Mechanical Properties of Friction Stir Welded Metal Matrix Composite- AA6061-B4C influenced by Tool Pin Geometry

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Abstract

The present work is focused on evaluating the mechanical properties of casted Aluminum Metal Matrix Composite [AA6061-B4C] and Friction stir welded Aluminum Metal Matrix Composite using different tool pin geometry and their extent of use in nuclear, aerospace, land transport, railway and marine industries applications. AMMCs' were made by stir casting process with varying weight percentage of B4C. AA6061-B4C composite friction stir welded joints were made by optimized rotational speed, transverse speed and tilt angle, with taper and square pin tool geometry profile. The welding process parameters and tool profile geometry plays larger role in deciding the weld quality. While making FSW AMMCs, the welded plates were maintained at constant thickness of 3mm. From the result obtained, it is observed that better mechanical properties were obtained at optimized tool rotating speed of 1400 rpm and transverse speed of 40mm/sec with tilt angle of zero deg. The Square pin tool geometry profile showed greater refinement of microstructure in AMMC. Higher tensile strength and hardness were obtained for 9% B4C reinforcement of casted AMMC.

Keywords: Friction Stir welding (FSW), AA6061-B4C MMC, Taper pin tool geometry, Grain refinement.

1 Introduction

Aluminum compositesreinforced with B4Care used in nuclear power plants because of their higher chemical and thermal resistant properties. Currently nuclear power plants uses aluminum based boron and metallic composites as a neutral absorber material [1] AMC's haveconsiderable mechanical and physical properties which includes thespecific strength, low thermal expansion co-efficient and good wear resistance.

Infusion welding, joining of composites brings certain drawbacks on mechanical properties. SoAMC'smay face many problems like high thermal expansion and conductivity, deleterious reaction with reinforcement and solidification shrinkages etc. [2]. Hence to overcome disadvantages of fusion welding, FSW is preferred method for joining AMC's to produce better weld quality product.

The main advantage of FSW is to fabricate the low cost and higher efficiency joints [3], and primarily it was used for aluminum alloys because metals were joined beneath the solidus temperature. Hence FSW was derived and has established many branches for research activity. It is one of the best sound developments in solid state joining method in past years [4].

In aerospace and automotive industries, aluminum alloys (AA6XXX AA7XXXX) are facing lot of issues with fusion welding process. For that issues could be resolve withadoptingFriction Stirwelding [5] process. FSW it offers metallurgic dominance over conversional fusion welding process. The considerable merits of FSW because of green environmentally beneficial welding practice due tolow energy consuming, withoutany gas release and without using welding consumables [6, 7]

