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Effect of tool pin diameters on friction stir welding of Aluminium alloy 5083

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***Abstract*— *Friction stir welding is a solid-state welding process invented by the welding institute (TWI) of UK in 1991. The main objective is to study the effect of rotational speed and tool pin diameters of straight cylindrical tool on mechanical properties of Aluminium Alloy5083. Three different tool pin diameters (2.5mm,4mm,6mm) have been used to fabricate the joints at three different tool rotational speeds (710,1120 and 1400rpm) by keeping the constant welding speed and axial force. Tensile properties and micro hardness of the joints have been evaluated*.

***Keywords*— solid state welding, friction stir welding, defects in FSW, parameters, Aluminium alloy.**

I. INTRODUCTION

Welding generally requires a heat source to produce a high temperature zone to melt the material, though it is possible to weld two metal pieces without much increase in temperature. There are different standards adopted for increase in temperature there is a still continuous search for new and improved methods of welding. There are two types of state welding are there .Those are solid state welding and liquid state welding

Now, we would know the advantages and disadvantages of solid state welding. Because, the work has been attempted on solid state welding

Advantages of solid state welding:

- Weld (bonding) is free from micro structure defects (pores, non–metallic inclusions, segregation of alloying elements)
- Mechanical properties of the weld are similar to those of the parent metals.
- No consumable materials (filler materials, fluxes & shielding gases) are required.
- Dissimilar metals may be joined (steel-aluminum alloy steel – copper alloy).
- A good weld is strong as the base metal.
- General welding equipment is not very costly.
- Portable welding equipments are available.
- Welding permits considerable freedom in design.
- A large number of metals/alloys both similar and dissimilar can be joined by welding.

Disadvantages of solid state welding:

- Though surface preparation is required. (degreasing, oxides removal, brush/sanding)
- Expensive equipment.

Manufacturing components of aluminium is not very complex; joining of these materials can sometimes cause serious problems. Lack of structural transformation in solid state and excellent thermal and electrical conductivity cause problems in fusion and resistance welding of aluminium alloys, that lead to the development of friction stir welding, a solid state joining technique is used where the two material work pieces are joined by friction between the surface of the plates and the contact surface of a special tool, composed of two main parts: shoulder and pin.

Shoulder is responsible for the generation of heat and for containing the plasticized material in the weld zone, while pin mixes and the material of the components to be welded, thus creating a joint. This allows for producing defect-free weld characterized by good mechanical and corrosion properties.

This paper summarizes the results of an experiment campaign in which the aluminium was friction stir welded, using various combinations of process parameters (speeds). Mechanical properties of the test welds were assessed by means of hardness test and tensile test.

II. METHODOLOGY

The two work pieces to be welded, with square mating (faying) edges, are fixture (clamped) on a rigid back plate. The fixturing prevents the work pieces from spreading apart or lifting during welding. The welding tool consisting of a shank, shoulder and pin, is then rotated to a prescribed speed and tilted normal with respect to the work piece. The tool is slowly plunged into the work piece material at the butt line, until the shoulder of the tool forcibly contacts the upper surface of the material and the pin is a short distance from the back plate. A downward force is applied to maintain the contact and a short dwell time is observed to allow for the development of the thermal fields for preheating and softening the material along the joint line.

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The maximum temperature created by FSW process ranges from 80% to 90% of the melting temperature of the work piece material. So that welding defects and large distortion commonly associated with fusion welding then, it is minimized or avoided. The heat flux in friction stir processing is generated by the friction and the deformation process. This heat is conducted to both the tool and the work piece. The amount of the heat will indicates a successful process which is defined by the quality, shape and microstructure of the processed zone, as well as the residual stress and the distortion of the work piece. The amount of the heat gone to the tool dictates the life of the tool and the capability of the tool to produce a good processed zone

DEFECTS IN FSW JOINTS:

- Open tunnel defect
- Kissing bond crack
- Weld failure due to insufficient downward pressure
- Weld failure due to increase downward pressure
- FSW joint sound

ADVANTAGES OF FSW:

- Due to absence of melting of material, the defects are raised like porosity and voids are less.
- Low distortion and residual stresses occurred in resultant welded zone.
- Higher mechanical properties like ultimate tensile strength, yield strength and hardness.
- Absence of toxic fumes and radiation make it a very environmental friendly process.
- Improved safety due to the absence of toxic fumes or the spatter
- No consumables – conventional steel tools can weld over 1000 m of aluminium and no filler or gas shielding is required for joining of aluminium.
- Easily automated on simple milling machines, lower setup costs and less training required.
- Can operate in all positions (horizontal, vertical, etc), as there is no weld pool.
- Generally good weld appearance and minimal under over-matching, thus reducing the need for expensive machining after welding.

