AN INVESTIGATION ON EFFECT OF TOOL ROTATIONAL SPEED ON AA6063/SIC SURFACE COMPOSITE FABRICATION VIA FRICTION STIR PROCESSING

Namrata Gangil[1], Sachin Maheshwari[2], Arshad Noor Siddiquee[3]
[1,2]Department of Manufacturing Processes and Automation Engineering,
Netaji Subhas Institute of Technology, New Delhi
[3]Department of Mechanical Engineering, Jamia Millia Islamia, New Delhi

Abstract
Aluminium metal matrix composites (AMMC's) were fabricated successfully on AA6063 aluminum alloy via friction stir processing (FSP) technique. Grooves of 2×2 mm^2 were made along the centreline of the base plate and SiC powder (14 micrometer) was filled and compacted in these grooves. FSP was carried out at various tool rotational speed in the range of 710-1400 rpm, and at a constant traversing speed, tilt and plunge of tool in a single pass processing procedure. The particle distribution in the composite zone was analysed using stereo zoom and optical microscope, and microhardness were evaluated by Vickers indentation test. Significant improvement in processing zone microstructure were observed when tool rotational speed was 1120 rpm. Grain refinement of matrix was observed in the range 5-9 micrometer.

Index Terms: Surface composite, friction stir processing, aluminum alloy, tool rotational speed, microstructure

I. INTRODUCTION

Frictions stir processing (FSP) is a special technique for refining and modifying the microstructure of metallic materials [1]. FSP is based on the principles of friction stir welding (FSW) process developed at "The Welding Institute (TWI), UK" in 1991 [2]. In FSP a rotating metallic tool with a shoulder and probe (pin) is first plunged in to base metal (BM) and then traversed along the surface of BM. The frictional rubbing of tool shoulder generates heat and softens the material and make it flow, thereby enabling the application of severe plastic deformation at extremely high strain rates [3]. Main applications of FSP for microstructural modification in metallic materials include superplasticity, homogenization of aluminium alloys and metal matrix composites, microstructural refinement of cast aluminium alloys, fabrication of surface and foam composites [4]. In fabrication of surface composite the spinning tool inserted in matrix material (i.e. BM) generates localized heat by friction to soften material and mixes it to consolidate the joint. The rotating tool travels with a relatively high forging force to produce a long processed zone such that entire surface can be processed by rastering tool translation as evidenced by Qu et al. [5].

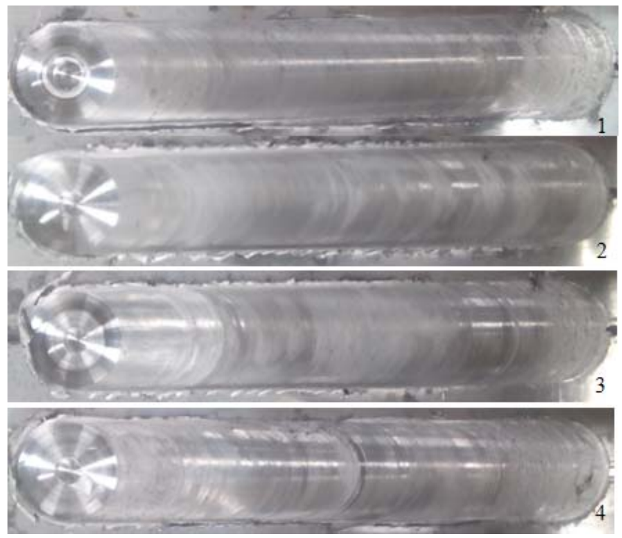
Recently, there is a huge rush in attempting fabrication of surface composite by embedding BM with reinforced materials through FSP route. Some investigates have reported studies on varying tool rotational and traversing speed, influence of number of passes and also the effect of shift in interpass rotational direction [4]. The researchers also report different methods of delivery of reinforcement particle into the substrate. In the fabrication of Al1050/SiC composite [6], SiC mixed with methanol and thin layer of this slurry is applied on the surface of the plate. One alternative method involves pre-placing reinforcing particles in various surface reservoirs such as holes [7] and grooves [8] prepared before performing FSP. For sealing the groove a rotating shoulder without pin is employed by most of the researchers. A thin aluminum sheet cover may be used to prevent these particles from escaping before they are incorporated in to the aluminum matrix during FSP [9].

During last decade the interest on aluminium and its alloys has raised in fabrication of aerospace and transportation structures and components mainly due to their noble properties such as high strength to weight ratio and fatigue and corrosion resistance. The properties of Al and its alloys such as strength, elastic modulus, and resistance to wear can be improved with corporation of ceramic particle into Al matrix. One such Al alloy AA6063 possesses is a material of choice in navel and automobile applications mainly due to it good corrosion resistance, formability, light weight and moderate strength [10] & [11]. The aim of the present study was to investigate the effect of tool rotational speed on SiC particle distribution in the fabrication of AA6063/SiC composites.

