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Friction Stir Processing and Mechanical Testing of SiC-Al_2O_3 and B_4C-Al_2O_3 Particulates Reinforced Aluminium Alloy Composites

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ABSTRACT:

This paper details the friction stir processing (FSP) and mechanical behaviour of hybrid composite materials. Boron carbide (B_4C), silicon carbide (SiC), aluminium oxide (Al_2O_3) particulates are reinforced with aluminium alloy (LM25) to fabricate hybrid composite specimens via FSP. The effect of FSP parameters such as tool rotational speed, traversing speed, groove width and micro hardness was investigated. Scanning electron microscopy analysis has shown that B_4C, SiC and Al_2O_3 particulates are dispersed well into the Aluminium alloy matrix. Mechanical test results have shown that the tensile strength and Vickers hardness of FSP aluminium alloy with B_4C and Al_2O_3 particulates are better than FSP aluminium alloy with SiC and Al_2O_3 particulates.

KEYWORDS:

Friction stir processing; Boron carbide; Silicon carbide; Metal matrix composites; Mechanical testing; Hardness

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1. Introduction

Metal Matrix Composites (MMC) can be processed using liquid state processing, semi-solid processing and powder metallurgy. In MMC, the matrix binds the reinforcements together. Good wetting is an essential condition for the generation of bond between the particulate reinforcements without failure. Friction stir process (FSP) is a solid state technique which has the ability to modify micro structures and provide improved properties over conventional processing technologies. FSP is used recently in aerospace, automotive, marine and railroad industries along with various applications. Friction stir processing is most commonly used with aluminium alloys [1-4]. Aluminium alloy exhibits extremely poor resistance to seizure and galling [4]. Experimental [5-7] studies of FSP were undertaken by many researchers. FSP is a process in which a rotating tool is driven into a desired weld seam and traverses across the length of the seam to form a solid joint, where as no melting of the work piece occurs in friction stir welding process. First the tool without pin traverses along the groove to forge the reinforcement particles as shown in Fig. 1. Then, the tool with the pin, as shown in Fig. 2, may moved along the desired line to cover the region. Due to the friction between tool and work piece, the work piece tends to soften and then plasticizes the composite materials introduced along the groove. During this FSP, the materials undergo plastic deformation resulting in the improved grain structure. FSP aims to modify the microstructure of a single work piece or multiple work pieces.

Fig. 1: Aluminium alloy filled with reinforcement

Fig. 2: FSP tool with pin

The material flow behaviour in FSP is predominantly influenced by the profile and dimensions of the FSP tool and process variables. Sun and Fujii [8] fabricated Cu-SiC particulates MMC using FSP in one and two passes. The joints processed after two passes have resulted in a particle-rich and free region formed in the stir zone. The particle rich region has a refined grain structure due to the SiC particulates. Barmouz et al [9] fabricated Cu-SiC particulates MMC using FSP with 5nm and 30 nm SiC particulates. FSP of copper with SiC particulates has increased the percentage of elongation and decreased the tensile strength compared to the base metal. When there are a minimum of three materials, it is called as hybrid composite. LM25 aluminium alloy is considered as the base matrix material. In this paper, hybrid composites are fabricated using aluminium oxide (Al_2O_3) with boron carbide (B_4C) and silicon carbide (SiC) particulates as the reinforcement materials. Mechanical tests are carried out to investigate the tensile strength, micro hardness using Vickers test and particulate dispersion into matrix using scanning electron microscope (SEM).

2. As-received and FSP specimens

Aluminium alloy plate of 160×50×34mm is machined out of blank using a vertical milling machine. Then, a slot of 160×1.4×2mm is made at the middle of the top surface using wire cut electrical discharge machining. The machining is carried out as two aluminium alloy bar specimens. In order to produce as-received composite specimens, Al_2O_3 particulates were contrived in the groove. The groove has to be made in the advancing side which is 1mm away from the centre line of the tool rotation on the aluminium plate [10]. The top surface of the groove was closed with a FSP tool without pin to prevent the escaping of Al_2O_3 from the groove. In the next stage, the FSP tool is plunged with the pin into the plate to stir the material along with the reinforcement to produce the MMC. The specimens were clamped to the backing plate using bolts. Then, FSP is followed for joining up of the aluminium alloy.

The base material used in the FSP is 160×70mm aluminium alloy LM25 and conforms to British Standard 1490. The reinforcement particles which have effect on the wear and mechanical properties were identified as SiC, B_4C and Al_2O_3 [11, 12]. A square groove was made with dimensions of 10mm width and 3mm depth tangent to the pin in the advancing side, which is 1mm far away from the centre line of the tool rotation on the aluminium alloy LM25 plate. Various mixer ratios of SiC, B_4C and Al_2O_3 particulates reinforcements are packed in the groove. The groove opening was initially closed by means of the tool without pin to avoid the escapement of reinforcement particles from groove. Tool travelling speed of 40 mm/min, axial force of 5 kN and tool onward tilt angle of 2.5° along the centre line were used in the FSP. The experiments were carried out on a vertical milling machine. The schematic of aluminium alloy plate for FSP with tool traverse is shown in Fig. 3. The finished FSP specimen is shown in Fig. 4.

