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HARDNESS TESTING OF FRICTION STIR WELDED AA 1200 ALUMINIUM ALLOY

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Abstract: Friction Stir Welding is set apart from other fusion welding techniques because of its ability to produce high quality welds in high strength aluminum alloys. The process forges the weld region locally to produce the joint and hence is solid state in nature as it does not involve full melting. In this experimental research work an investigation was carried out on FSW butt joint, to study the changes in its micro hardness. The welded joints were made on AA1200 grade aluminum strips of 4 mm thickness with the help of High Carbon High Chromium (HCHCR) alloy tool of different pin profiles. Three different pin profiles viz. straight cylindrical, triangular and square were used to fabricate the joints at two different tool rotational speeds.

Keywords: Friction Stir Welding, Hardness Testing, AA1200, Aluminium Alloy.

1. INTRODUCTION

Friction stir welding is a solid-state joining process where the metal is not fully melted during the process. It is mostly used for applications where as far as possible the original metal characteristics must remain unchanged. [1]. This process is mainly used on large pieces of aluminium, which cannot be easily heat treated after welding to recover the original characteristics of the material [5].

In FSW, the two pieces or plates which are to be joined are held rigidly with their edges butting together. The tool is of cylindrical shape with a profiled probe. Frictional heat is generated between the wear resistant welding tool and the material of the work pieces when the tool is rotated and slowly forced into the joining line of the two butting workpieces. This frictional heat causes the workpieces to soften without reaching the melting point and allows the travel of the tool along the weld line. The heat plasticizes the workpiece material and it is stirred from the leading edge of the tool to the trailing edge of the tool probe. It is then forged by the intimate contact of the tool shoulder and the pin profile (Fig. 1). The thickness of the aluminum plates which can be welded by this process ranges from 1.5mm to 30mm. The welding equipment can be simply a conventional milling machine which instead of a milling tool carries a cylindrical shouldered tool with a probe.

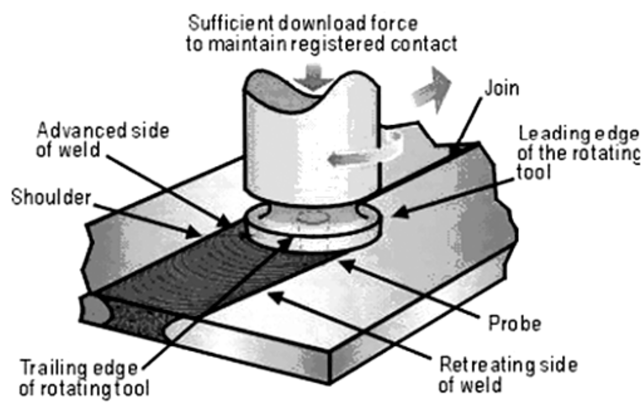

Figure 1: Friction Stir Welding

FSW has many advantages in comparison with other welding processes like, good mechanical properties, no porosity, low shrinkage, no requirement of consumables and fillers, no gas shield required, lower setup costs, improved safety due to the absence of toxic fumes or the spatter of molten material, process can be easily automated on simple milling machines with less training required. However, there are some disadvantages of the process as well like exit hole is left when tool is withdrawn, heavy-duty clamping necessary to hold the workpieces together, less flexible, often slower traverse rate etc. [2],[3].

2. PROBLEM IDENTIFICATION

FSW is a solid state joining process which is widely replacing the routinely used fusion welding processes for joining aluminium alloys, in which the material that is being welded does not melt and recast. The weld quality is decided by various welding parameters like tool pin profile, rotational speed of tool, transverse rate, tool tilt and plunge depth etc. [6],[10].

TWI has patented the friction stir welding process and very less information is available [4]. So the present investigation is an attempt to understand the influences of pin profile and rotational speed of the tool on friction stir processed (FSP) zone formation in aluminum alloy. Three different tool pin profiles (Straight cylindrical, Triangular and Square) are used to fabricate joints at two different tool rotational speeds. The mechanical hardness of the joints is evaluated.

