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Characterization of AA6063/SiC-Gr Surface Composites Produced by FSP Technique

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Abstract

Friction stir processing (FSP) is a novel technique used for the production of surface composite, refinement of microstructure and enhancing the mechanical properties. In this work, surface matrix composite (SMC) was fabricated on the surface of aluminium alloy (6063) with ceramic reinforcement using friction stir processing technique. SiC and Gr was used as reinforcement. The chosen FSP parameters such as traverse speed of 30 mm/min, tool rotational speed of 1000 rpm and 10 KN of axial load. The FSP tool made of HcHCr with cylindrical threaded profile pin having shoulder diameter of 18 mm, pin length of 5.8 mm and pin diameter of 6 mm was used. The FSP was carried out using friction stir welding machine. Three combinations of surface composites (Al/0.8Vol.%SiC, Al/0.8Vol.%Gr and Al/0.4Vol.%SiC-0.4Vol.%Gr) were fabricated. Optical microscope (OM) and scanning electron microscope (SEM) was used to study the microstructural changes. The recrystallized grain structure was observed in the FSPed zone. The microhardness of friction stir processed plates was analyzed using a Vickers hardness tester. Sic reinforced Al alloy surface composite resulted higher microhardness.

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Keywords: Surface Matrix Composite; SiC and Gr particulates; AA6063; Friction Stir Processing; Microstructure; Hardness

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1. Introduction

Aluminum is the second bountiful metal on earth. Aluminium alloy has characteristics like low density, high specific strength, physical and mechanical properties and corrosion resistance [1]. Because of good strength to weight ratio, high thermal conductivity and good corrosion resistance, the aluminum and its alloys are popularly used in structural materials. Due to poor wear resistance; its tribological applications have been limited. The use of non deformable hard ceramic particles such as SiC, Al_2O_3 as reinforcements to form aluminum matrix composites has been well studied. Many researchers were carried out the research work on fabrication of surface composite using FSP process [2]. Some more research work were also done on fabrication of surface composite by deep groove processing method and the effect of FSP process parameters on the microstructure and mechanical properties were studied [3, 4].

Friction stir welding (FSW) was invented by The Welding Institute (TWI) at UK in 1991 as a solid state joining technique. Without being limited to welding, friction stir processing has found various applications such as grain refinement, superplasticity improvement, formation of intermetallic and composite fabrication [3-5]. Sharifitabar et al [6-8] fabricated the Al_2O_3 reinforced AA5052 aluminium surface composite with multi pass FSP technique. Dolatkhah et al [7] successfully fabricated the surface composite of micron sized SiC powder reinforced 5052 aluminum sheets with optimized FSP parameters. Magdy et al [9,10] has conducted FSP on 6082-T651 aluminum alloy by applying overlapping passes with three different traverse speeds. The increase in number of passes decreased the grain size and improved the elongation property. Yoshihiko Hangaia et al [11] investigated the porosity of AA1050 porous aluminum with uniform pore size distribution by the amount of stirring action and it is ineffective when stirring action is excess. The tool material and its profile used for the FSP work played a major role in fabricating the surface composite. The different tool pin profile was studied by Elangovan et al [12] and reported that the square pin profile resulted the finer grain refinement with improved hardness. Of the three pin profiles used by Azizieh et al [3] on fabricating AZ31/Al_2O_3 nano composites, threaded pin profile resulted the fine grain refinement than the other tool pin profiles. Ademkurta et al [13] fabricated AA1050/SiC_p surface composite and obtained higher microhardness in FSP zone. Wei et al [14] fabricated SiC_p reinforced 5A06Al aluminium alloy surface composite and found good bonding of matrix/reinforcement.

In this present study, FSP is used to fabricate and modify the surface characteristics of AA6063 aluminium alloy by reinforcing SiC and graphite (Gr) ceramic particulates. The metallurgical and mechanical characteristics of fabricated AA6063/SiC+Gr surface composite were examined.

