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Analysis of Temperature Profile on Friction Stir Welded Aa6061 And Aa7075 Aluminium Alloys

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Abstract: The study of temperature distribution during FSW process with dissimilar Aluminium alloys is needed a clear observation on heat generation during process. Low and High strength AA 6061 and AA7075 with 10mm thickness are chosen for welding. The process parameters like TRS, WS, Pin profiles, tool offset and tilt angle plays a crucial role to produce the sound welds. Cylindrical, pentagonal and triangular hybrid tool pin profiles are considered at weld speeds of 40,50,60 mm/min and tool rotation of 710,900,1120 rpm with a tool offset of 0, 0.5, 1mm. The tilt angle which is considered as another parameter is constant at 2^0 throughout the process. The numbers of trail runs are selected by using Taguchi technique (L9) orthogonal array with four factors each at three levels to provide the interaction between the parameters. The temperature history at nugget zone, HAZ and the zones close to TMAZ are measured using thermocouples for either of the Al alloys. The temperature distribution curves were drawn and it is identified from the investigation that more temperature transfer was done towards AA6061.

Keywords: Aluminium alloys, Friction Stir welding, Process parameters, Temperature distribution.

1. INTRODUCTION

Aluminum is light in weight, and offer good corrosion resistance with good strength to weight ratio along with additional properties needed for aerospace, defense, marine, automotive, ammunition and for other fields of applications aluminum is the best ideal material. Indian launch vehicles mostly limited to main four key alloys as AA2014, AA2219, AA6061 and AA7075 with this the main objective the of the research is fabricate the joints with dissimilar combinations of these materials, and improve the joint strength along with mechanical properties of heat treatable Al-alloys, still now lot of work is limited to join those materials in similar fashion with limited thickness up to 8 mm. In this paper the research is focus on fabrication of butt joint of 10 mm thick dissimilar Al-alloys.

Friction stir welding (FSW) was invented by W.M. Thomas at The Welding Institute (TWI) of UK in1991. It is quite different and serves major needs when compared to other welding processes. That is the reason why it is emerging as a major method of welding in the industries of aerospace, ship-building, automotive, and railway industries. It utilizes a non-consumable electrode and welds two dissimilar base metals below their solidus temperatures. At high temperatures below the melting point of the work piece, atoms are permitted to diffuse along the weld joint to fill in any remaining voids and complete the joining process. This helps to retain the same phase of the base metal before and after completion of the welding process. Apart from this it has a variety of other uses such as Excellent tensile and fatigue strength, no splatter, no fume, Low energy consumption, Low shrinkage, no filler wire, Good mechanical reproducibility, no skilled welder required. It is more often used for soft materials like aluminium [1]. The tool used in this process has a specially designed tip having a suitable profile for obtaining the higher quality of the weld. Tool travelling and rotation speeds, among other welding parameters, are most important variables that may affect the joint properties. Alongside of these parameters the distribution of the temperature also plays a important role because ,during the process of Friction stir welding the tool tip undergo translatory and rotary motions due to which a tremendous plastic deformation takes place and the temperature increases rapidly at the weld zone and there might me a slight change in the nature of base metals around the heat affected zone[2].There comes the need of studying the temperature distribution profile on the both sides of the weld region. By, this we can find the nature of heat distribution and further we can make necessary research to minimize the heat affected zone and at the same time increase the quality of the weld. The schematic diagram of FSW process is shown in figure below.

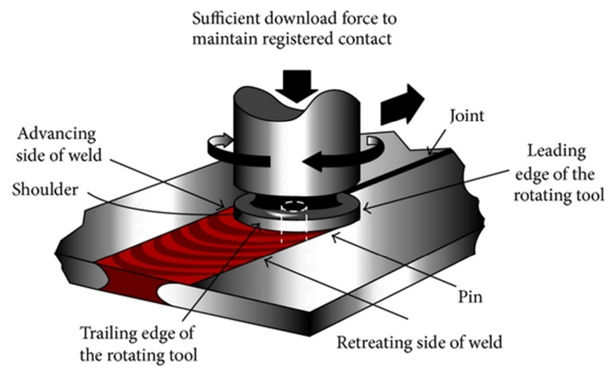

Fig. 1: Schematic diagram of FSW process

Aluminium alloys due to their high flexible properties are used for different industrial purposes. Aluminium alloys are used mainly in aircraft constructions because of their high strength-to-weight ratio. That is the reason aluminium alloys are important due to their improvised mechanical properties and chemical properties .out of all the available aluminium alloys the series 6000 is very commonly used in the industry due to its properties. Both materials of AA6061 and AA7075 are mainly used in various engineering applications. Unfortunately, if we study literature less work is done on both the alloys in spite of their well known uses [3]. The feasibility of friction stir welding process is used to join dissimilar Al alloys with excellent bond strength [4]. So, research is being done in the field of joining these two dissimilar metals to improve the scope of applications.