DISADVANTAGES OF FSW:

- Clamping of the work-piece is a very important criterion in the process
- Weld speeds are slower which result in longer processing times.
- Surface thickness is reduced marginally during the process as no filler material is involved.
- If the plates are not clamped properly, due to the tool speed and axial force acting, there is possibility of breaking of the tool tip and the tip getting stuck in the weld zone

Friction Stir Welding –Applications:

- Shipbuilding and marine industries
- Aerospace industry
- Railway industry
- Land transportation
- Automotive applications
- Other industry sectors

ALUMINIUM ALLOY 5083:

The properties of the various aluminum alloys has resulted in aluminum alloys has resulted in aluminum being used in industries as diverse as transport, food preparation, energy generation, packaging, architecture and electrical transmission applications. Depending upon the application, aluminum can be used to replace other material like copper, steel, carbon, zinc, tin plate, stainless steel, titanium, wood, paper, concrete and composites.

Physical properties	Density(kg/m3)	Melting point(°c)	Modulus of elasticity E(Gpa)	Poisson's ratio(μ)
Base metal(5083)	2650	570	72	0.33
Mechanical properties	yield stress(Mpa)	ultimate tensile strength(Mpa)	Hardness number(BHN)	Elongation (%)
Base metal(5083)	220	270-345	75	10-13

III. WORKING SET UP

A conventional vertical 3 axis milling machine was used for friction stir processing (FSW) of AA5083. The machine could achieve the maximum speed of 3000 rpm and 10-horse power. The AA5083 plate dimensions of 150mm (L) 70mm (W) 5mm (T) were used in present study. The AA5083 plates were clamped rigidly on backup plate to produce butt joint using the FSW technique. The experiments are conducted on the AA5083. Before the friction stir welding, the weld surface of the base material was cleaned. The FSW tool is then placed in to the bit and zero tilting angle is applied because FSW tool shoulder is flat.

The sample plunged with downward ward feed rate in to the sample then moves linearly through rotating tip along butt line with certain feed rate of 25mm/min. When the central point of the tool reaches the given welding length of 70mm, the linear movement's stops and the tip is lifted out of the sample with a certain upward feed. Undesired the rotating pin was inserted into an initially predrilled

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hole. AA5083 butt joint was made using H13tool under controllable process parameters like tool pin diameters (2.5mm,4mm,6mm), rotational speed range (710 -1400 rpm) by keeping the constant welding speed 25mm/min and axial force 7KN. The range of values of each factor was set at different levels. Based on this, a total of 3 experiments in each tool pin, having a combination of different levels of factors were carried out.

Table.1: given parameters required for working set up

Process parameters	**Values**
Rotational speed (RPM)	710,1120,1400
Welding speed(mm/min)	25mm/min
Axial force	7KN
Tool material	H13
Tool dimensions	Shoulder diameter18mm, pin length 4.5
Tool pin dimensions of a straight cylindrical tool	2.5mm, 4mm& 6mm

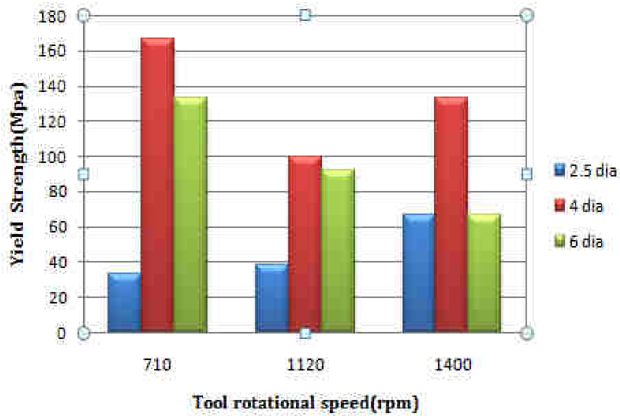
IV. RESULTS & DISSCUSSIONS

Table.2: Results of straight cylindrical tools at different tool pin diameters of YS, UTS, POE values

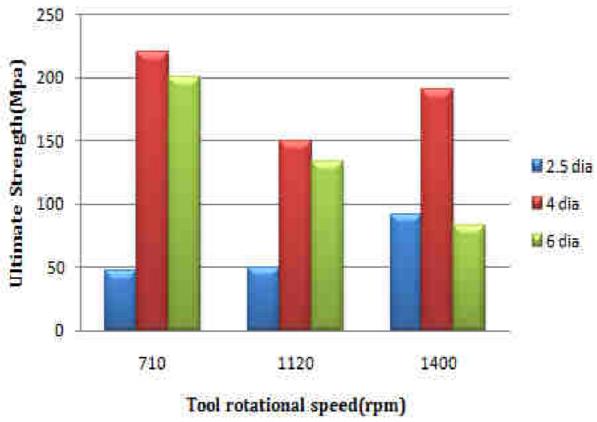
	Tool rotational Speed(rpm)								
Tool pin diameter	710			1120			1400		
(MM)	YS	UTS	POE	YS	UTS	POE	YS	UTS	POE
2.5	33.33	46.66	2.85	38	50	3.18	66.66	91.66	4.7
4	166.6	220	5.88	100	150	2.27	133.3	190	5.77
6	133.3	200	3.82	91.66	133.3	2.6	66.66	83.33	2

The material flow behaviour is predominating influenced by FSW tool pin dimensions and FSW process parameters. Rotational speed appears to be the most significant process variable since it also tends influence the translational velocity. Very high rotational speeds could raise the strain rate, and there by influence the recrystallization process, which in turn could influence the FSW process.

