International Journal of Current Engineering and Technology
ISSN 2277 - 4106

Available at http://inpressco.com/category/ijcet

Research Article

Effect of Tool Pin Profile on Mechanical Properties of Single and Double Sided Friction Stir Welded Aluminium Alloy AA19000

Ram Niwas Bishnoi[a*], Pawan Kumar Sapra[b] and Raman Bhambhu[c]

[a]Department of Mechanical Engineering, OITM, Hisar, India, 125001
[b]Department of Mechanical Engineering, BMSCE, Muktsar, India, 152026
[c]Department of Mechanical Engineering, PPIMT, Hisar, India, 125001

Accepted 15 September 2013, Available online 01 October 2013, **Vol.3, No.4 (October 2013)**

Abstract

In present work, an investigation has been carried out on friction stir welding (FSW) in 6mm thick plates of AA19000 aluminium alloy using high carbon high chromium alloy steel tool. Three different tool pin profiles namely straight cylindrical threaded and square have been used to fabricate the joint at constant tool rotational speed of 1400 rpm and traverse speed of 20mm/min. Shape of the tool pin profile and weld side are process variables. It has observed that hardness value of double sided welded joints is slightly greater than single sided welded joints. From this investigation it is found that threaded tool pin profile produces mechanically sound weld and superior tensile properties as compared to other joints. Single sided welded joints have shown lower tensile strength and also percentage of elongation and lower hardness value as compared to the double sided welded joints and this trend is common for all welded joints.

Keywords: *Friction Stir Welding; Aluminium Alloy AA19000; Tool Pin Profile; Mechanical Properties.*

Introduction

AA19000 aluminium alloy (Al–Mg–Si alloy) has been most widely used in the fabrication of light weight structures because of requirement of a high strength-to-weight ratio and good corrosion resistance. Friction stir welding (FSW), a solid-state welding process was invented and experimentally proven by W. Thomas and his team at the Welding Institute UK in December 1991. This technique is being applied to the aerospace and shipbuilding industries. This process is attracting an increasing amount of research interest.

A non-consumable rotating tool with a specially designed probe (pin) and shoulder is inserted into the joint line between two pieces of sheet or plate material, which are butted together [Kumbhar N.T. et al. 2008]. A rotating steel pin pierces a hole in the joint line between the work pieces to a predetermined depth and moves forward in the direction of the weld as shown in Figure-1. Top surface of work piece is in contact with tool shoulder. Two main functions of tool are: (a) to heat the work piece, and (b) movement of material to produce the joint.

Many attempts have been made on FSW on aluminium alloys. Scialpi et al. (2007) studied the effect of different shoulder geometries on the mechanical and micro-structural properties of a friction stir welded joints. The three studied tools differed from shoulders with scroll and fillet, cavity and fillet, and only fillet used in the present study. Elangovan et al. (2008) studied the effect of tool pin profile and welding speed on FSP zone formation in AA2219 aluminium alloy. He used five different tool pin profile (straight cylindrical, tapered cylindrical, threaded cylindrical, triangular and square) with three different shoulder diameters in present study. Out of five tool pin profiles used, square pin profile showed better result among them.

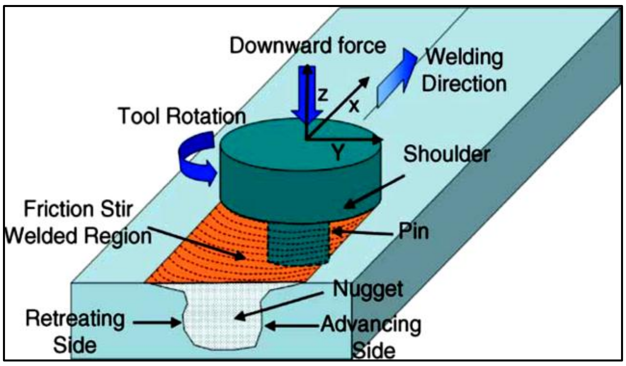

Figure1 Friction Stir Welding [R.S. Mishra et al. 2005]

Experimental Work

The base material used in this study was aluminium alloy AA19000 plates having thickness of 6mm. The base material tensile strength was 147 N/mm² with elongation

*Corresponding author **Ram Niwas Bishnoi** is working as Asst. Prof.

of 13.2 % and Vickers hardness no. is 42. The rolled plates of 6 mm thickness, AA19000 aluminium alloy, were cut into the size (204 mm × 104 mm) by power press and final size (200×100) was made on vertical milling machine. Square butt joint configuration was prepared to fabricate the joints.

Non-consumable tools made of high-carbon high chromium steel have been used to fabricate the joints. The dimensions of the tool are presented in Table 1. Single sided and double sided welding procedure was followed to fabricate the joints.

