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Effect of Boron Carbide on Properties of Aluminum 6063 Alloy Joined By Friction Stir Welding

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ABSTRACT: This research work mainly talks about the mechanical properties of aluminum 6063 alloy welded joint. The most widely used Friction Stir Welding (FSW) method was used to join this alloy. To facilitate the friction stir welding process, the conventional universal milling machine was used. The tool rotational speed of 1200 rpm and feed of 60 mm /min are selected to join aluminum 6063 alloy. One specimen is joined without boron carbide powder and other one is joined with boron carbide powder. The effect of addition of boron carbide on welded joint was studied using tensile test, impact test and hardness test. These test reveals that the addition of boron carbide increase the hardness of the weldment and also impact strength but decreased the tensile strength of aluminum 6063 alloy.

KEYWORDS: Aluminum 6063 alloy, FSW, boron carbide, Tensile test, Impact test, Hardness test

1. INTRODUCTION

Aluminum alloys are most widely used in aircraft industries and automobile industries because of light weight, good resistance to corrosion, good weldability, high strength to weight ratio. But the difficulty in welding of this alloy is the formation of hot cracking. This hot cracking problem can be controlled by refining the grain structure. Many methods are available to control the grain size thereby controlling the hot cracking and improved properties of materials (1-5). Friction stir welding is also another way to reduce hot cracking tendency and also improved properties of materials. Many researchers reported that the friction stir welding is used to improve the properties of materials (6-7). Some researchers incorporate the hard particles like SiC, B_4C during friction stir welding to improve the properties of the materials. Mojtaba Salehin et al packed SiC in to a groove made on 6061 aluminum alloy plate and friction stir processing was performed. They found that SiC nanoparticles were distributed in desirable manner and the microhardness value was 160 VHN in the enriched zone which was 3.2 times more than that the hardness of the particle depleted zone (8). In Mahmoud Abbasi work, AZ31 magnesium alloy sheet was welded using friction stir welding and also processed by incorporation of SiC particles. The test result revealed that the mechanical properties and corrosion behavior considerably improved (9). Sun and Fujii introduced SiC particle of size 5 µm in to pure copper joints during friction stir welding process and found that SiC dispersed copper joints exhibit 110 VHN compare to the joint without SiC particles (10). S.Sahraeinejad et al produced metal matrix composites by incorporating Al_2O_3, SiC, B_4C particles in an Al 5059 matrix by employing friction stir processing. They reported that the average microhardness value within the stir zone increased from 85 VHN to 170 VHN in the B_4C reinforced composite than Al_2O_3, SiC (11). In Yong Zhao work, friction stir processing with B_4C particles is used to improve the wear resistant and microhardness of surface composite layers of 6061 aluminum alloy (12). In Abbas et al report, AZ31 magnesium alloy were welded together using the friction stir process with previously inserted SiC powder particles in the nugget zone to produce good weld strength (13). Wear studies were carried out on Al base metal, Al-SiC particles, Al-MoS_2 and Al-SiC-MoS_2 by Soleymani et al and found that hybrid composite has the highest wear resistance compare to other samples (14). An attempt was made to incorporate SiC particles of 12 µm in the weld zone during friction stir welding of Al 6351 alloy and results revealed that the mechanical properties of the SiC particle added Al 6351 alloy welded joints are superior in both as-weld and under annealed condition, compared to their plain Al 6351 alloy welded joints (15).
The aim of this work to study the mechanical properties of FSW joints of aluminum 6063 alloy without addition of B_4C particle and with addition of B_4C particle.

2. EXPERIMENTAL WORK

2.1 Materials:
The material involved in this work is an alloy of Al-Si-Mg alloy known as aluminum 6063 alloy. The base material characterization tests were conducted to find out the chemical composition and mechanical properties. The chemical composition and mechanical properties of the base metal were presented in table 1 and 2 respectively.