II. MATERIALS AND METHODS

The FSP experiments were performed on samples of 170×50×4.75 mm^3 dimensions. In all samples for surface composites, grooves of 2×2 mm^2 were made along the centreline of plates and SiC powder (14 micrometer) was filled and compacted in these grooves. A pinless tool was employed to initially cover and compact the grooves filled with SiC particles to prevent it from sputtering during FSP. An FSP tool made of high carbon high chromium (HCHCr) steel as shown in Fig. 2 was used in this study. A cylindrical tool having shoulder diameter 22 mm and a threaded (thread pitch being 1 mm) pin of 6 mm diameter 2.5 mm in length was used. The FSP was carried out on an indigenously retrofitted FSW machine with varied tool rotational speed (710, 900, 1120 and 1400). For all experiments the traverse rate, tool tilt and shoulder plunge were fixed at 63 mm/min, 2.5° and 0.35 mm respectively. The friction stir processed plates is shown in fig. 1.

After FSP, microstructural analysis of processed zone was carried out for which specimens were prepared using standard metallographic procedure. The metallographic samples were subsequently etched with extended flick reagent (15 ml hydrochloric acid, 10 ml hydrofluoric acid and 90 ml distilled water) for 3 minutes. Macroscopic images were taken using Stereozoom microscope (Focus, Japan). Microstructural observations were carried out by employing OM (QS Metrology, India). Microhardness of samples was measured under a load of 100 gm and for dwell time of 15 seconds using micro-hardness tester (Mitutoyo, Japan).



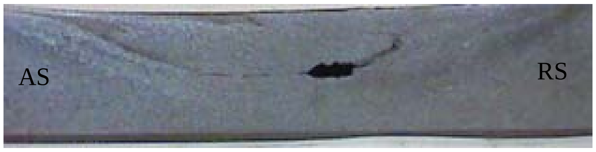
Fig, 1: Friction stir processed plates at (1) 710 rpm (2) 900 rpm (3) 1120 rpm (4) 1400 rpm.

III. RESULTS AND DISCUSSION

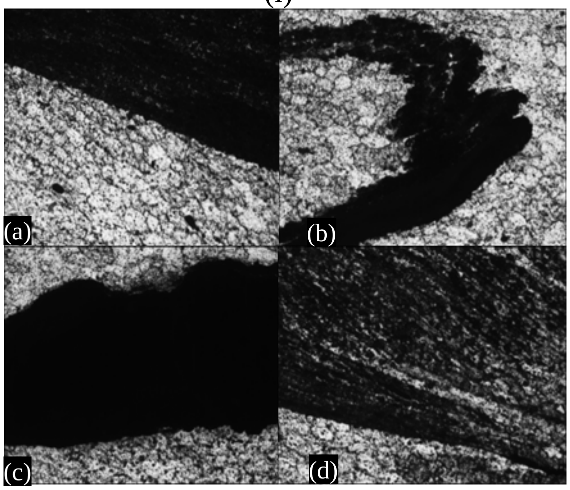
Macro and micro-structural, bead geometry, analysis along with indentation test were carried out to investigate the influence of processing parameters on fabricated surface composites was evaluated.

A. Macro and Microstrucrure

The macro and microstructural images of the samples processed with 710-1400 rpm are shown in fig. 2-5 (i) & (ii (a-d)). It is evident from figures that when workpiece is processed with 710, 900, and 1400 rpm, a significant amount of SiC could not mixed with the matrix material results in SiC clusters or agglomeration which is shown in fig. 2 (c), 3 (c) and 4 (c). Whereas, in 1120 rpm processed sample reinforced zone depicts negligible particle accumulation, homogeneous microstructurere, and excellent bonding with the matrix material as shown in fig, 4. The grain size and percent volume fraction of SiC in 710, 900, 1120, and 1400 rpm processed reinforced zone are found 9, 7.9, 5, and 8 micrometer, and 14.8, 17, 23, and 16 vol. %, respectively.