Table 1 Tool Material and Dimensions

Specifications	Values
Tool Material	HCHCR Steel
Length of tool	60 mm
Tool shoulder diameter	18 mm
Pin diameter	7.2mm
Pin length for single pass	5.7 to 5.8 mm
Pin length for double pass	3.2 to 3.3mm

Friction stir welding was performed at a constant tool rotation speed of 1400 rpm and a welding speed of 20 mm/min and tool plunge depth of .05mm by the friction stir welding machine (Hindustan Machine Tools, India; capacity: 40 kN; 2000 r/min). The tool was tilted forward at zero angle from the vertical to make a good weld surface. A vertical milling machine was used to fabricate the joints. Figure-2 showed the two plates joined together with the help of FSW. Time taken for single sided welding was 10 min and for double sided welding was 20 min. Tensile specimens were prepared according to ASTM guidelines to evaluate the tensile strength, elongation and joint efficiency. The dimensions of tensile specimen are shown in Figure-3.

Tensile testing of the specimens was carried out on Universal Testing Machine (F.I.E., India; capacity: 1000kN) at a room temperature. The specimen was loaded as per ASTM specifications, so that tensile specimen undergoes deformation. The specimen finally failed after necking and the load versus displacement was recorded.

Figure 2 Welded Plate

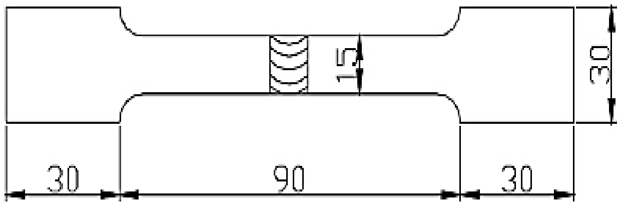

Figure 3 Dimensions of Tensile Specimen

Micro hardness test was done on Vickers Hardness Tester (F.I.E., India; capacity: 50kgf). The load used in Vickers hardness testing was 1kgf for a period of 15 seconds. After the indentation, the dimensions of the diamond impression were recorded i.e. the horizontal and vertical diagonals were recorded using the scale of the eye piece. The tester was calibrated to directly give the values of micro hardness. The hardness values were obtained at 5 different points in the welded region and average of these 5 values has been taken as final value of hardness. Table-2 shows the numbering of welded specimen according to the tool profile.

Table 2 Welded Specimens

S. No.	Specimen No.	Type of FSW Welding	Tool Pin Profile
1	S-1	Single Sided	Square
2	S-2	Single Sided	Straight Cylindrical
3	S-3	Single Sided	Threaded
4	S-4	Double Sided	Threaded
5	S-5	Double Sided	Square
6	S-6	Double Sided	Straight Cylindrical

Results

Tensile Testing

The welded specimens were taken under tensile testing and the values of ultimate tensile strength, percentage elongation and joint efficiency were noted. The results of tensile loading of welded specimens in single and double sided are shown in Table 3. The variation of ultimate tensile strength, percentage elongation and joint efficiency are shown in Figure 4-6 respectively.

Table 3 Tensile Test Results of Welded Specimens

Specimen No.	Ultimate tensile Strength (n/mm$^{2)}$	% Elongation	Joint Efficiency
S-1	82	13	56
S-2	68	12.6	46.3
S-3	98	14.16	67
S-4	101	17.3	68.7
S-5	100	16.94	68
S-6	100	15.82	68

In welding, joint efficiency is the ratio of the strength of a joint to the strength of the base metal, expressed in percentage: Joint efficiency η = joint strength / parent strength