2. Experimental Procedure

Aluminium alloy (AA6063) plate having size of 100x50x10 mm were used as a matrix and SiC and Gr as reinforcement in this research work. The measured chemical composition of the matrix material is given in Table 1. To produce a surface composite, a groove having the dimension of 0.8 mm × 5 mm was contrived in the middle of the specimens as shown in the Fig. 1. The SiC and Gr particulates were embedded and compressed into the groove in three combinations such as Al/0.8 vol.% SiC, Al/0.8 vol.% Gr and Al/(0.4 vol.% SiC + 0.4 vol.% Gr). In order to prevent scattering of the particles, the upper surface of the groove was closed using a pinless FSP tool. The FSP tool shown in Fig. 2 was used to fabricate the surface composite at different combinations. The used tool for the FSP was made of High Carbon High chromium (HCHCr) steel with cylindrical threaded pin profile with shoulder diameter of 18mm, pin diameter of 6 mm and pin length of 5.8 mm. The FSP parameter such as tool rotational speed of 1000rpm, axial load of 10kN and 30 mm/min of traverse speed were used. From the Friction Stir Processed (FSPed) plate, specimen of 50 X 15 mm was extracted at the middle of the specimen. The specimens were polished and etched with keller's reagent. The macrostructure of the etched specimens was captured using digital optical scanner. The microstructural characterization of the fabricated surface composite was carried out using optical microscopy and Scanning Electron Microscopy (SEM). The microhardness of the surface composite was measured using Vickers microhardness tester.

Table 1 The chemical composition of aluminum alloy AA6063

Element	Si	Fe	Mn	Mg	Zn	Ti	Cr	Ni	Al
% wt.	0.63	0.83	0.069	0.38	0.16	0.029	0.017	0.011	Balance

Fig. 1 Grooved Specimen

Fig. 2 FSP Tool

3. Results and discussion

The surface composite AA6063 reinforced with SiC and Gr was successfully fabricated using FSP process. The crown appearance of the fabricated surface composite plates of AA6063/SiC, AA6063/Gr, AA6063/(SiC+Gr) and FSPed aluminum alloy are presented in Fig. 3(a-d). Macrograph of the different combinations of FSPed zone was presented in Fig. 4(a-d). It clearly depicts that, the chosen FSP process parameters produced the defect free surface composite layer.

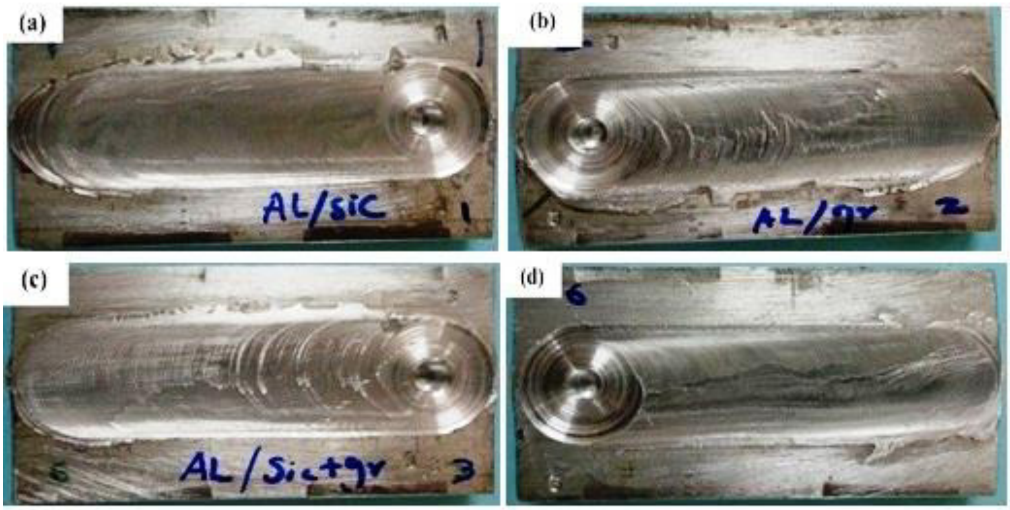


Fig. 3.The crown appearance of surface composite layer (a) Al/0.8 vol.%SiC (b) Al/0.8 vol.% Gr (c) Al/0.4.vol. % SiC+0.4 vol.% Gr (d) FSPed aluminum alloy