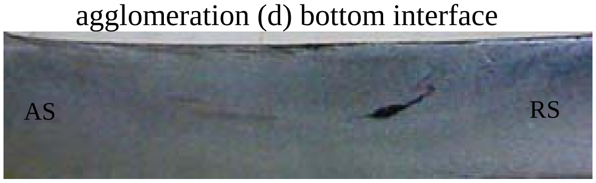


(i)

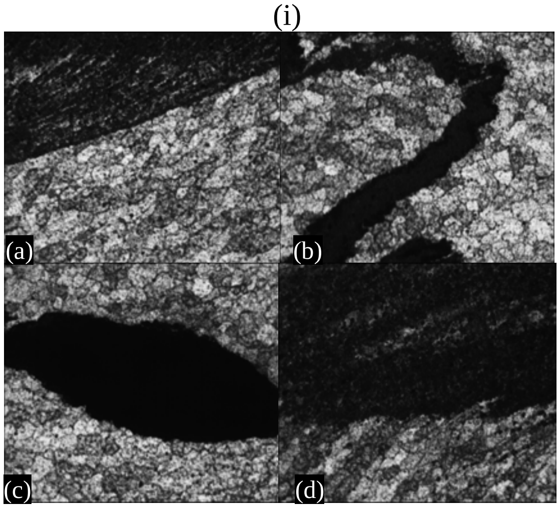


(ii)

Fig. 2: Images of sample processed with 710 rpm (i) Macrograph of cross-section, (ii) Microstructure at 100X magnification showing (a) AS(advancing side) interface (b) RS (retreating side) interface (c) SiC agglomeration (d) bottom interface



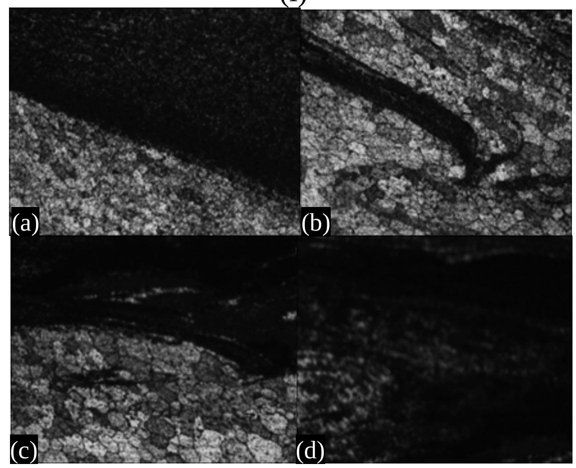
(i)



(ii)

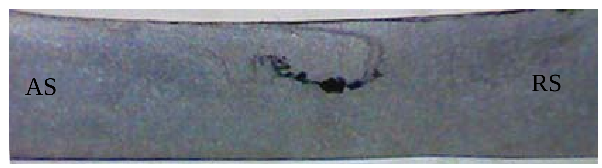
Fig. 3: Images of sample processed with 900 rpm (i) Macrograph of cross-section, (ii) Microstructure at 100X magnification showing (a) AS interface (b) RS interface (c) SiC agglomeration (d) bottom interface

(i)

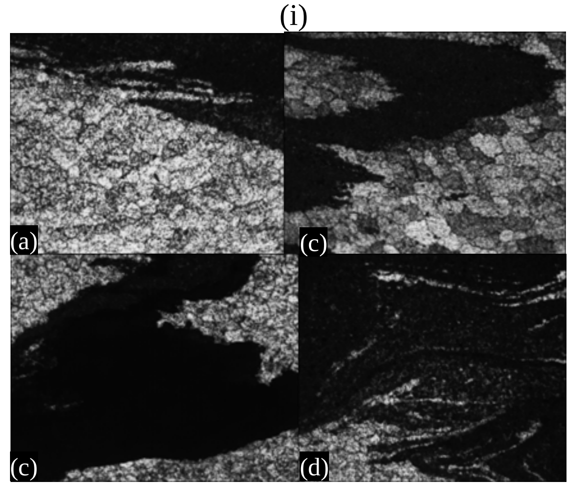


(ii)

Fig. 4: Images of sample processed with 1120 rpm (i) 0Macrograph of cross-section, (ii) Microstructure at 100X magnification showing (a) AS interface (b) RS interface (c) bottom (d) stirred zone



(i)



(ii)

Fig. 5: Images of sample processed with 1400 rpm (i) Macrograph of cross-section, (ii) Microstructure at 100X magnification showing (a) AS interface (b) RS interface (c) SiC Agglomeration (d) stirred zone

B. Microhardness

Microhardness profile was generated along width of processed zone at 1 mm equidistant point and the same is shown in Figure. It was traced 1 mm below the top surface.

