VOL. 10, NO. 12, JULY 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

EFFECT OF TOOL GEOMETRY ON SURFACE MODIFICATION OF ALUMINIUM 6063 BY FRICTION STIR PROCESSING

D. Amirtharaj, G. Rajamurugan, S. Sivachidambaram and D. Dinesh
Department of Mechanical Engineering, Bannari Amman Institute of Technology, Erode, India
E-Mail: rajadmt@gmail.com

ABSTRACT

Aluminium alloy 6063 has a wide application in special machine elements, architectural sections, automobiles and frame systems. AA6063 has high strength to weight ratio but low hardness and wear resistance property. Friction Stir Processing (FSP) is a surface modification process through which mechanical properties of the surface can be improved by reinforcing ceramic particles. In this present investigation, surface property of Aluminium alloy 6063 is modified by reinforcing Boron Carbide (B_4C) powder particles via FSP. The distribution of B_4C particles were examined for different reinforcing techniques, based on Hardness and Impact strength, by keeping volume fraction (22.38%) constant. The tool pin profiles such as threaded cylindrical and square pin were also compared for the best distribution of B_4C in the surface of base metal through different reinforcing techniques. The tool rotational speed 1200rpm, travel speed 40mm/min and axial force 10kN are kept constant.

Keywords: friction stir processing, boron carbide, tool geometry.

1. INTRODUCTION

Friction Stir Processing (FSP) is a modification of Friction Stir Welding (FSW), which is a solid state processing technique. In FSP, instead of welding of two base metals surface processing is carried out on the base metal surface to improve the surface property. FSP is a plastic deformation technique below the base metal melting temperature, used to modify surface Properties [1, 2].FSP uses a non-consumable tool similar to the FSW tool with shoulder and pin. The rotational tool with pin and shoulder is plunged into the surface and moved over the desired surface. Due to the rubbing action between tool shoulder and base metal surface frictional heat is developed, and plastic deformation takes place with stirring action of rotational tool. In the stir zone the material suffers microstructure modification [3].

Aluminiumalloys which has wide structural applications in aerospace, transportation and military due to its low density, high strength to weight ratio and resistance to corrosion. But its poor wear resistance makes it limited for several applications [4]. FSP is a technique which can reinforce ceramic particles into the base metal surface, which results in high hardness and wear resistance properties. By adding additives it forms Metal matrix composites into the base metal surface. Strengthening additives like ceramic particles can be introduced into the holes or grooves on the surface of base metal before FSP; they will be included into the stir zone by the stirring of the tool pin and will be dispersed uniformly into the metal surface [5]. Several researches uses different techniques like Square groove, V-groove, serial holes and Zig Zag holes to reinforce the additive particles via FSP [3-8].

The additives packing methods before FSP is a major controlling factor to get a good surface properties [8]. FSP is effective when additives are packed in groove placed under the tool pin [10]. Agglomeration of additive particles can occur in the FSP stir zone, which deteriorate microstructure and mechanical properties of the surface [6]. Akramifard *et al.* uses the zig zag holes method to reinforce SiC particles and prevents agglomeration [6]. The fine distribution of additives particles without agglomeration will results in good mechanical properties [3]. The porosity and interfacial reaction between matrix and reinforcement are avoided due to the below melting point temperature via FSP [9].

In this present investigation, surface property of Al 6063 is modified by reinforcing Boron carbide (B_4C) powder particles, through square grooves, v-grooves, serial holes and zig zag holes, via FSP. The distribution of B_4C is examined with each reinforcing techniques and two different tool pin profiles by keeping surface composite volume fraction (22.38%) constant. A single pass FSP is carried out for comparison of best technique and tool pin profile. The tool pin profiles such as threaded cylindrical pin and square pin profile were used for comparison.