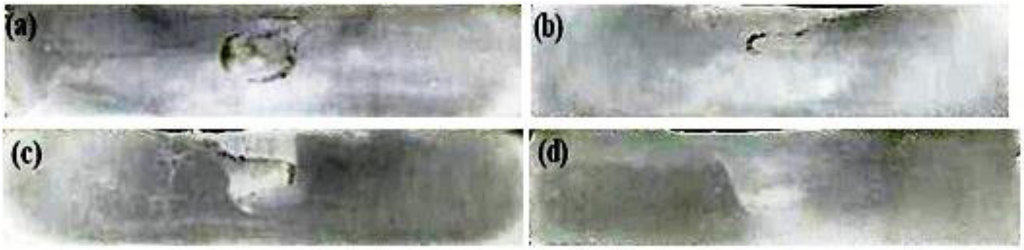


Fig. 4. Macrographs of the surface composite layer (a) Al/0.8 vol.%SiC (b) Al/0.8 vol.% Gr (c) Al/0.4. vol.% SiC+0.4vol.% Gr (d) FSPed aluminum alloy

3.1 Microstructure

Fig. 5(a-c) show the micrographs of the FSPed AA6063 aluminum alloy. The different zones of FSPed AA6063 were observed using optical microscope such as Transition Zone (TZ), Heat Affected Zone (HAZ) and Stir Zone (SZ). The refined grain size is observed in the SZ.

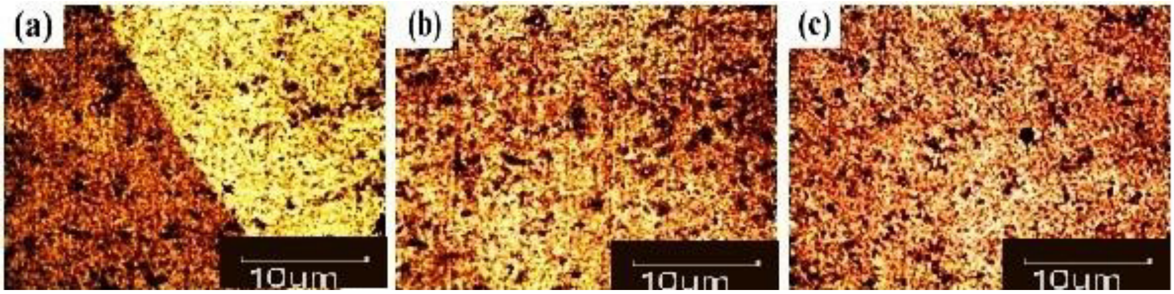


Fig. 5. Microstructure of the FSPed AA6063 aluminum alloy (a) TZ (b) HAZ and (c) SZ

Fig. 6(a-c) shows the micrographs of AA6063/0.8 vol.% of SiC surface composite. The refined microstructure along with homogeneous distribution of SiC particles were observed in the SZ. Fig. 7 (a-c) and Fig.8 (a-c) show the micrographs of AA6063 reinforced with 0.8 vol.% Gr and AA6063 reinforced with 0.4 vol.% SiC and 0.4Vol.% Gr respectively. Fig. 8b shows the HAZ of the reinforced alloy, where the accumulation of graphite particulates were seen. The better bonding between ceramics and Al matrix is observed in the fig. 8c.