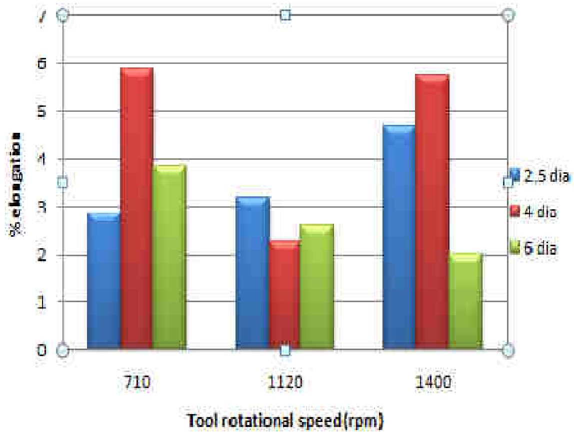
Higher weld speeds are associated with low heat input, which resulting faster cooling rates of the weld joint. This can significantly reduce the extend of metallurgical transformations taking place during welding and the local strength of individual regions across the weld zone at low axial force, the formation of non symmetrical semi circular features at the top surface of the weld shown poor plasticization and consolidation of the material under the influence of the tool shoulder. A pin diameter places a crucial role in material flow and in turn regulates the welding parameters of the FSW process. Friction stir welds are characterised by well defined weld nugget and flow contours



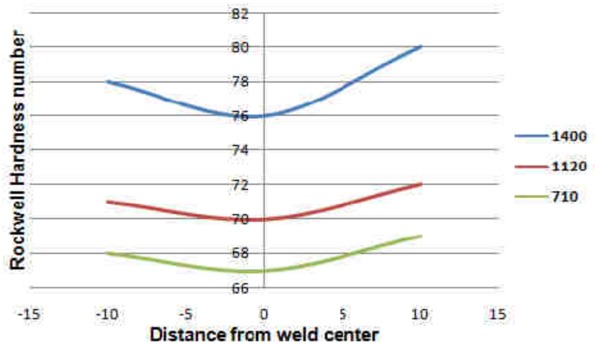
Graph.1: Effect of tool pin diameters and rotational speed on yield strength



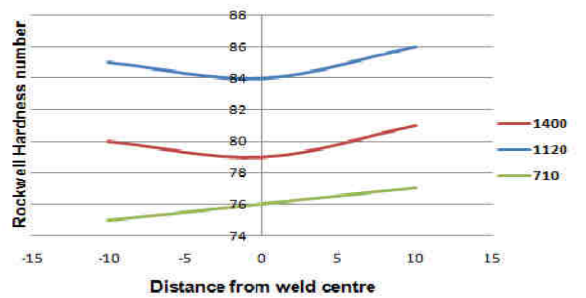
Graph.2: Effect of tool pin diameters and rotational speed on ultimate strength



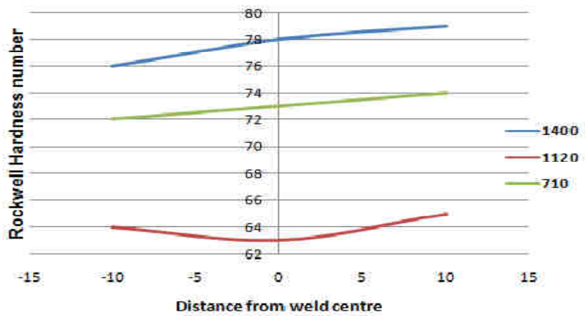
Graph.3: Effect of tool pin diameters and rotational speed on percent of elongation



Graph.4: Effect of 2.5mm pin and rotational speed on hardness



Graph.5: Effect of 4mm pin and rotational speed on hardness



Graph.6: Effect of 6mm pin and rotational speed on hardness

V. CONCLUSIONS

The butt joining of AA5083 aluminium alloy was successfully carried out using FSW technique. The samples were characterised by mechanical properties like yield strength, ultimate strength, hardness, percentage of elongation. The following conclusions are deduced from the present investigation

The optimum operating conditions of FSW have been obtained for two plates of aluminium alloy AA5083 welded in butt joint. The optimal process parameters of the present FSW process can be considered to be the rotational speed of 710 rpm at an axial force of 7KN, with a welding speed of 25mm/min.

Out of the three pin diameters of a straight cylindrical tool (2.5mm,4mm&6mm) adopted in this FSW process, the maximum yield strength, ultimate strength and percentage of elongation were observed through 4mm pin diameter and they are 166.66Mpa, 220Mpa, 5.88% respectively at a rotational speed of 710rpm.

Out of the three pin diameters (2.5mm,4mm&6mm) adopted in this process, the maximum hardness of 84 at weld centre was observed through the 4mm diameter pin only.

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