3. EXPERIMENTAL MATERIAL AND ITS SPECIFICATION

Experimental materials and its specifications are given below.

3.1. Work piece Material

Aluminum AA1200 has many properties like good workability, reflectivity, atmospheric corrosion resistance, high thermal conductivity, and weldability etc.

The work pieces that are welded by this process are in the form of two sheet strips of aluminum having a 1200 grade quality. The size of work pieces is given in Table 1.

Table 1
Work Piece Size

Specifications	*Values*
Material	Aluminum
Grade	AA1200
Length	200 mm
Width	100 mm
Thickness	4 mm

The work pieces were prepared i.e. their edges were made parallel and straight by filing.

3.2. Welding Tool

The material used for welding tool is high carbon high chromium steel having hardness 48 HRC. Three different tool pin profiles i.e. straight cylindrical, triangular and square were used to fabricate the joints. The specifications of the tool are given in Table 2.

Table 2
Tool Material and Dimensions

Specifications	*Values*
Tool Material	HCHCR Steel
Length of tool	60 mm
Tool shoulder diameter	20 mm
Pin diameter	5 mm
Pin length	4.8 mm

The tool material HCHCR steel has high percentage of chromium i.e. around 12% with 0.8 – 1.2 % of carbon. This provides high cutting speed with long life to the material. With this, sharpness of tool increases with its finish. The tool material comes in 25 mm diameter and length as per requirement. Straight cylindrical geometry was prepared on the lathe machine. Triangular and square pin profiles were prepared on the milling machine. The circumscribing circle for both triangular and square pins was 5 mm.

3.3. Equipment used for Friction Stir Welding

An indigenously designed and developed vertical milling machine was used to fabricate the joints at the workshop of YMCAUST, Faridabad. The specifications of the machine are given in Table 3.

Table 3
Milling Machine Specifications

Specifications	*Values*
Make	BALTIBOI (semi automatic)
Spindle position	Vertical
R.P.M. range	45 to 2000
Longitudinal bed range	900 mm
Cross bed range	600 mm
Diameter of tool holder	70 mm
Longitudinal feed range	14 to 900 mm/min

3.4. Equipment for Micro Hardness Testing

Micro hardness testing was done on Vickers Hardness tester at Deep Testing Laboratories, Faridabad; the specifications of which are given in Table 4.

Table 4
Specifications of Hardness Tester

Specifications	*Values*
Name	Micro Vickers Hardness Tester
Make	Chroma (Pune)
Range	5 – 3000 gms
Indenter	Diamond pyramid with 136°

4. EXPERIMENTAL METHODOLOGY

The experimental methodology is given in following sub sections.

4.1. Friction Stir Welding

The rolled plates of 4 mm thickness, AA1200 aluminum, were cut into the required size (200 mm × 100 mm) by power hacksaw. Square butt joint configuration was prepared to fabricate the joints. The initial joint configuration was obtained by securing plates in position using mechanical clamps. The work piece sheets were held on a supporting bar of mild steel having a flat surface with the help of strap clamps and V-blocks on the bed of the machine. The clamping was done in a way that during the process spindle of the machine was clear of the way and clamps did not obstruct the spindle.

Two different tool rotational speeds were used for three different tool pin profiles and in total 6 joints (3 × 2) were fabricated by passing the tool pin through the joint. An initial depression of 0.1 mm to the shoulder of the tool was given to provide sufficient axial pressure. The welding process took 10 minutes to complete the single pass weld. The various process parameters used for the experimentation are given in Table 5.

Table 5
Welding Process parameters

Parameters	*Values*
Rotational Speed	2000 rpm, 1400 rpm
Welding Speed	20 mm/min
Tool inclined angle	0°
Shoulder deepness inserted into the surface of base metal	0.1 mm

4.2. Micro Hardness Testing

Micro hardness test was done on Micro Vickers Hardness Tester at Deep Testing Laboratories. Indentation method is used for Micro hardness testing. A permanent deformation on the surface of test sample was created using a diamond pyramid. The hardness of the test sample was calculated from the load required to create the deformation of particular dimensions.