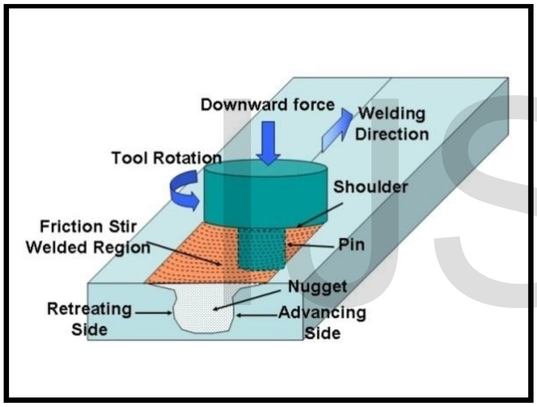


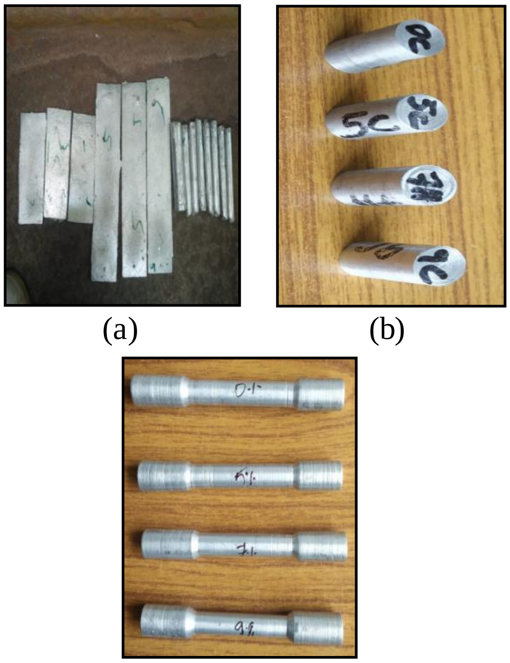
Figure.1. Principle of FSWmethod

The conception of FSW is, it usesnon-consumption rotating tool. It consists of shoulder and pin infused into faying surface of the plates that are attached in positionbesides the support plate using a holding structure. The plate ismovedlinearly in the wayof joint line which is indicated in the Figure.1. Modification of tool pin profile in FSW givessignificantlyindicates the temperature and development of welding zonesand preciselyresolveswelded joints characteristics. The tool surface has performs dual action like formation of heat and mechanical sweeping of soften metal.The heat input during friction action between work piece and tool leads to softening of the surface area around the pin. This frictionaction performs weld due to plastic deformation (in semi liquid solid state joining) of the material.

The heat conducted into the work piece defines the by weld quality, micro structure and distortion of work piece than conventional fusion welding technique. The initialweld plungingplaysa virtual role in formation of weld in FSW, as it creates the initial thermo-mechanical conditions in the work material, which are required prior to start of the linear welding phase. The tool geometry plays anextensive role in formation of weld because tool pin will have maximum contact with work material. In the current research work, investigation is conducted on material fabrication based on path,insightful results of ultimate tensile strength on welded joints with varying tool pin profile.

2 Experimental Details

Primarily stir casting process is used to fabricate the B4Creinforced Al matrix composites by adding B4Chaving of size 90µ, into aluminum molten metal to obtain AMC's. Fabricated AMCs will have different weight percentage of B4C [2]. As per ASTM standards tensile and hardness specimens were prepared and the mechanical properties have been evaluatedas shown in Figure.2.



(a) (b)

(c)

Figure.2. (a) CastedAMC's (b) Hardness Specimens(c) Tensile Specimens

Figure.3.showsthe machined AMC's Plates,cut with dimensions of 150*150*3mm using power hacksaw machinefrom casted AMC's for the purpose of to prepare tensile specimens from welded joints using Friction Stir Welding machine.

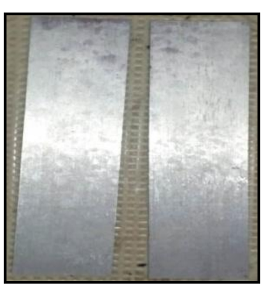
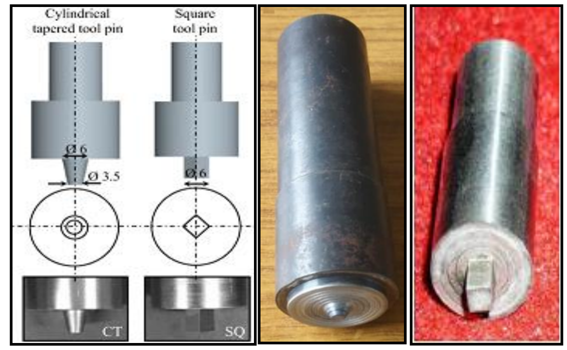


Figure.3. Machined AMC's Plates

The square and taper pin profile tools were fabricated using material with high carbon high chromium (HCHCr) steel tool hardened to HRC 62.The FSW tool is as shown in the Figure.4.



(a) (b)

Figure.4.(a) Dimensions (b) Fabricated tools (Square and Taper pin profile)

Process parameters have a greater influence in friction stir welding. The welding parameters considered are: toolspeed rangingfrom750rpm to 1500 rpm, transverse speed from 30mm/min to 100mm/min, tilt angle from 0º to 2º and tool pin profiles.

These parameters are optimized process parameters obtained from literaturesurvey and previous work and are designed to produce good quality welding. Butt jointspecimenswere fabricated using FSW machine by changing the tool pin profile (square and taper)keeping process parameters constant for both pin profiles to obtain weld joint. As per ASTM standard E08, tensile test was performed,the Figure.5.shows dimension of tension test specimen.

