCOM) in room temperature condition as per ASTM G99-04 standard. Composite and base alloy wear test specimens of 8mm diameter were extracted from the middle of processed region and polished on the 1600grade emery sheet before the test. The counter discs were made of hardened EN-24 steel and polished at the surface roughness (Ra) of 0.2µm. All wear tests were conducted at sliding speeds of a 1 m/s under normal load of 40N for sliding distance up to 2000m.The test samples and the disc were cleaned with acetone before and after the test and weighed to an accuracy of 0.01mg by electronic weighing balance. All wear tests were repeated two times and an average of two were taken. The worn-out surfaces of the base alloy and composite specimens were examined through SEM.

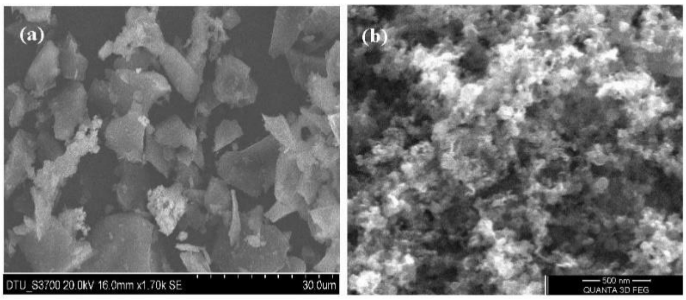

Fig. 1 SEM micrograph of B_4C particles (a) micro sized (b) nano sized

Fig. 2 Experimental set-up of TIG arc surfacing

III. RESULTS AND DISCUSSION

3.1 Microstructure

With micro sized particles the TIG arc process was not takes place in right manner due to insufficient melting and larger size of the particles. Insufficient mixing and melting occurs with the base material as a result of poor surface obtained. The heat input was increased for mixing with the substrate as result of excessive melting took places on the surface. The micro size B_4C particles not produced good surface. With the nano sized particles the mixing of particles with substrate uniformly took place and good bonding generated hardened surface. Sufficient melting occurs on the surface till the depth of the groove as a result of uniform surface composite produced. The nano composite surface modified by TIG arc at torch speed of 1.25mm/sec is shown in Fig. 3. The macrostructure of the cross section of the TIG arc surface is shown in Fig. 4(a). It clearly shows the fusion took place till the full depth of the grooves and sufficient melting occurred.

Fig. 4(b) shows the optical micrographs of TIG arc surface. The TIG arc generated sufficient heat for melting of base alloy and mixing with hard nano reinforcement particles. The temperature produced approximately 900°C and grain coarsening take place on the surface. Between liquid Aluminium and B_4C particles reaction obtained and the possible phases of Al_3BC, Al_3B_{48}, Al_3BC_3 Al_4C_3, and B_4C may took place on the melted region according to ternary phase diagram [23].