The SEM analysis was also utilized for measuring the reinforcement particles size and worn morphology of surface hybrid composites. After FSP, micro structural inspections were carried out at the cross section of the nugget zone of surface hybrid composites normal to the FSP direction. Before taking SEM images, the surface is mechanically polished and etched with Keller's reagent. The size of the nugget zone is normally equal to the size of the rotating pin, width and depth of 8mm and 3.5mm respectively. The SEM of Al-B_4C/Al_2O_3, Al-SiC/Al_2O_3 in rpm surface hybrid composites and as-received aluminium alloy were analysed. The particles of SiC, B_4C and Al_2O_3 were observed to be dispersed uniformly in the nugget zone for all hybrid composites made by FSP. The rotating tool gave sufficient heat generation and a tangential force to distribute the reinforcement particulates to flow towards the wider area [13]. From the SEM image at the stir zone for Al-B_4C/Al_2O_3 composite, as shown in Fig. 5, it is observed that the bonding of carbide particles and solid lubricant with surrounding matrix depicts any interfacial reactions.

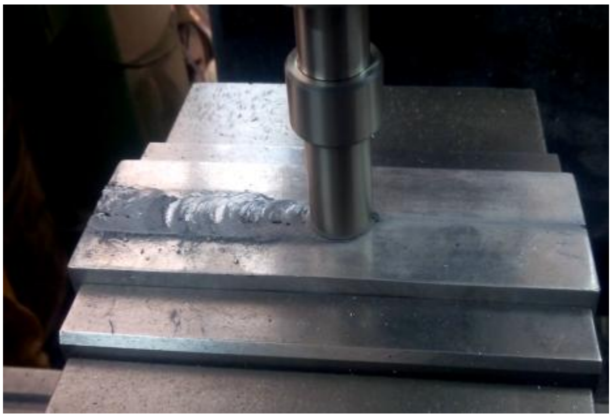

Fig. 3: FSP of hybrid composite during tool traverse

Fig. 4: Finished FSP specimen

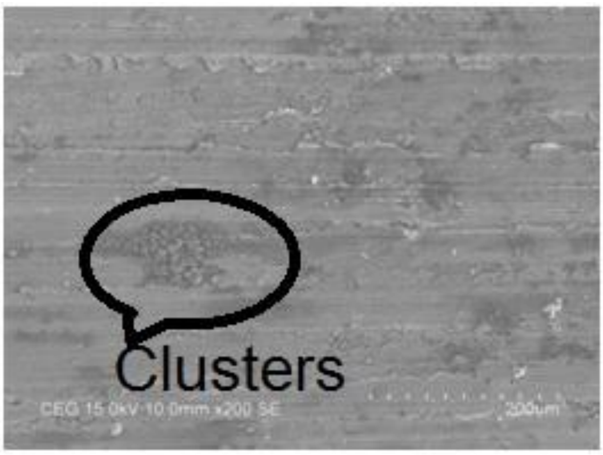

Fig. 5: SEM microstructure of processed composite

3. Mechanical testing

The tension test specimens were taken from the surface hybrid composites normal to the FSP direction and made as per ASTM E8 standard by using wire cut electrical discharge machining to the required dimensions. The tensile test is carried out to the pin normal to the FSP direction. Tension tests were performed at room temperature using the FSP composite and as-received Aluminium alloy specimens. FSP used the rotational and traverse speeds of 1400 rpm and 40 mm/min respectively. Table 1 gives the comparison of tensile strengths for as-received and aluminium alloy reinforced with SiC-$Al_2O_3$and B_4C-Al_2O_3 specimens. It is seen that the combination of Aluminium alloy with B_4C-Al_2O_3 specimen has higher tensile strength than the base metal. The tensile strengths of the FSP Aluminium alloy with SiC-Al_2O_3 specimens were reduced as compared to the B_4C-Al_2O_3 specimens. The presence of hard SiC particles enhances the hardness and consequently reduces the elongation of specimen. Moreover, the presence of SiC particles could restrict the grain boundary sliding.

Table 1: Tensile strength (MPa) of hybrid composite specimens

Specimen	LM25 with SiC-Al_2O_3	LM25 with B_4C-Al_2O_3
1	153	200
2	250	240
3	260	280
4	240	290

Micro hardness tests were carried out at the cross section of nugget zone of surface hybrid composites normal to the FSP direction. Samples were tested with a load of 15g and duration of 15 sec using a Vickers digital micro hardness tester. Vickers hardness test specimen of 15×5×10 mm dimensions is shown in Fig. 6. The physical quality of the indenter and the accuracy of the applied load as per ASTM E8 must be controlled in order to get the correct results. After the load is removed, the two impression diagonals are measured, usually to the nearest 0.1-μm with a filer micrometre to obtain averaged Vickers hardness (HV). Table 2 gives the comparison of micro hardness test results for as-received and aluminium alloy reinforced with SiC-$Al_2O_3$and B_4C-Al_2O_3 specimens. Reduction in hardness for FSP specimens may be due to remarkable softening which occurred during FSP. The micro hardness is high for B_4C-Al_2O_3 reinforcement.