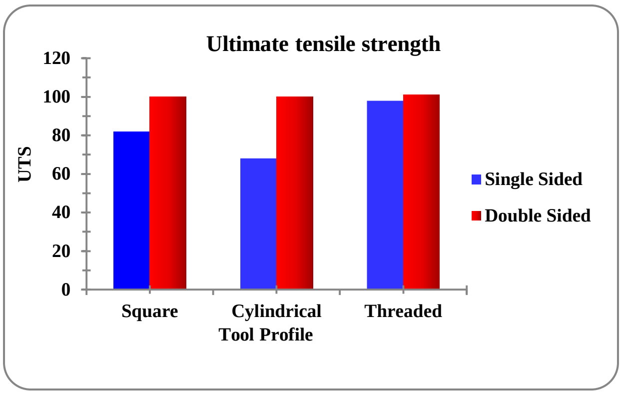

Figure 4 Variation of Ultimate Tensile Strength

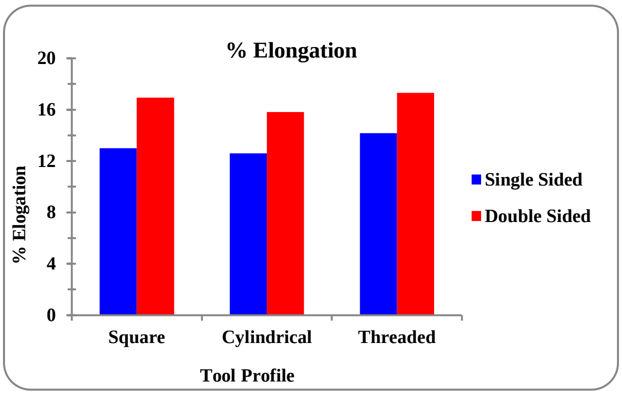

Figure 5 Variation of Percentage Elongation

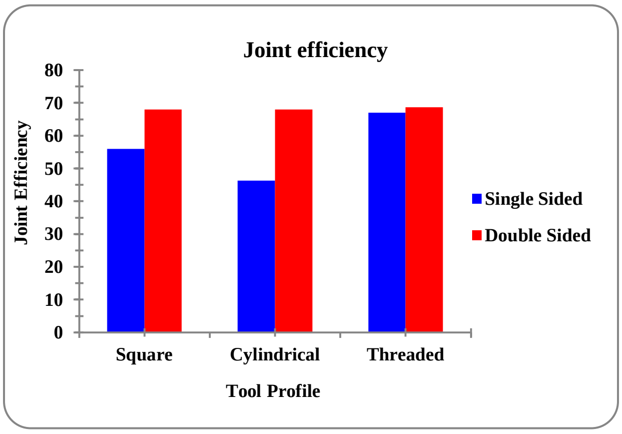

Figure 6 Variation of Joint Efficiency

From the figures, it can be seen that the tool profile and passing of tool in full depth in single sided and half in double sided are having influence on tensile properties of the FSW joints. In single sided, the highest tensile strength of the joints was obtained by using the threaded pin profile tool. The threaded pin profiles tool is best and tensile strength significantly decreases for square and cylindrical pin profile tool due to defect formation.

Threaded tool pin profile tool exhibited superior tensile properties compared to other joints, irrespective of tool rotational speed in double sided.

The joints fabricated by single sided welding have shown lower tensile strength and percentage of elongation compared to the joints fabricated by double sided welding and this trend is common for all the tool profiles. During tensile testing, the specimens are fails in the HAZ zone. Figure 7 shows the failure of welded specimen during tensile testing.

Figure 7 Failure during Tensile Testing

Microhardness Testing

The welded samples were tested for micro-hardness on Vickers Hardness Tester. The hardness values were obtained at 5 different points in the welded region and average of these 5 values has been taken as final value of hardness. An average value of micro hardness result of welded specimens in single sided and double sided is shown in Table 4. The obtained micro-hardness trend is shown in figure 8.

Table 4 Average Value of Micro Hardness of Welded Specimens

Specimen No.	Vickers Hardness
S-1	25
S-2	25
S-3	27
S-4	32
S-5	31
S-6	29

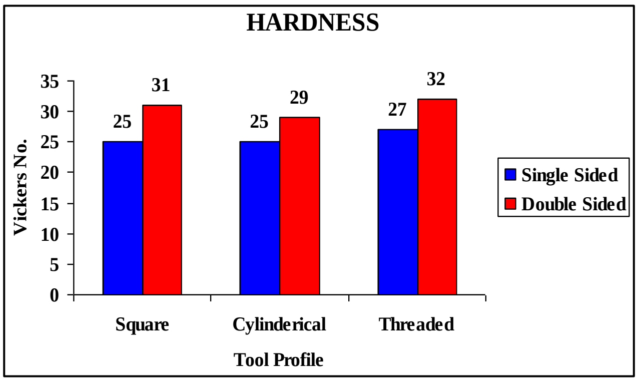

Figure 8 Variation of hardness

It can be observed from the figure that the hardness values of the weld zone or the nugget is lower than the base materials. This indicates the improved ductility of the weld. The values of hardness in single sided exhibit a minimum in hardness associated with weld nugget of the weld as compared to double sided.

Conclusion

In this investigation an attempt has been made to study the effect of tool pin profile (straight cylindrical, threaded, and square) on tensile strength in single and double sided friction stir welding of AA19000. The joints fabricated by double sided FSW have shown higher ultimate tensile strength and percentage elongation as compared to the joints fabricated by single sided and this trend is common for all the tool profiles. Micro-hardness of double sided FSW specimens are higher as compared to the joints fabricated by single sided FSW.

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