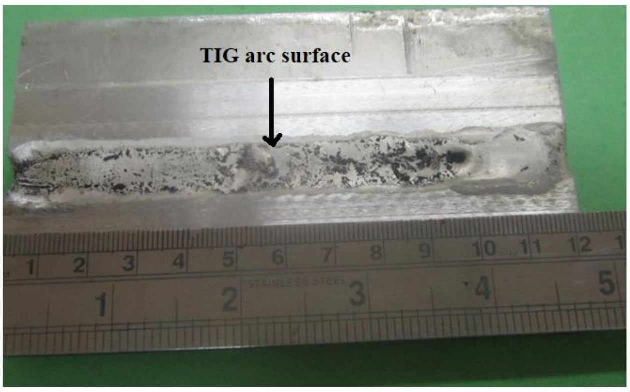

Fig. 3 TIG arc composite surface

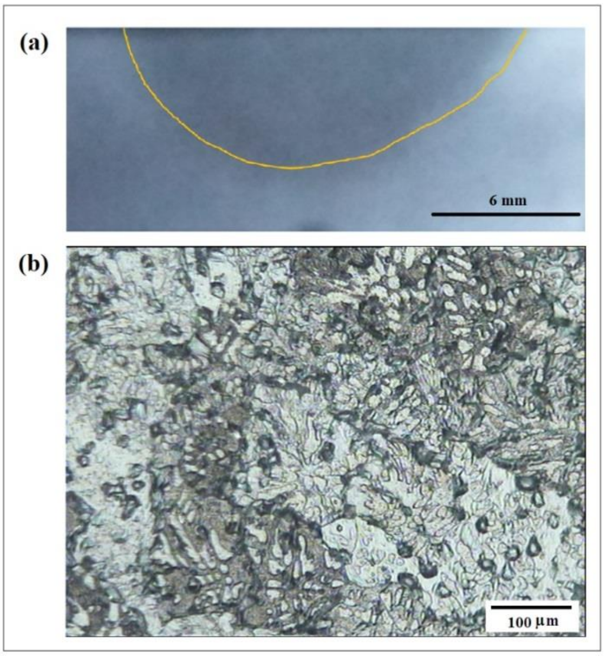

Fig. 4 TIG arc composite surface (a) Macrograph (b) Microstructure

The dark and white region interface indicates the Al-B_4C phases in optical micrograph (Fig 5(a)). Fig. 5 (b) shows the various elements in the XRD pattern. The Al_3BC, B_2O_3 and B_4C elements were traced in the XRD pattern. Various researchers are reported that the melting of Aluminium with B_4C the various elements were formed. The elements are Al_3BC, AlB_{10}, β-AlB_{12}, Al_3BC and AlB_2 [24-25].

3.2 Microhardness

Fig. 6 shows the microhardness profile of the samples were extracted from the cross section of composite region. Maximum hardness value of 112Hv was obtained on the composite surface produced at the arc travel speed of 1.25mm/sec. The uniform hardness was observed throughout the depth of the composite surface.

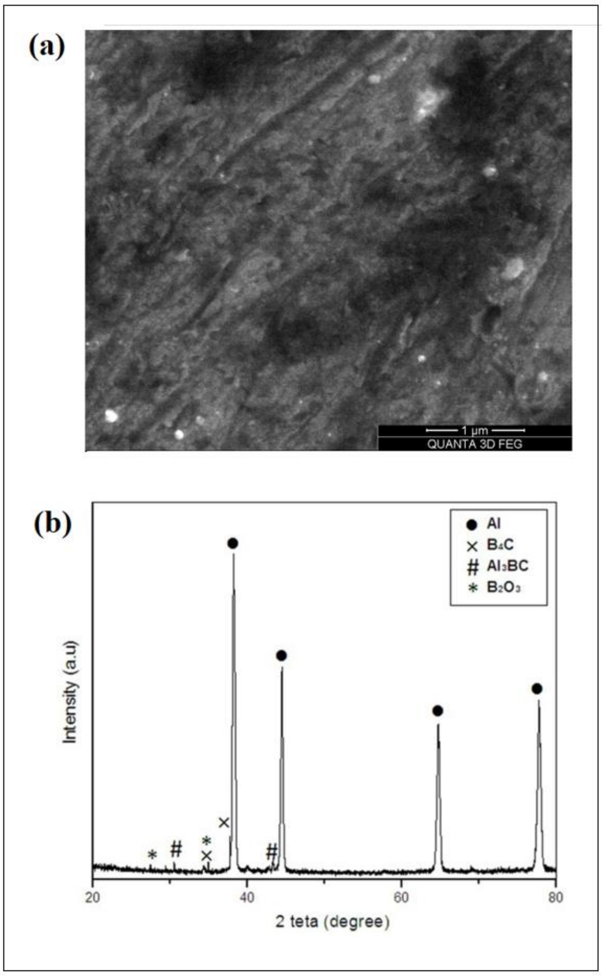

Fig. 5 TIG arc composite surface (a) SEM image (b) XRD pattern

Suitable heat input is required for producing enhanced uniform hardness composite surface. Lesser heat input is insufficient to melt the material and mixing with reinforcements. Excessive heat input generates more melting as a result of surface was not formed uniformly. The heat input was estimated by using following equation [17]. At 2mm/sec TIG arc speed the heat input generated was very low and the composite surface not obtained due to insufficient melting and mixing of the reinforcement with base alloy.

$$Q = \frac{\eta \; x \; I \; x \; V \; x \; 60}{S \; x \; 1000} \ldots\ldots\ldots\ldots\ldots\ldots.(1)$$

Where Q-Heat input (kJ/mm), η-TIG arc efficiency (0.6), V-Arc voltage (12V), I-current(130A) and S-Travel speed (mm/min). Behnam Lofti et al., (2014) [26] reported that process parameters are responsible for generation of heat input in order to produce Al-Si/SiC cladded surface on A380 aluminium alloy.