The chemical as well as the physical properties of both materials should be given prior importance before conducting the friction stir welding process. The chemical compositions of both the metals are given below.

In the research done previous it is proved that any of these metals alone cannot perform well up to the desired level. So, welding of two different alloy materials is encouraged. For this, purpose the perfect welding parameters are chosen and the welding is done accordingly.

The Space Shuttle Program of NASA implemented this new weld technique in its manufacturing process of the external tank in 2001. The first friction stir welded tank flew in 2009. Since then, NASA has developed multiple tools and advanced processes to enhance its welding capabilities on aerospace hardware [5]. So, from this it is clear that any mis welding's leads to great losses in the industry of manufacturing process. To obtain a very good and precise quality of weld it is very essential to take a very special care on the welding parameters and study various working conditions extensively. Two aluminium alloys AA7075-T651 and AA6061-T651 under better mixing of both materials the good strength of weld is obtained at 900 rpm, 90mm/mm with taper cylindrical threaded tool[6]. FSW welds were made with A356 and AA6061 by changing the process parameters TRS (1000-1400 rpm) ,and weld speed of (80-240 mm/min) there will be a change in heat input and process parameters were optimised. [7]. The preliminary investigation on microstructure and mechanical properties of dissimilar AA2024-T351 and AA6056-T4 aircraft alloy welds are affected by the transverse and rotational speeds [8]. In dissimilar welds AA2024-T351 and AA6056-T4 ,the material location at the RS exhibit formation of good welds which is about 90% of AA6056-T4 alloy.

After carefully studying this literature deeply we came to a conclusion on accuracy in welding process and fixed standard welding parameters for obtaining well weld which helps in the experimentation process.

2. EXPERIMENTATION

Aluminium Alloy plates of 10 mm thick AA6061 and AA7075 are initially machined for 100X150X10 mm size are cut from the stock and they are further machined to remove the grease and dirt particles from the surfaces. The process is carried on vertical milling machine. The Chemical composition and mechanical properties of parent materials was tested as per ASTM standards and listed below. Specially designed tools are used to join the plates; tool material was made up of H13 tool steel with different pin profiles. The tools are prepared by considering the previous literatures to design the shoulder and pin profiles and the experimental process was carried out with different process parameters like rotational speed, welding speed, tilt angle, tool offset and pin profiles.

The selection of number process parameters with their levels were selected by using L9 orthogonal array, the presented work was carrying with 4 parameters. The experiments are performed at a rotational speed of 710-1120, traverse speed of 40-90, tool offset of 0-1, with three hybrid pin profiles (T, Cy, P) at a constant tilt angle of 2^0. The previous literatures strongly recommended that, the hard material is always kept an advanced side (AS) and the soft material is placed on retreating side (RS). In FSW process the material in stir zone was experienced by the thermo mechanical cycle, in this stage Al alloys are highly involved in hot working process, the temperatures at stir zone (SZ), AS and RS side of parent metal are observed.

Table1: Chemical Composition of Base Metal:

AA 6061	Mg	Si	Fe	Cu	Cr	Mn	Ti	Zn	Al
Standard	0.8-1.2	0.4-0.8	Max 0.7	0.15-0.4	0.040.35	Max 0.15	Max 0.15	Max 0.25	Bal
Tested	1.02	0.611	0.261	0.192	0.145	0.108	0.016	0.008	Bal

AA 7075	Zn	Mg	Cu	Cr	Fe	Si	Mn	Ti	Al
Standard	5-6	2.1-2.9	1-2	0.18 -0.28	Max 0.5	Max 0.4	Max 0.3	Max 0.2	Bal
Tested	5.63	2.37	1.70	0.215	0.175	0.0769	0.0499	0.0201	Bal

Table2: Mechanical properties of base metals:

Parent Material	AA7075	AA6061
Tensile strength (MPa)	568	270
Yield strength (Mpa)	514	214
% of elongation	11	22

3. DESIGN AND DEVELOPMENT OF PIN PROFILES

From the previous studies, it has reported that FSW process mainly depend on the tool profiles, because it is responsible to produce the sufficient amount of heat to soften the base materials. A special care and design consideration has to be taken to design the pin profiles to join 10 mm thick dissimilar Al alloys. It is very important to note that the concept of swept volume plays an important role in deciding the tool profile.