TABLE 1 CHEMICAL COMPOSITION OF BASE METAL

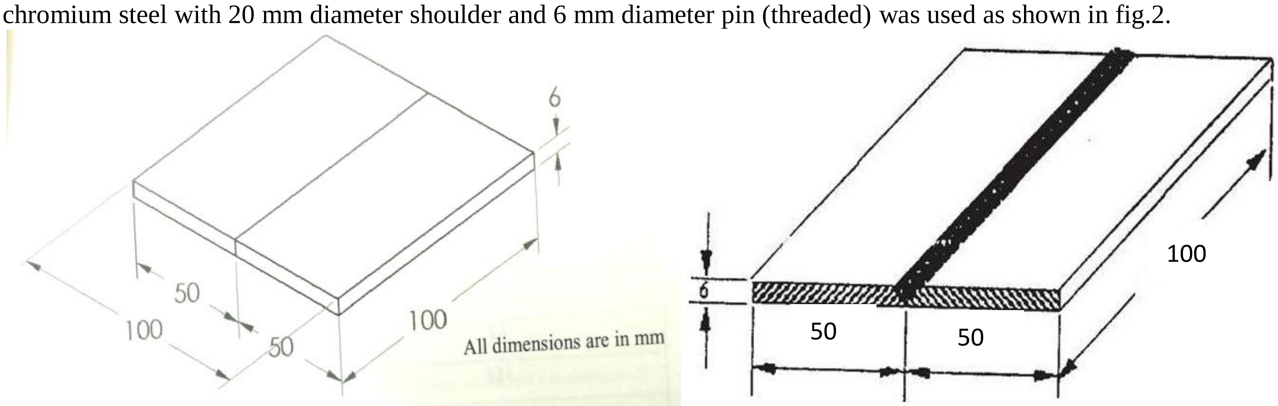
Material	Composition (Wt. %)				
	Al	Si	Mg	Mn	Cu
AA6063 alloy	98.6	0.431	0.55	0.039	0.035

TABLE 2 MECHANICAL PROPERTIES OF BASE METAL

Sl.No	Property	Values
1	Vickers hardness	84 VHN
2	Ultimate tensile strength	131 N/mm²
3	Yield strength	73 N/mm²
4	Impact strength	12 J

2.2 Welding:

The specimens of 100 mm x 50 mm x 6 mm size are selected for this work. One specimen is joined by friction stir welding without addition of boron carbide (figure 1a). In an another specimen 'V' groove is made (figure 1b) to fill boron carbide and then friction stir welding has been applied with addition of boron carbide particles. For joining both the Specimens, universal milling machine was employed (fig.2). To facilitate the welding process, specially designed tool of high carbon high chromium steel with 20 mm diameter shoulder and 6 mm diameter pin (threaded) was used as shown in fig.2.



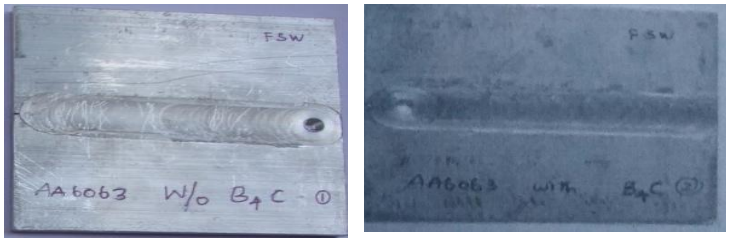
(a) (b)

Fig.1 Specimens

(a) (b)

Fig.2- (a) FSW by milling machine (b) tool for FSW

Tool rotation speed and tool traveling speed of 1200 rpm and 60 mm/min were selected for FSW process. The FSW joints were shown in fig.3.



(a) (b)

Fig.3- (a) FSW without B_4C (b) FSW with B_4C

2.3 Characterization tests:

The welded joints were cut by using wire Electric Discharge Machining (wire-EDM) for tensile test according to American Society for testing materials (ASTM E8M-04) as shown in fig. 4 to evaluate the yield strength, ultimate tensile strength.

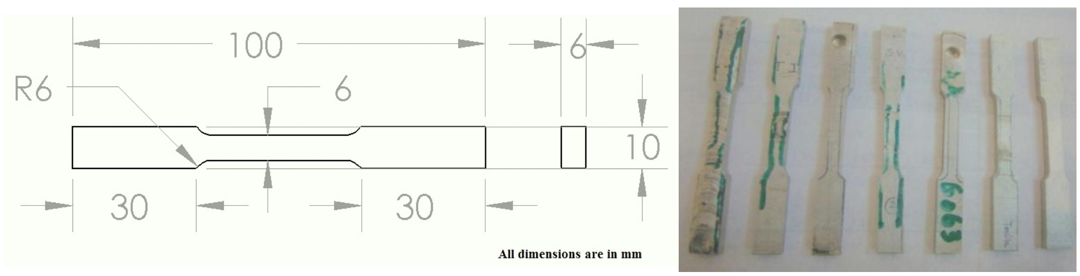


Fig. 4 Tensile test specimens

The hardness of the weld metal is measured by using Vicker's hardness tester with 0.5 kg load with a dwell time of 10 sec. The impact strength of the welded joints is found by employing impact testing machine. For finding impact strength, the charpy specimens were prepared from the welded joints as per the ASTM E23-07a standard.