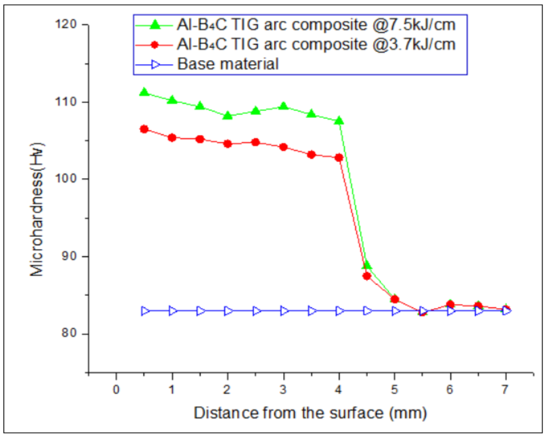

Fig. 6 Microhardness profiles of TIG arc surface

Fig. 7 Wear test specimens

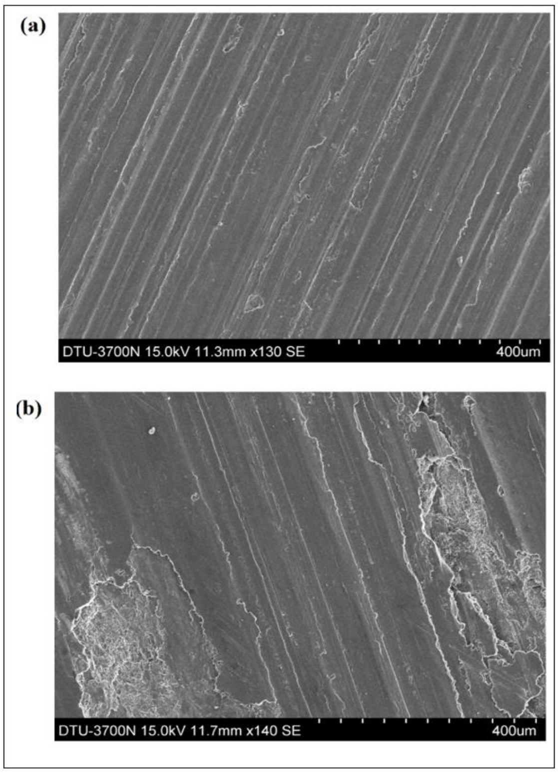

Fig. 9 SEM micrograph of worn out sample of (a) Composite specimen (b) Base alloy

The wear test samples take out from the composite surface and base alloy is shown in Fig. 7. Wear rate vs the sliding distance of TIG arc surface composites and base material is shown in Fig. 8. The TIG arc surface produced at higher heat input specimen wear resistance is higher than other samples due to the higher hardness. The B_4C particles act as a load bearing element and the intermetallic elements such as Al_3BC and B_2O_3 resists the removal of material from the composite surface. The oxidation and abrasive wear mechanisms were accountable for removal of material from the composite specimens. In the base alloy the deeper scratches and micro cracks were formed due to lower hardness of the material. The SEM image clearly indicates the abrasive marks, oxide layer on the worn surfaces (Fig.9).

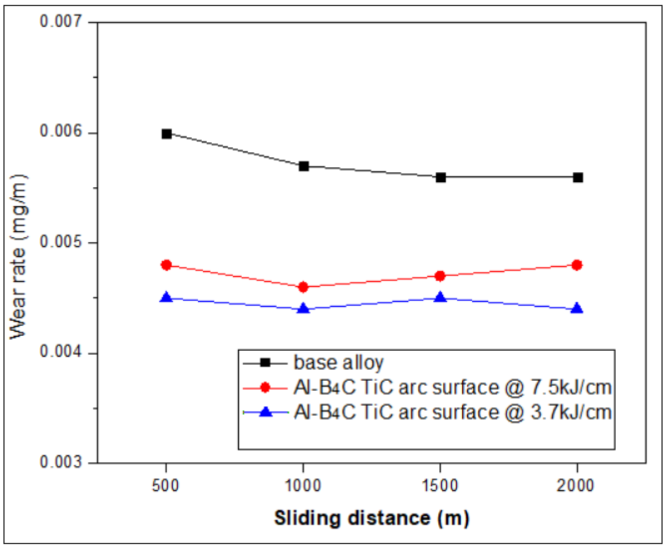

Fig. 8 Variation of wear rate vs sliding distance of TIG arc surface

IV. CONCLUSIONS

In this study, the deposition of B_4C particles on Aluminium 5083 by TIG arc process has been attempted. The TIG arc method is an effective method for enhancing the surface hardness and wear resistance of the material. Nano sized particles was more effective than micro sized particles for producing surface composite.The optimum process parameter generates required heat input for melting and melting of the base alloy with reinforcements in order to produce quality surface. The composite specimen produced with heat input value of 7.2 kJ/cm has higher hardness value of 112Hv and lower wear rate of 0.0045mg/min. Formation of intermetallic and hard nano reinforcement particles are the main reasons for improvement of the surface properties.

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