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Analyzing the Tensile Strength of Friction Stir Welded Butt Joints of Aluminium Alloy Plates (AA6063) - A Review

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Abstarct : *By using a rotating tool and the friction generated by the tool, plates of Al alloy are joined together in their solid state, this joining process is known Friction stir welding (FSW). The heat generated during FSW is a function of tool shoulder diameter & tool pin diameter. Even total heat generated has been modelled as a function of these two parameters and plasticize metal on both sides of a joint, producing a good quality weld. The main objective of this paper is to review the tensile strength of friction stir welded butt joint configuration between similar aluminium alloy plates (AA6063) through various process parameters. The main parameters involved in the process are tool rotational speed and transverse speed. A conventional friction stir welding set up is used which comprises of non-consumable high speed steel tool rotating which comes in contact with the aluminium plates and completes the weld. Tensile Strength has been analyzed with the help of the Tensometer. This paper reviews the work done in above mentioned area.*

Keywords: *Friction Stir Welding, AA 6063 Aluminium Alloy, Tensile Strength*

I. INTRODUCTION

It was the year 1991, when the "The Welding Institute (TWI)" invented a very phenomenal joining process namely, Friction Stir Welding (FSW) which is a kind of solid state welding process and later it was patented by them [1]. The process of joining i.e., welding materials uses a third body tool to join different joint configurations. Due to the generation of heat because of the contact between tool and material, a plasticized region is developed at the junction of materials. It then mechanically intermixes the two pieces of metal at the place of the joint. The softened (plasticized) metal is joined using mechanical pressure which is applied by the tool.

Friction Stir Welding (FSW) can be considered as a green technology because no gases are evolved during the process. Also, there are no toxic fumes or smoke produced during or after the welding process. The process is energy efficient and environmentally friendly [17].

In today's scenario friction stir welding has shown its advantages over aluminium alloys by assuring static as well as dynamic mechanical behaviour which is very often better than the joints welded by conventional fusion processes

Aluminium alloys in the present modern world are suitable for wide range of applications such as sign frames, intricate shapes for architecture, frames of window, doors, etc, in the construction of false ceiling and roof, automobile industries, aerospace industries, railway fabrication, high speed ships and construction of heavy structures due to its light in weight and higher strength to weight ratio, corrosion resistance, and relatively low cost. In many of the fabrication methods & processes, a great challenge is always faced by the technologists and designers in the primary joining method i.e., welding [2]. Presence of a cohesive oxide layer, very high range of thermal conductivity, high coefficient of thermal expansion, shrinkage due to solidification etc are some of the common difficulties related with any type of joining process.

II FSW PROCESS

Friction Stir Welding uses a constantly rotated non consumable cylindrical-shouldered tool with a profiled probe is transversely fed at a constant rate into a butt joint between two clamped pieces of butted material. The probe is slightly shorter than the weld depth required, with the tool shoulder riding at the top of the work surface [3].

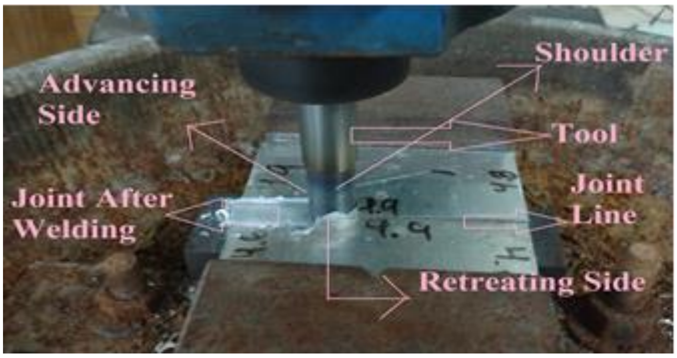

Figure 1: Advancing & Retreating Side In FSW Process

As the tool approaches towards one side there were two sides thus created in the aluminium plates. These were advancing

side and retreating side. The side which comes along the path of rotating tool in the same direction as of tool is known as advancing side while the one which has material flow direction opposite to the tool direction is known as retreating side.
The tool used for performing the friction stir welding can described by categorizing it into three different parts namely, probe (tool pin) which is responsible for the generation of heat(as first the tool is rotated and its pin is submerged into the work-piece) and furthermore, mechanically intermixing of the materials by extruding and forging action. Second part of the tool is shoulder which also plays an important role in the friction stir welding. As the shoulder rest on the upper surface of the welding plates (workpiece) it generates heat (or contributes in the generation of heat and thus makes the material soft) and furthermore it provides a forging action to press the materials extruded during the mechanical mixing and for this purpose the tool is deliberately tilted at some angle (tilted 00 - 30 about the Y-axis) such that the leading edge of the shoulder is slightly above the workpiece[4]. Third part of the tool is used for positioning it in the tool holder so that welding can be performed.

The tool performs three main functions, that is, heating of the work piece, movement of material to produce the joint and containing the hot metal below the tool shoulder.

III EXPERIMENTAL PROCEDURE

A. Material

In the applications such as sign frames, intricate shapes for architecture, frames of window, doors, etc, and in the construction of false ceiling and roof, aluminum alloy (AA 6063) material is extensively used. Moreover, it generally produced with quiet good surface finish, thereby making them suitable for anodizing.
The chemical and mechanical properties of AA 6063 aluminium alloy plates is listed in Table 1 and Table 2.