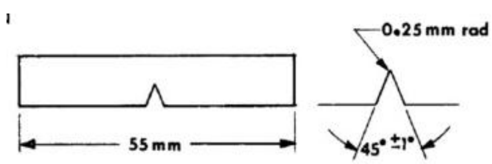
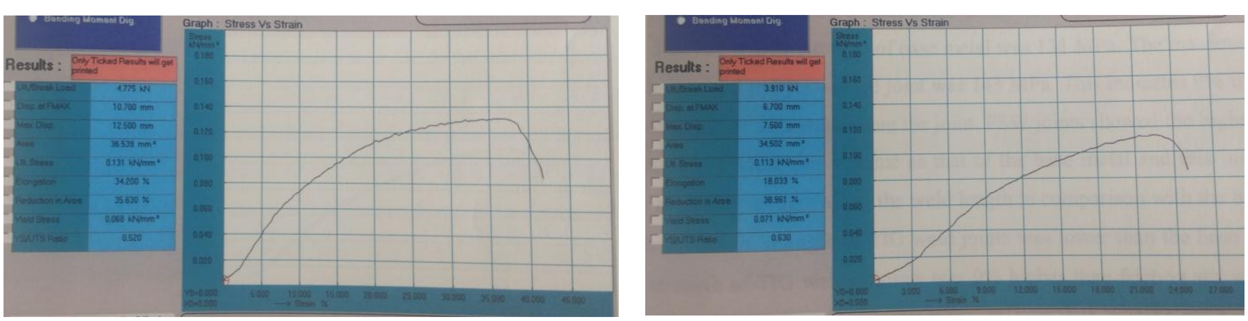


Fig.5 Charpy specimen for impact test

3. RESULTS AND DISCUSSION

3.1 Tensile properties

The tensile properties of the base metal, FSW joints with and without addition of B_4C were evaluated and presented in the table 3. All weld specimens were used to evaluate the tensile properties and the graphs are shown in fig.6 and 7.



(a) (b)

Fig.6 Stress – Strain diagram for all weld tensile test of 6063 alloy (a) FSW without B_4C (b) FSW with B_4C

TABLE 3 TENSILE PROPERTIES OF AA6063 JOINTS

Sl.No	Types of joints	Yield strength (N/mm²)	Ultimate tensile strength (N/mm²)	% elongation
1	Base metal	73	131	35%
2	FSW joint without addition of B_4C	68	131	34.2%
3	FSW joint with addition of B_4C	71	113	18%

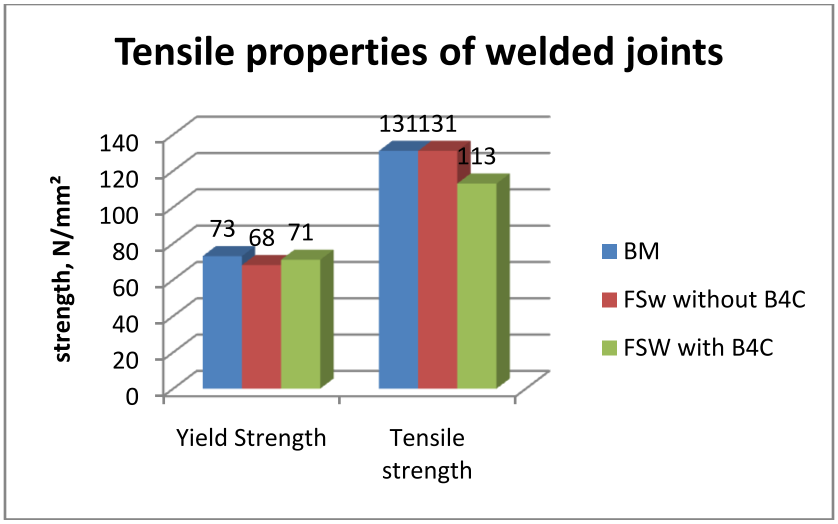


Fig.7 Tensile properties of welded joints

The yield strength and tensile strength of base metal are 73 N/mm² and 131 N/mm² respectively. The welded joint of FSW without addition of B_4C shows the yield strength of 68 N/mm² and the ultimate tensile strength of 131 N/mm². The yield strength is reduced slightly whereas the tensile strength is remains same. When B_4C is added to the FSW joints, the yield strength is not affected much but the ultimate tensile strength is reduced by 14%. The percentage elongation is also reduced and the value is 18%. While FSW joints without addition of B_4C shows the percentage elongation of 34.2% which almost equal to parent metal percentage elongation. Based on the results, the ultimate tensile strength and percentage of elongation of FSW joint with addition of B_4C are less than the FSW joint without addition of B_4C. Hence, the addition of B_4C leads to reduction of tensile strength and percentage of elongation.

3.2 Hardness

The hardness values are measured across the welded joint using Vicker's hardness tester and the average values are given the table 4.