2. EXPERIMENTAL PROCEDURE

Aluminium alloy 6063 plates with size of 100mm×60mm×6mm were used for this investigation. The chemical composition of Base Metal (BM) Al 6063 is given in the Table-1. Boron carbide with particle size, less than 10µm is used as the reinforcement. Square groove, v-groove, serial holes and zig zag holes with constant volume capacity are machined on the plates as shown in the Figure-1. The dimensions for grooves and holes are given in the Table-2. Two different tool pin profiles were used as shown in the Figure-2. The tool is made of high speed steel, hardened to 51HRC.The tool shoulder diameter is 24mm, pin diameter is 8mm and pin length is 3.2mm constant for both tools. The serial holes are drilled in the centre axis of the plate. The Zig Zag holes are drilled at 2mm offset distance from the centre axis. The spacing between each hole is 3.7mm. Each method has 27 holes. Volume capacity for square groove, V-groove and holes are kept constant. Therefore volume fraction for each reinforcing method is 22.38% constant.The grooves and holes were packed with B_4C particles and then a single pass FSP is carried out. The tool rotational speed 1200rpm, travel speed 40 mm/min and axial force 10KN are kept constant [11]. Rockwell superficial hardness (HR15T) test and Impact test were taken from the processed specimen. ASTM E23-02a standard is used for impact test specimen.

Table-1. Chemical composition of Al 6063.

Elements	Al	Si	Mg	Fe	Cu	Mn	Cr	Zn	Pb
Weight %	98.75	0.354	0.456	0.210	0.054	0.029	0.019	0.052	0.047

Table-2. Dimensions for grooves and holes.

Square groove	Width = 1.91mm	Depth= 3mm Constant
V-groove	Angle of V = 65^{o}	
Drilled hole	Diameter = 3mm	

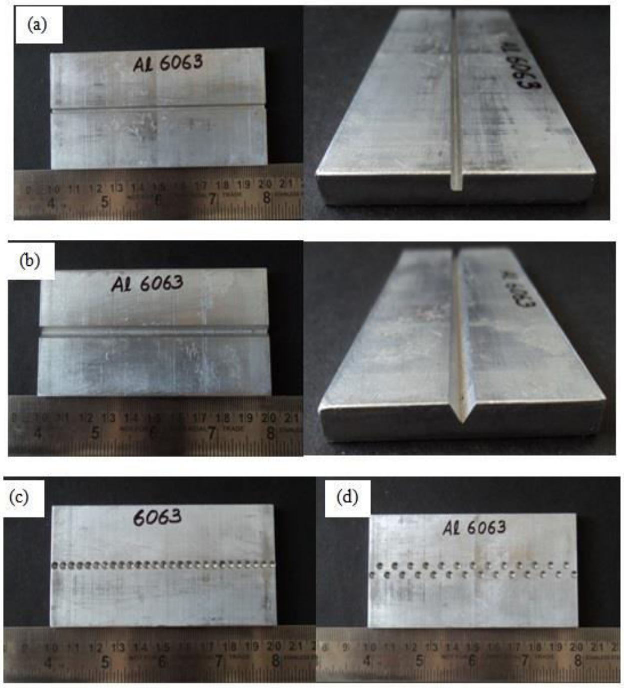


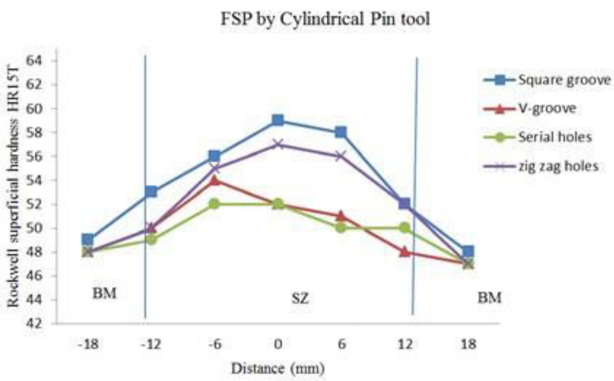
Figure-1. Reinforcing techniques (a) square groove, (b) V-groove, (c) serial holes, (d) zig zag holes.

Figure-2. (a) M8 threaded cylindrical pin tool, (b) Square pin tool.