The load used in Vickers hardness testing was 0.1 kg for a period of 10 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 micro hardness was recorded at a distance of 5 mm from the centre upto a distance of 20 mm on both sides so that the variation of hardness over the friction stir zone could be known.

5. RESULT AND DISCUSSION

5.1. Results of Micro Hardness Test

The values of micro hardness as a function of position from the weld centre-line are shown in Fig. 2 to Fig. 7.

5.2. Discussion on Micro Hardness Results

Micro hardness values for friction stir welded specimens are shown in Fig. 2 to Fig. 7. The hardness of the parent metal was approximately

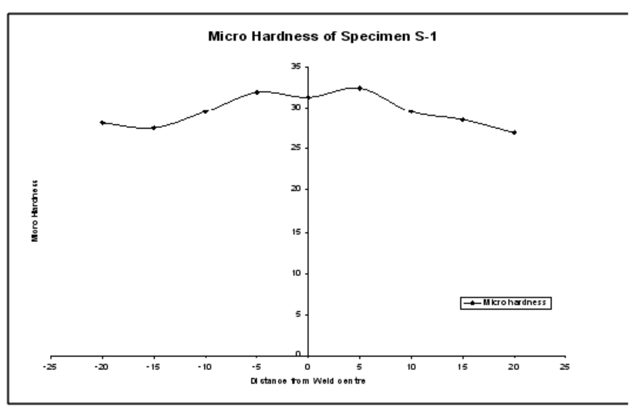

Figure 2: Micro Hardness of Specimen S-1 (Straight Cylinderical, 2000 rpm)

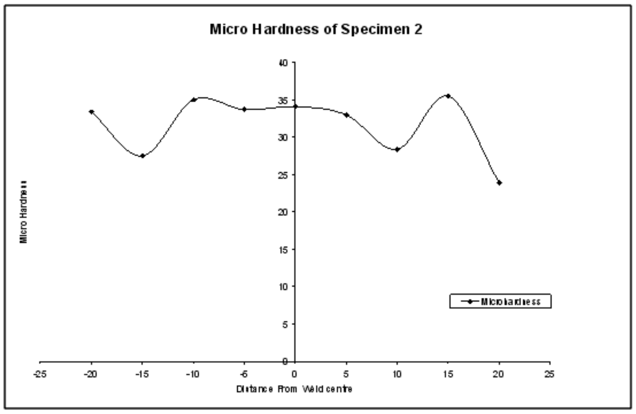

Figure 3: Micro Hardness of Specimen S-2 (Straight Cylinderical, 1400 rpm)

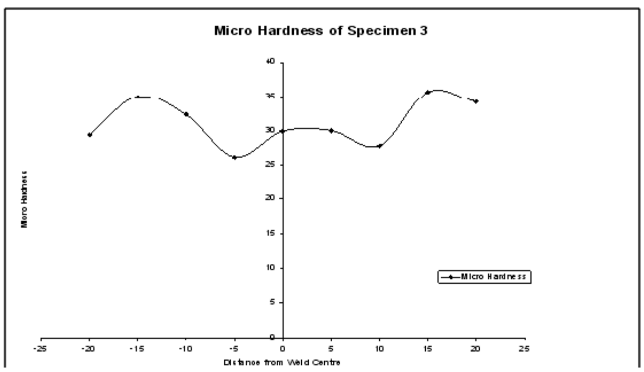

Figure 4: Micro Hardness of Specimen S-3 (Triangular, 2000 r.p.m.)

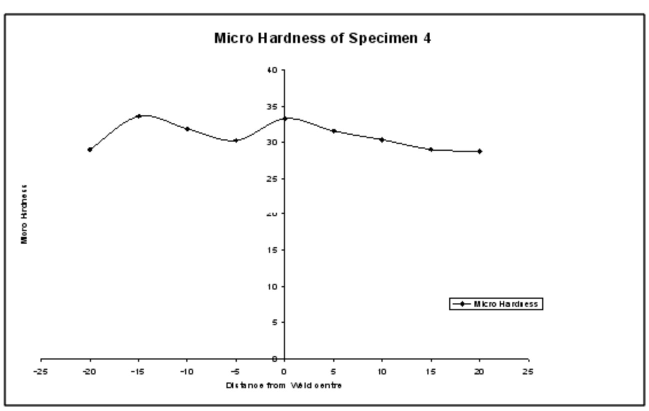

Figure 5: Micro Hardness of Specimen S-4 (Triangular, 1400 r.p.m.)