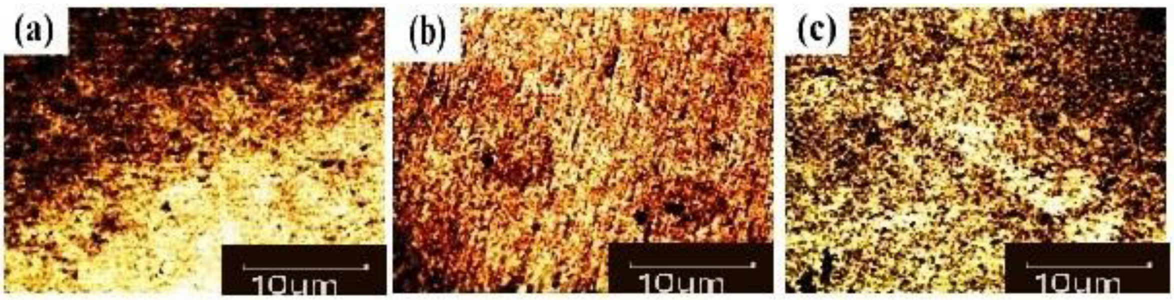


Fig. 6. Microstructures of the FSPed Al6063/0.8Vol.%SiC (a) TZ (b) HAZ and (c) SZ

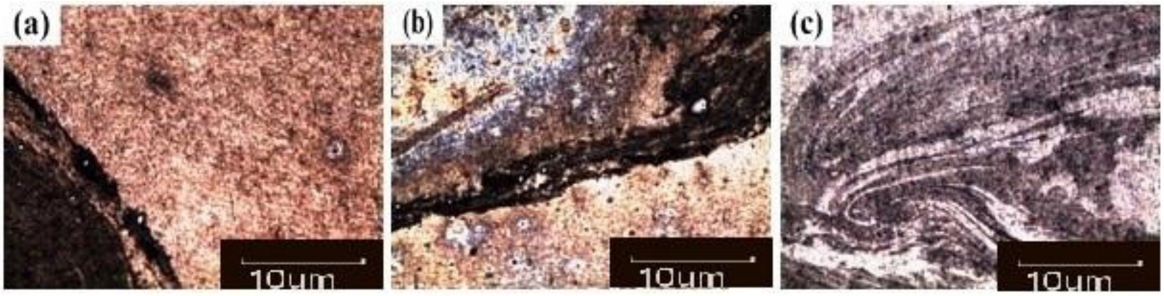


Fig. 7 Microstructure of the FSPed AA6063/0.8vol.% Gr (a) TZ (b) HAZ and (c) SZ

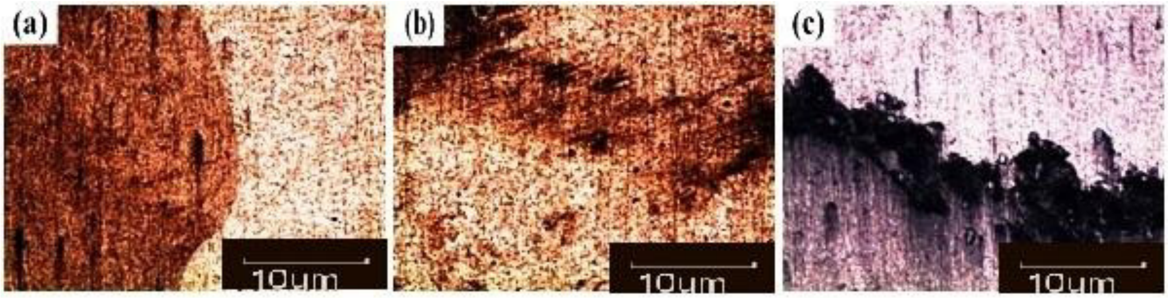
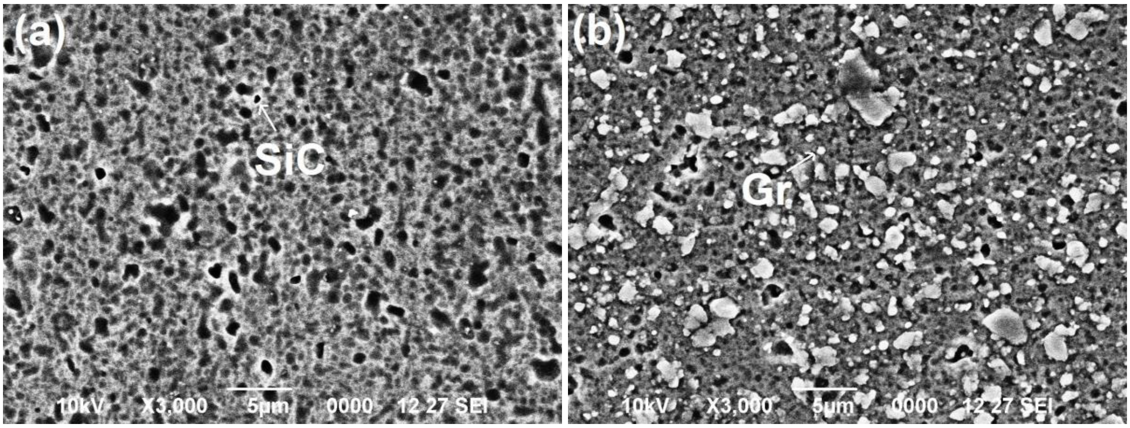