3. RESULT AND DISCUSSION

a) Hardness

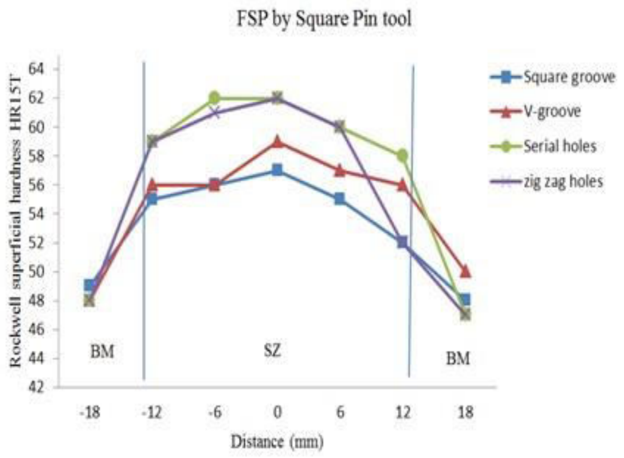
In the friction stir processed zone the Rockwell superficial hardness test is conducted. Figure-3(a), 3(b) shows the hardness comparison in the Stir Zone (SZ), processed with cylindrical pin tool and square pin tool for corresponding reinforcing techniques. The higher hardness value in the stir zone is obtained when the Square pin profile tool is used as shown in the Figure-3(b). Compared to other reinforcing techniques the serial holes technique processed with square pin tool shows uniform distribution and higher hardness. Figure-3(c) separately shows the hardness value in the stir zone when B_4C particles are packed into serial holes and FSP is carried out by square pin profile tool. Thus the serial holes reinforcing method can be employed to reinforce the additive particles with square pin profile tool based on hardness. The increase in hardness in the stir zone is due to uniform distribution of B_4C particles into the base metal surface. The tool geometry with square pin profile plays important role in achieving higher hardness value and uniform distribution.



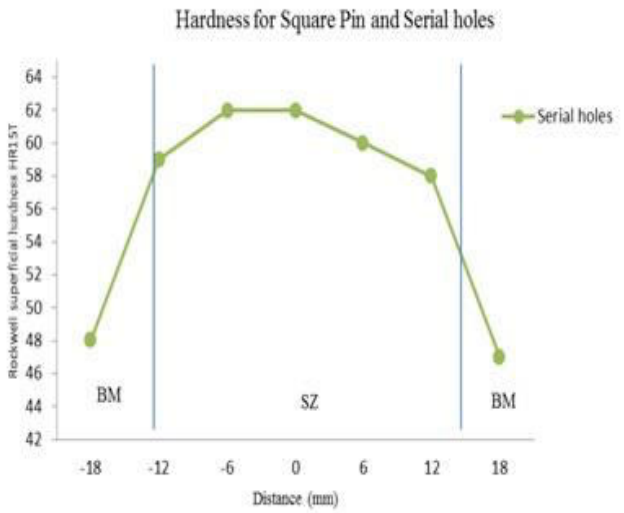
(a)

ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com



(b)



(c)

Figure-3. Hardness comparison for different additive packing methods (a) FSP by cylindrical pin tool, (b) FSP by square pin tool, (c) hardness for FSP by square pin tool and serial holes.

b) Charpy impact test

Figure-4 shows impact strength comparison of base metal, cylindrical pin tool and square pin tool processed with B_4C particles packed into square groove, V-groove, serial holes and Zig Zag holes. The impact strength value of FSP processed specimen gets decreased due to the reinforcement and increased hardness. The toughness of serial holes reinforcement method processed by square pin tool is higher than other reinforcing method but lower than base metal. This shows uniform distribution B_4C particles in the stir zone. Thus the square pin profile tool with serial holes method can beemployed to reinforce the additive particles to obtain higher impact strength than other reinforcement methods.