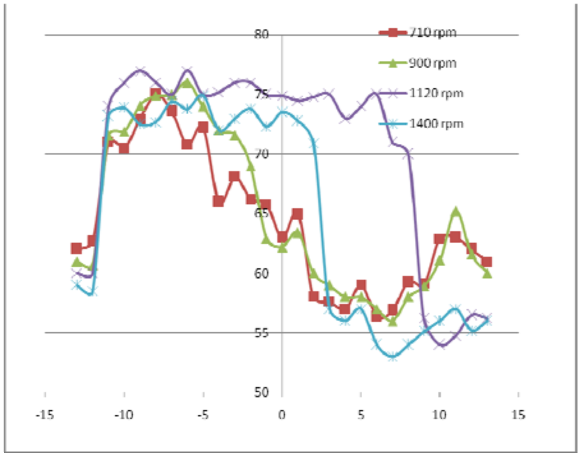


Fig. 6: Microhardness curve.

Microhardness plot traced along width from AS to RS as shown in Fig. Average microhardness along width for samples processed with 710, 900, 1120 and 1400 rpm found is 64.33, 64.92, 70.07, and 64.87 HV, respectively.

After T6 heat treatment of 6063 aluminium alloy precipitates of magnesium silicide (Mg2Si) forms by combining Si and Mg and increases its strength [10]. The hardness of reinforced zone is higher than the hardness of as-received AA6063-T6 aluminium alloy. There is a notable increase in the microhardness of unreinforced regions in all tha samples compared to BM sample due to dissolution of strengthening precipitates [11] and absence of SiC particles. In present investigation, the average hardness of sample processed with 1120 rpm is higher than hardness of base metal (67 HV) which may be attributed to the homogeneous and better dispersion of SiC particles in the matrix. Moreover, the results demonstrate the significant effect of the tool rotational speed on the particle distribution and defect formation in the fabrication of surface composites.

IV. Conclusion

The AA6063/SiC composite were fabricated successfully via FSP. The effect of tool rotational speed on microstructure and miocrohardness of metal matrix composite was studied. Particle agglomeration has consistently reduced and distribution of particles has continuously improved upto 1120 rpm tool rotational speed. The composite fabricated with 1120 rpm tool rotational speed exhibited homogeneous microstructure, higher average microhardness and good bonding with the substrate among all fabricated composites.

REFERENCES

[1] R. S. Mishra, and M. W. Mahoney, “Friction stir welding and processing”, ASM International, 2004.

[2] W. M. Thomas, E. D. Nicholas., J. C.Needham, M. G. Murch, P. Templesmith, and C. J. Dawes, “Improvements to Friction Welding”. International Patent Application PCT/GB92/02203 and GB Patent Application No.9125978.8, UK Patent Office, London, 1991.

[3] A. N. Siddiquee, S. Pandey, and N. Z. Khan, “Friction Stir Welding of austenitic stainless steel: a study on microstructure and effect of parameters on tensile strength”, Materials Today: Proceedings 2, pp. 1388-1397, 2015.

[4] N. Gangil, A. N. Siddiquee, and S. Maheshwari, “Aluminium based in-situ composite fabrication through friction stir processing: a review”, Journal of alloys and compounds, vol. 715, pp. 91-104.

[5] J. Qu, H. Xu, Z. Feng, D. A. Frederick, L. An, and H. Heinrich, “Improving the tribological characteristics of aluminum 6061 alloy by surface compositing with sub-micro-size ceramic particles via friction stir processing”, Wear, vol. 271, pp. 1940-1945, 2011.

[6] A. Kurt, I. Uygur, and E. Cete, “Surface modification of aluminium by friction stir processing”, Journal of Materials Processing Technology”, vol. 211, pp. 313-317, 2011.

[7] H. Izadi, and A. P. Gerlich, “Distribution and stability of carbon nanotubes during multi-pass friction stir processing of carbon nanotube/aluminum composites”, Carbon, vol. 50, pp.4744-4749, 2012.

[8] J. F.Guo, J. Liu, C. N. Sun, S. Maleksaeedi, G. Bi, M. J. Tan, and J. Wei, “Effects of nano-Al_2O3 particle addition on grain structure evolution and mechanical

behaviour of friction-stir-processed Al", Material Science and Engineering A, vol. 602, pp. 143-149, 2014.

[9] E. R. I. Mahmoud, M. Takahashi, T. Shibayanagi, and K. Ikeuchi, "Wear characteristics of surface-hybrid-MMCs layer fabricated on aluminum plate by friction stir processing", Wear, vol. 268, pp. 1111-1121, 2010.

[10]M. Das, G. Das, M. Ghosh, M. Wegner, V. Rajnikant, S. GhoshChowdhury, and T. K. Pal, "Microstructure and mechanical properties of HPT processed 6063 Al alloy, Material Science and Engineering A", vol. 558, pp. 525-532, 2012.

[11]K. J. Al-Fadhalah, A. I. Almazrouee, and A, S. Aloraier, "Microstructure and mechanical properties of multi-pass friction stir processed aluminum alloy 6063", Materials and Design, vol. 53, pp. 550-560, 2014.