Table 1: Chemical Composition [5] 755-2

Element	Percentage Present (%)
Manganese	0.0-0.10
Iron	0.0-0.35
Silicon	0.20-0.60
Magnesium	0.45-0.90
Zinc	0.0-0.10
Titanium	0.0-0.10
Chromium	0.0-0.10
Copper	0.0-0.10
Aluminium	Balance

B. Tool Material & Tool Design

Tool material is one of the important parameter in the determination of the suitability of a tool for a particular application. The heat generated during FSW is a function of tool shoulder diameter & tool pin diameter. Even total heat generated has been modelled as a function of these two parameters.

Table 2: Mechanical Composition [5] Source: BS EN 755-2

Property	Value Source: BS EN
Proof Stress	50 Min Mega Pascal
Tensile Strength	100 Min Mega Pascal
Elongation	27 %
Shear Strength	70 Mega Pascal
Hardness Vickers	25 HV

As FSW is a solid state welding process so the temperature here during the welding process is below the melting point of the workpiece therefore it is quiet reasonable to select a tool material which which can withstand such a high temperature. Moreover, it should not buckle during the process thus it must have good strength, hot hardness and wear resistance. During the welding process the tool will reach temperatures in the range of 500 degree Celsius at tool tip depending on the type of material being welded. The tool material must have good hardness, toughness and wear resistant properties at elevated temperatures.

Table 3: Properties of HSS [7]

Properties	Values
Melting Point	600 Degree Celsius
Ultimate Tensile Strength	58000 per square inch
Density	7972 kg per meter cube
Thermal Expansion	9.7 microns per meter per degree Celsius
Modulus Of Elasticity	221 Giga Pascal

For improving the quality of the welding zone and for reducing the rate of wear during plunging, the tool pin employed for welding is having a cylindrical pin profile is used. Usually, the length of the tool pin is kept around 60%-70% of the thickness of the plate used. Pin's diameter is determined by the required pin's strength and wear resistance. Machining a radius at the bottom of the threads will increase tool life by eliminating stress concentrations at the root of the threads [8].

Figure 2: Friction Stir Welding Tool

C. Welding Parameters

For this review study following parameters were considered:-

Table 4: Welding Parameters

Constant Welding Parameters	Variable Welding Parameters
• Axial Force • Tool Pin Length • Pin Diameter • Tool Material • Tool Length • Tool Shoulder Plane	• Rotational Speed Of The Tool • Welding Speed

IV TENSILE TESTING

The results [12] of tensile test on specimens prepared are shown in the table no. 5 below:

Table No. 5: Result of Tensile Test Source: S.Kalainathan et al.

Specimen No	*Rotational Speed (rpm)*	*Transverse Speed(mm/min)*	*Ultimate Tensile Strength(MPa*
21-21	800	50	103
22-22	800	60	117
22'-22'	800	70	110
23-23	1000	50	119
24-24	1000	60	128
25-25	1000	70	121
26-26	1200	50	128
27-27	1200	60	134
28-28	1200	70	130
29-29	1400	50	119
30-30	1400	60	122
30'-30'	1400	70	119

Tensile test was carried out on the welded plate specimens using American Society for Testing of Materials standard respectively. The tensile load was applied on the welded joint specimens using a Tensometer. For each welded plate a set of 3 samples were subjected to tensile test and the average value were calculated.

V. CONCLUSION

In this paper, critical reviews on the friction stir welding of aluminium alloy AA 6063 plates were carried out successfully. The samples were characterized by tensile strength. The following conclusions were therefore made:

1. The optimum operating conditions of Friction Stir Welding was obtained for two aluminium alloy 6063 plates welded in butt joint configuration by friction stir welding.
2. From the results the better performance occurred was at Sample 27-27.
3. The better value of tensile strength of 134 Mega Pascal was obtained at rotational and transfer speed of 1200 rpm and 60mm/min respectively
4. Both Yigezu et al. [13] and Kumar et al.[14] reported that the tensile strength increases linearly when the tool rotational speed increases to an extent in FSW.
5. It was observed that usually the tensile strength was low at lower welding speeds, increased as speed increases and finally decreased after increasing to a certain extent [15].
6. The tensile strength of the specimen was found better with weld made at a transverse speed of 60 mm/min and at the same time there was a increase in tensile strength with the increase in rotational speed. This may be due to the uniform temperature distribution offered by tool at the weld region.
7. An adverse effect was seen when the rotational speed is increased beyond 1200 rpm. This is due to the distortion found at the welded region which is caused at higher rotational speed.

VI FUTURE ASPECTS

1. The reviewed literature shows that there is a lot more have to be done in the field of materials that can joined by this process such as plastics, composite materials, etc.
2. The effect of tool geometry over the microstructure of the welded region and a detailed study regarding that is missing in the literature
3. Detail study of the effect of preheating, nano-particle inclusion and quenching on mechanical properties of FSW joints is lacking in the literature
4. The surface topographical behaviour of FSW joints are not briefly discussed in the literature [16]

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