Swept volume is the total volume that can be accommodated or used at the weld during the welding process. We have different swept volumes for different shaped profiles. In this experiment different pin profiles like Triangle, Square, Pentagon, Hexagon and Octagon, Cylindrical profiles are designed by considering the swept volume values. The swept volume of Triangle, Square and Pentagon profiles have the higher value than the other profiles so Triangle, Square and Pentagon are used in fabrication.

Table 3: Swept volume values for selected tools

S NO	Tool profile	Swept volume
1	Triangle	2.4
2	Cylindrical	1
3	Pentagon	1.45

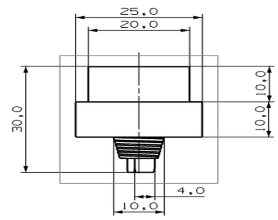

Fig.2:Dimensions of pin profile

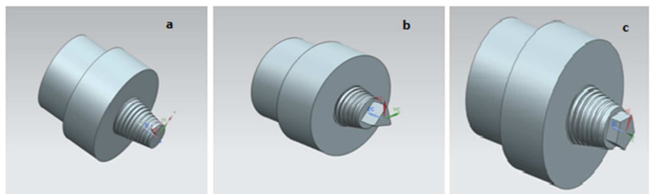

Fig.3: Photographs of FSW pin profiles

The thickness of the plates are uniform throughout the length, so fixed type pin profiles selected for this process and the tool dimensions are taken as per the standard ratios of shoulder to pin dimensions published in previous article [9]. It is strongly recommended from the previous studies that the ratio between tool shoulder to pin diameter as 3 (D/d=3). The pin length has a stronger affect on the traverse force than the pin diameter.

Table 4: Chemical composition of tool material:

H13 Tool Steel	Cr	Mo	Si	V	C	Mn	Ni	Cu	P	S
Standard	4.75-5.50	1.1-1.75	0.8-1.5	0.8-1.2	0.32-0.45	0.2-0.5	Max0.3	Max 0.25	Max 0.030	Max 0.030
Tested	5.29	1.39	1.04	0.896	0.359	0.275	0.223	0.086	0.011	0.002

The prepared pin profiles are further processed to heat treatment to improve the Hardness, Toughness and other mechanical properties

Temperature profile:

Fig.4: Temperature measurement with infrared thermometer

There are different factors which effects on temperature profile during the process are pin profile, spindle speed and welding speed, when spindle speed was increases heat generation was high, which cause to increasing the interface temperature, whereas higher traverse speed causes more heat exerted from the weld zone.

The temperature profile of the weld zone and its surroundings can be calculated by using two methods: one among them is calculating the temperature directly by using the laser thermometer, the second option available is by calculating it with the help of formulae available.

4. RESULTS AND DISCUSSIONS

The observations shows that more than 80% of the heat taken between the tools pins to work pieces, it's a good sign for producing sound welds and also help to reduce the defects occurring during the process. An appropriate amount of heat generation is required for softening of joining materials which cause to reduce the thermo mechanical stresses on tool during processes.

To understand the effect of temperature on hardness, the maximum temperature observed on AS and RS of the welds made by different pin profiles.

Table 5: Experimental observations at various process parameters

TRS	WS	OFFSET	PINS	AS temp.	Tool temp.	RS temp.
710	40	0	Triangular	208	223	200
710	60	0.5	Cylindrical	200	208	195
710	50	1	Pentagonal	195	200	188
900	40	0.5	Pentagonal	224	258	208
900	60	1	Triangular	195	210	191
900	50	0	Cylindrical	206	212	201
1120	40	1	Cylindrical	200	228	192
1120	60	0	Pentagonal	212	239	202
1120	50	0.5	Triangular	218	248	205

FSW weld images:

The welds processed at various conditions are ordered by using L-9 orthogonal array and the images of the same are shown below.