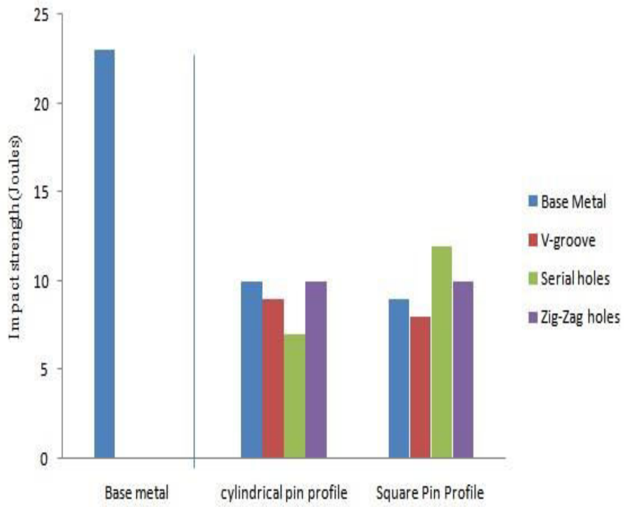


Figure-4. Comparison of impact strength of base metal and FSP specimen.

3. CONCLUSIONS

Friction stir processing is an effective method to improve hardness by reinforcing Boron carbide particles into the base metal surface. The maximum hardness and impact strength is achieved, when the B_4C particles are packed into the serial holes and friction stir processed with square pin profile tool. Increased hardness in the Stir zone shows the uniform distribution of B_4C particles. Thus serial holes reinforcement method with square pin tool can be employed for surface modification via FSP.

REFERENCES

[1] D. C. Hofmann and K. S. Vecchio. 2005. Submerged friction stir processing (SFSP): animproved method for creating ultra-fine-grained bulk materials. Mater SciEng A. 402: 234–241.

[2] A. Dolatkhah, P. Golbabaei, M. K. Besharati Givi and F. Molaiekiya. 2012. “Investigating effects of process parameters on micro structural and mechanical properties ofAl5052/SiC metal matrix composite fabricated via friction stir processing” Mater Des. Vol. 37, pp. 458–64.

[3] R. Ramesh and N. Murugan. 2012. “Production and Characterization of Aluminium 7075 – T651 Alloy / B_4C Surface Composite by Friction Stir Processing,” No. 1, pp. 88–90.

[4] Min Yang, Chengying Xu, Chuansong Wu, Kuo-chi Lin, Yuh J. Chao and Linan An. 2010. “Fabrication of $AA6061/Al_2O_3$ nano ceramic particle reinforced composite coating by friction stir processing” Mater Sci. Vol. 45, pp. 4431-4438.

[5] Q. Liu, L. Ke, F. Liu, C. Huang and L. Xing. 2013. “Microstructure and mechanical property of multi-walled carbon nanotubes reinforced aluminum matrix

composites fabricated by friction stir processing," Mater. Des., Vol. 45, pp. 343–348, March.

[6] H. R. Akramifard, M. Shamanian, M. Sabbaghian, and M. Esmailzadeh. 2014. "Microstructure and mechanical properties of Cu/SiC metal matrix composite fabricated via friction stir processing," Mater. Des., Vol. 54, pp. 838–844, February.

[7] M. N. Avettand-Fènoël, A. Simar, R. Shabadi, R. Taillard and B. de Meester. 2014. "Characterization of oxide dispersion strengthened copper based materials developed by friction stir processing," Mater. Des., Vol. 60, pp. 343–357, August.

[8] D. R. Ni, J. J. Wang, Z. N. Zhou and Z. Y. Ma. 2014. "Fabrication and mechanical properties of bulk NiTip / Al composites prepared by friction stir processing," Vol. 586, pp. 368–374.

[9] A. Thangarasu, N. Murugan, I. Dinaharan and S. J. Vijay. 2014. "Synthesis and characterization of titanium carbide particulate reinforced AA6082 aluminium alloy composites via friction stir processing," Arch. Civ. Mech. Eng., pp. 1–11.

[10] J. Gandra, R. Miranda, P. Vilac, A. Velhinho and J. P. Teixeira. 2011. "Journal of Materials Processing Technology Functionally graded materials produced by friction stir processing," Vol. 211, pp. 1659–1668, 2011.

[11] L. Karthikeyan, V. S. Senthil Kumar. 2011. "Relationship between process parameters and mechanical properties of friction stir processed AA6063-T6 aluminum alloy," Materials and design Vol. 32, pp. 3085-3091.