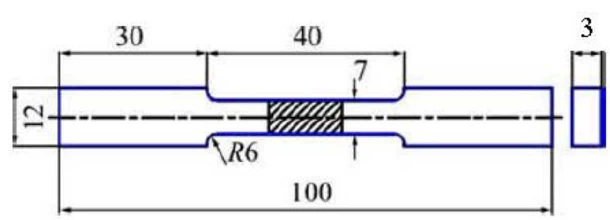


Figure.5.Tension Test Specimen Dimensions ASTM E08 (mm)

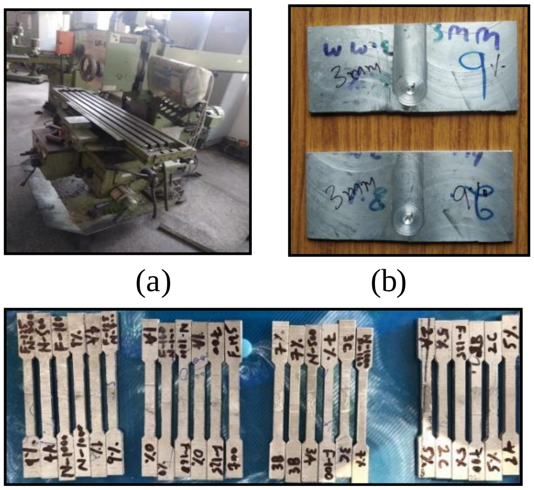

(a) (b)
(c)

Figure.6. (a) FSW Machine (b) Welded Plates using FSW (c) Tensile test specimens

3 Results and Discussions

Table.1.shows mechanical properties AMC's produced by stir casting process. These fabricated AMCs have different weight percentage of B4C.The average ultimate tensile strength and hardness recorded are tabulated as shown below.

Table.1. Mechanical properties of produced AA6061-B4C Composites

Sl No	B4CWt %	Ultimate Tensile strength (MPa)	VHN
1	0	198.32	69.66
2	5	236.75	74.00
3	7	279.70	87.66
4	9	313.80	100.20

3.1 Hardness Test

Figure.7. shows micro hardness tested specimen using Vickers hardness tester. This was considered with a load of 300gm for 10seconds dwell time. Hardness was measured by penetration made at different locations at the top surface. Thecross section of specimen was taken from prepared sample with average value of 10 reading measured on top surface of fabricated AMCs having different weight percentage of B_4C.

From table.1, it was observed that, micro hardness of AMC's has improved with the increase in weight % reinforcement. Reinforcement particles are added to melt which gives supplementary substrate for solidification to trigger, thus it increases the nucleation rate and minimizes the grain size. Due to the particles present in the hard surface area, the hardness of the developed composites is increased to provide more resistance to plastic deformation.

Figure.7. Hardness Tested Specimen

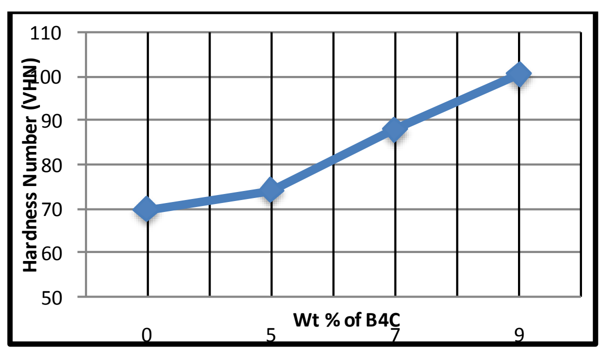


Figure.8. Hardness of stir casted AMC

3.2 Tensile Test

Tensile test was conducted on prepared specimen according to ASTM standard E08 using Universal Tensile Testing Machine with a capacity of 50KN.

Gear rotation speed of1.25, 1.5 and 2.5mm/minas considered with gradual loading. The tested tensile specimen is shown in figure- 8.From table.1; it was observed thatultimate tensile strength was enhanced with increase in weight % of B4C reinforcement. As the reinforcement used is stiffer than the matrix the distribution of load from matrix to reinforcement has taken place and resulted in an enhanced yield strength and higher modulus of elasticity when compared to base material.