TABLE 4 HARDNESS SURVEY OF AA6063 JOINTS

Sl.No	Types of joints	Hardness value (VHN)
1	Base metal	84
2	FSW without addition of B_4C	61.5
3	FSW with addition of B_4C	122.7

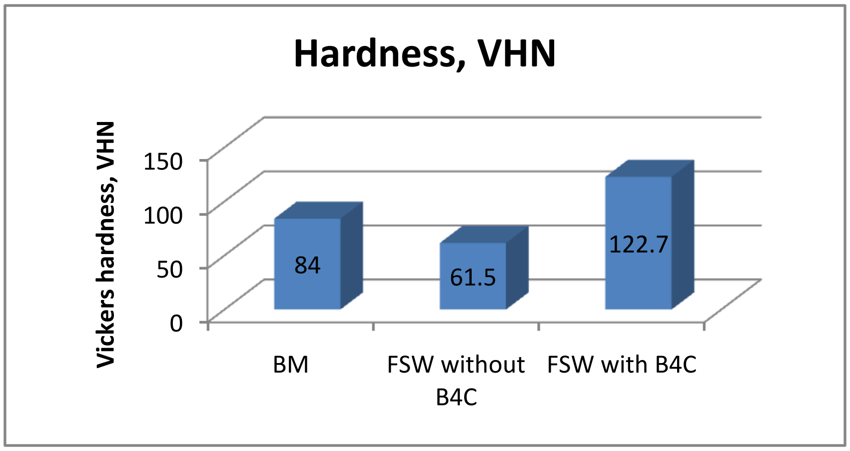


Fig.8 Hardness value of welded joints

The average hardness value of the base metal is 84 VHN. But, the hardness value of FSW joint without addition of B_4C is 61.5 VHN which indicates that hardness is reduced by 26.7% due to heat generated during this process causes softening of the welded area. Whereas, the FSW joint with addition of B_4C increases the hardness value to some extent in the weld metal region and the hardness value is 122.7 VHN. This is because of B_4C is dispersed in 6063 aluminum alloy welded joint and exhibit good hardness.

3.3 Impact strength

The impact strength of the welded specimen was measured using a charpy impact test machine and these values are presented in the table 5.

TABLE 5 IMPACT STRENGTH OF AA6063 JOINTS

Sl.No	Types of joints	Impact strength (Joules)
1	Base metal	12
2	FSW joint without addition of B_4C	14
3	FSW joint with addition of B_4C	13.5

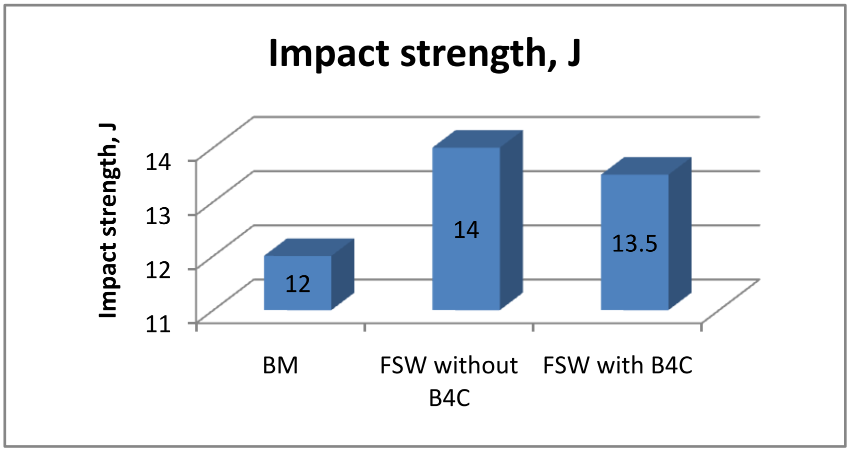


Fig.9 Impact strength of welded joints

The impact strength of the base metal is 12 Joules. But, the impact strength of FSW joint without addition of B_4C is 14 Joules which is slightly higher than the base metal impact strength. While B_4C is added to base metal during FSW, the impact strength is 13.5 Joules which is better than the base metal impact strength (fig.9).

4. CONCLUSION

In this investigation, FSW process was successfully applied with and without addition of B_4C to join AA6063 alloy. The mechanical properties like yield strength, ultimate tensile strength, percentage elongation, hardness and impact strength have been studied. The following conclusions have been made.

- The tensile strength of the FSW joint without addition of B_4C is same as parent metal whereas the same is reduced by 14% when FSW joint with addition of B_4C.
- The percentage elongation is also reduced when the material is welded with addition of B_4C.
- The yield strength is almost same as base metal when the joint is made with addition of B_4C.
- The hardness is increased when the specimen is welded with addition of B_4C compare to joint without addition of B_4C and base metal.
- FSW joint exhibited good impact strength than the base metal.

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