Fig. 6: Micro hardness sample

Table 2: Vickers hardness (HV) of hybrid composite specimens

Specimen	LM25 with SiC-Al_2O_3	LM25 with B_4C-Al_2O_3
1	110	160
2	115	155
3	80	135
4	105	160

4. Conclusions

The primary research on FSP focuses on aluminium alloys. FSP forces material flow at the temperature lower than the melting temperature. Lowering the tool rotational speed and the feed rate has resulted in poor distribution of B_4C, Al_2O_3 and SiC particles. The increase in groove width did not affect the distribution of B_4C, Al_2O_3 and SiC particles in a significant manner. From the SEM analysis, it is observed that the particles were distributed uniformly throughout the matrix. The tensile strength and hardness are high for FSP materials.

REFERENCES:

[1] Z.Y. Ma, S.R. Sharma and R.S. Mishra. 2006. Effect of multiple-pass friction stir processing on microstructure and tensile properties of a cast aluminum-silicon alloy, *Scr. Mater.*, 54, 1623-1626. http://dx.doi.org/10.1016/j.scriptamat.2006.01.010.

[2] P. Cavaliere and P.P. De Marco. 2014. Friction stir processing of a Zr-modified 2014 aluminium alloy, *Mater. Sci. Engg. A*, 462, 206-210. http://dx.doi.org/10.1016/j.msea.2006.04.159.

[3] F.C. Liu, Z.Y. Ma and L.Q. Chen. 2009. Low-temperature superplasticity of Al-Mg-Sc alloy produced by friction stir processing, *Scr. Mater.*, 60, 968-971. http://dx.doi.org/10.1016/j.scriptamat.2009.02.021.

[4] L.B. Johannes, I. Charit, R.S. Mishra and R. Verma. 2007. Enhanced superplasticity through friction stir processing in continuous cast AA5083 aluminum, *Mater. Lett.*, 464, 351-357. http://dx.doi.org/10.1016/j.msea.2007.02.012.

[5] Z.Y. Ma, R.S. Mishra and F.C. Liu. 2009. Superplastic behaviour of micro-regions in two-pass friction stir processed 7075Al alloy, *Mater. Sci. Engg. A*, 505, 70-78. http://dx.doi.org/10.1016/j.msea.2008.11.016.

[6] G. Buffa, L. Fratini, S. Pasta and R. Shivpuri. 2008. On the thermo-mechanical loads and the resultant residual stresses in friction stir processing operations, *CIRP Ann. Manuf. Technol.*, 57, 287-290. http://dx.doi.org/10.1016/j.cirp.2008.03.035.

[7] Y. Morisada, H. Fujii, T. Nagaoka and M. Fukusumi. 2006. Effect of friction stir processing with SiC particles on microstructure and hardness of AZ31, *Mater. Sci. Engg. A*, 433, 50-54. http://dx.doi.org/10.1016/j.msea.2006.06.089.

[8] Y.F. Sun and H. Fijji. 2011. The effect of SiC particles on the microstructure and mechanical properties of friction stir welded pure copper joints, *Mater. Sci. Engg. A*, 528, 5470-5475. http://dx.doi.org/10.1016/j.msea.2011. 03.077.

[9] M. Barmouz, P. Asadi, M.K. Besharati Givi and M. Taherishargh. 2011. Investigation of mechanical properties of Cu/SiC composite fabricated by FSP: Effect of SiC particles' size and volume fraction, *Mater. Sci. Engg. A*, 528, 1740-1749. http://dx.doi.org/10.1016/j.msea.2010.11.006.

[10] A. Devaraju, A. Kumar and B. Kotiveerachari. 2013. Influence of rotational speed and reinforcement on wear and mechanical properties of aluminium hybrid composites via friction stir processing, *Mater. Des.*, *45*, 576-585. http://dx.doi.org/10.1016/j.matdes.2012.09.036.

[11] R.I. Essam, T. Makoto, S. Tishiya and I. Kenji. 2010. Wear characteristics of surface-hybrid-MMCs layer fabricated on aluminum plate by friction stir processing, *Wear*, 268, 1111-1121. http://dx.doi.org/10.1016/j.wear.2010.01.005.

[12] S. Soleymani, A. Abdollah-zadeh and S.A. Alidokht. 2012. Microstructural and tribological properties of

Al5083 based surface hybrid composite produced by friction stir processing, *Wear*, 278-279, 41-47. http://dx.doi.org/10.1016/j.wear.2012.01.009.

[13] A. Devaraju and A. Kumar. 2011. Dry sliding wear and static immersion corrosion resistance of aluminum alloy 6061-T6/SiCp metal matrix composite prepared via friction stir processing, *Int. J. Adv. Res. Mech. Engg.*, 1(2), 62-68.

EDITORIAL NOTES:

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