Figure.9.TensileTested Specimen

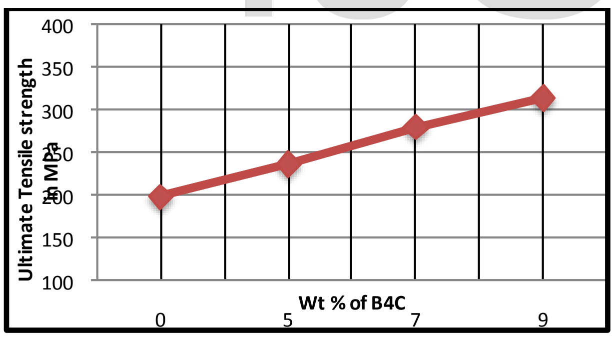


Figure.10.UTS of stir casted AMC

3.3 Tensile Strength of FSW

Table.2 shows tensile strength of FSW AA6061-B4C composites using tool pin profile with fabricated AMCs having different weight percentage of B_4C.The average ultimate tensile strength recorded are tabulated for taper pin profile and square pin profile.

Table 2: Tensile Strength of FSW AA6061-B4C Composites using Tool pin profile

Sl No	Wt % of B4C	Ultimate Tensile strength (MPa)	
		Taper pin profile	Square pin profile
1	0	187.90	198.20
2	5	219.50	230.52
3	7	253.10	257.80
4	9	283.40	289.72

The tensile specimens were extracted from welded joints with reference to the transverse direction. These joints are made by FSW using taper and square tool pin profile by constant process parameters. The extracted tensile specimen follows ASTM standard E08shapes. The dimensions are shown in Figure.5.The specimens prepared were tested on Universal Testing Machine with gradual loading. The results show that the tensile properties of welded pieces were changed to different probe profiles

The highest tensile strength was obtained in the joint made by square pin profile tool at a tool speed of 1400rpm, with transverse speed of 40 mm/min and a 0º tilt angle. In addition, tensile strength of weld was improved significantly, with increase in B4C's weight percentage.

The tool with square profile has more surface area which can produce a pulsating stirring action and make the material flow. Thus the square pin profile tool leads to better material flow and grain refinement. It can also improve the stir efficiency because of the four edges shape. Thus, the mechanical properties induced by this profile are superior rather than the taper pin profile [9].


Figure.11.TensileTested Specimen

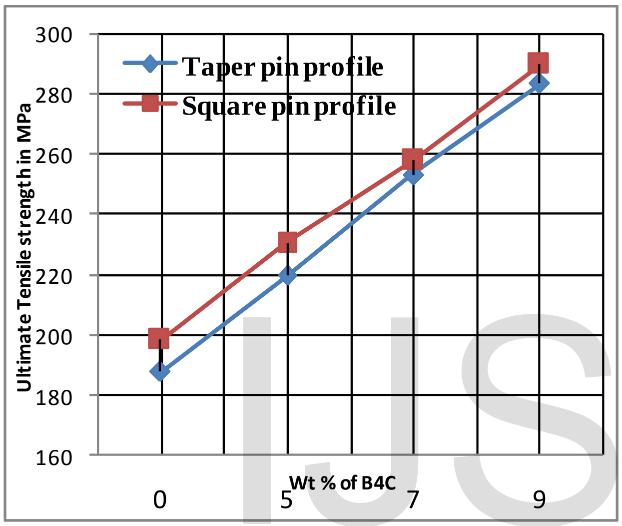


Figure.12.UTS of FSW AMC

4 Conclusions

1. AA6061-B4C composites were produced using stir casting technique by varying the weight % of B4C as reinforcement and with AA6061 as matrix material
2. Hardness of developed composites was significantly improved from 70VHN to 100.20VHN by increasing wt % of B4C
3. Ultimate tensile strength of AMC' was enhanced from 198.32MPa to 313.80MPa
4. With optimized speed of 1400RPM, 40mm/min and 0° tilt angle, square tool pin profile giveshigher tensile strength than taper tool pin profile on FSW composite.

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