32 HV. The hardness of the stir zone varied with position ranging from 30 HV to 40 HV. It can be observed that hardness value of friction stir welded zone is higher than the parent metal. There are two main reasons for the improved hardness of friction stir zone. Firstly, grain refinement plays an important role in material

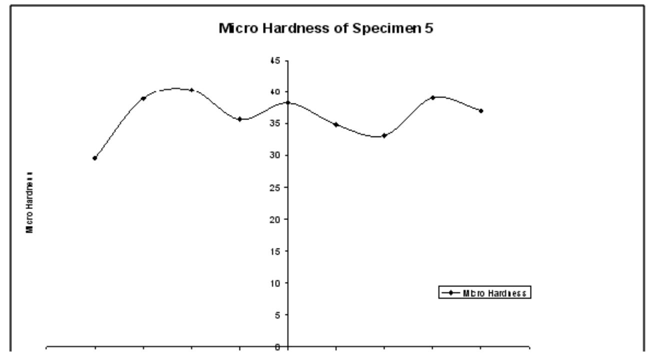

Figure 6: Micro Hardness of Specimen S-5 (Square, 2000 rpm)

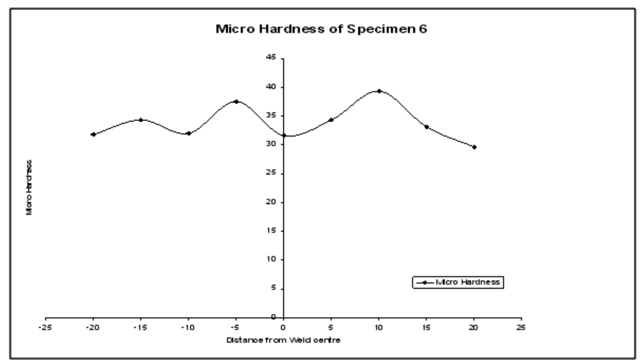

Figure 7: Micro Hardness of Specimen S-6 (Squre, 1400 rpm)

strengthening and since the grain size of friction stir zone is much finer than that of parent metal so hardness increases as the grain size decreases [8]. Secondly, the small particles of intermetallic compounds are also a benefit to hardness improvement [9].

Hardness increases with increasing distance from the stir zone. Minimum value was recorded at distance of ± 10 mm from the centre of the weld, with a slight increase occurring at the centre of the weld.

6. CONCLUSION AND SCOPE FOR FURTHER WORK

6.1. Conclusions

In this investigation an attempt has been made to study the effect of tool rotational speed and tool pin profile on the formation of friction stir processing zone in AA1200 aluminum alloy. From this investigation, we conclude that the welded specimens show an increase in micro hardness in the welded region.

6.2. Limitation of Present Work

TWI has patented the friction stir welding process, therefore a very little information and literature is available about the effect of process variables on the mechanical as well as metallurgical properties of the weld. The various process parameters which affect the weld include, rotational speed of the tool, welding speed, pin profile and dimensions like diameter, length etc, shoulder diameter, tool material, shoulder geometry etc.

As the effect of all the process parameters is difficult to analyze collectively hence only two parameters i.e. pin profile and rotational speed has been considered in this investigation.

Due to the limitation of the vertical milling machine speed range, only two speeds i.e. 1400 and 2000 rpm are considered.

6.3. Scope for Further Work

There are a large number of parameters in any experimentation and it is not possible to check the effect of varying each and every parameter. So further work can be done on:

- Variation in the tool material and other parameters may be taken into consideration.
- Position of oxide layer and its effect may be studied.
- Welding can be done on high melting point alloys such as steels etc.
- Mathematical models can be developed for various parameters.
- Temperatures at various points and heat input per unit volume can be calculated.

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