Fig. 8. Microstructure of the FSPed AA6063/0.4vol.%SiC+0.4vol.%Gr (a) TZ (b) HAZ and (c) SZ

Fig. 9 (a-d) shows the SEM micrograph of the FSPed zone of AA6063 reinforced with the ceramic particulates. It clearly depicts the particle distribution and well bonding of reinforcements with the base metal. The presence of SiC and graphite particulates is observed in Fig. 9 (a-c).The inhomogeneous distribution of SiC particles were observed in the SZ (Fig. 9a).



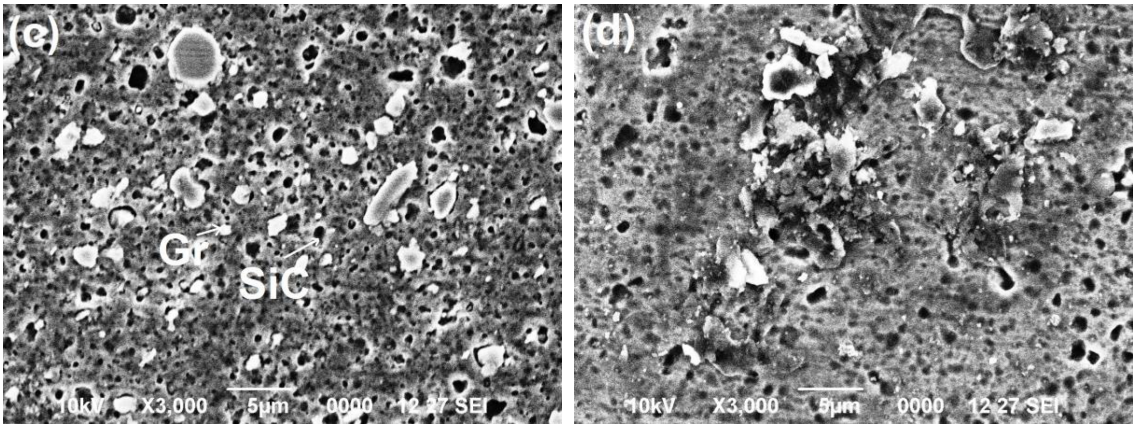


Fig. 9. SEM micrographs of FSPed SZ of AA6063 with (a) 0.8 vol.% SiC (b) 0.8vol.% Gr (c) 0.4vol.%SiC+0.4vol.% Gr and (d) FSPed aluminum alloy

3.2 Microhardness

The microhardness of FSPed plates were measured using Vickers microhardness tester with the load of 500g for 5 seconds. The average hardness of as-received AA6063 was 48Hv. The microhardness of FSPed aluminum plate is decreased to 39 Hv. The decrease in microhardness of the FSPed zone can be attributed to softening of aluminum alloy during FSP process. Microhardness of the surface composite layer fabricated with SiC reinforcement was increased to 62 Hv.

4. Conclusions

In this work, FSP was performed on Aluminium alloy (6063) reinforced with Sic and graphite ceramic particulates. The surface composite layer was successfully fabricated and the following conclusions were derived.

1. The grain size of the surface composite layer fabricated with SiC and Gr ceramic particulates were refined.
2. The microstructural study shows the homogenous distribution of the ceramic particulates in the SZ and good bonding with matrix material.
3. The microhardness analysis resulted the higher hardness value in surface composite layer fabricated with SiC particle than the other reinforcements.

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