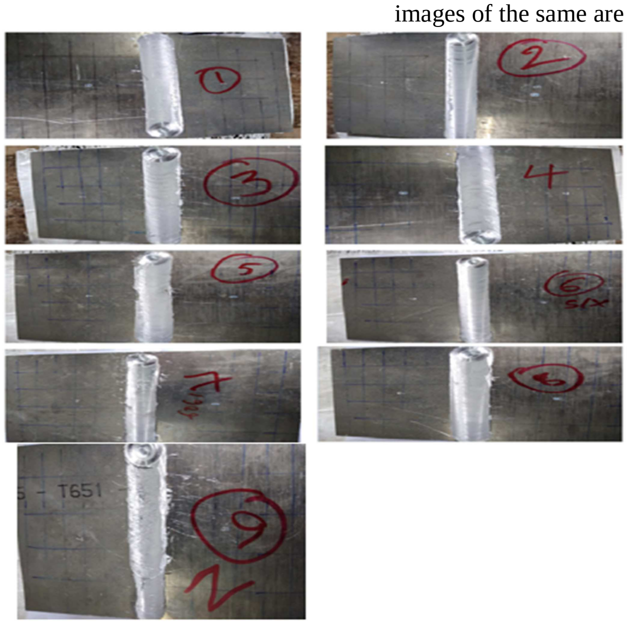

Fig5: weld images

Temperature profile graphs:

The temperature profile measured along the length of the weld measured with the help of infrared thermometer and the measured values plotted in graphs are shown below.

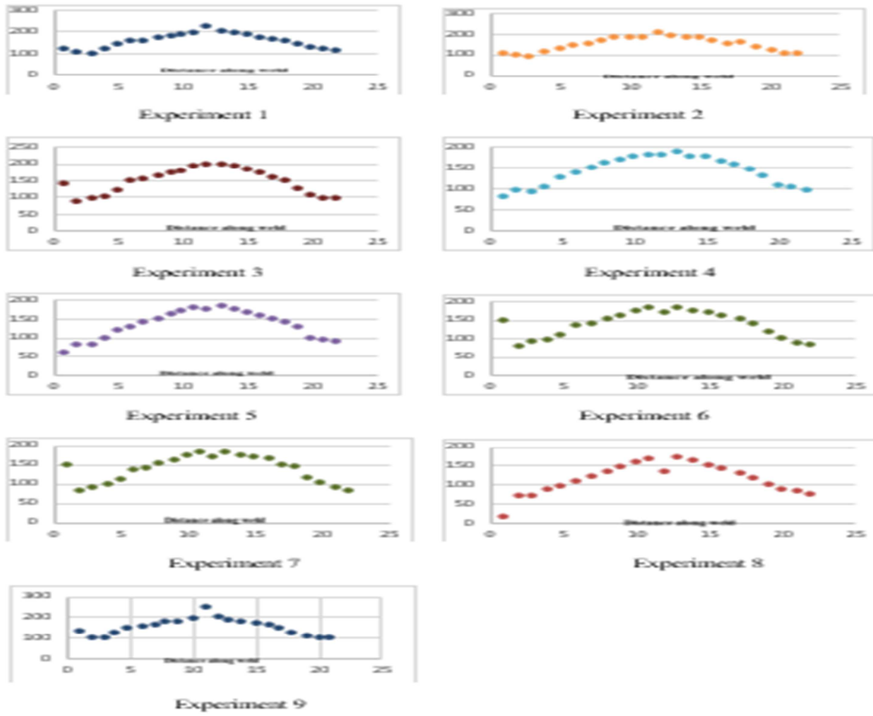

Fig.6: Temperature Distribution profiles

The temperature distribution of the welded samples throughout the length and their comparison is shown in the given figure.

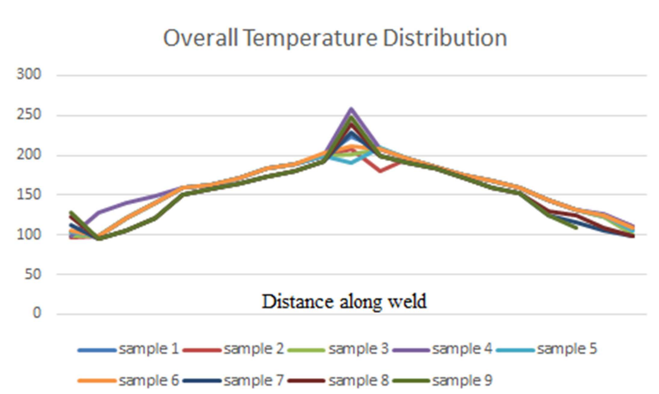

Fig.7: Comparision of temperature distribution among the samples

5. CONCLUSION

From the experimental study the observed results are concluded as follows,

- Temperature generation during FSW process mainly depends on process parameters.
- The temperature profile shows that all the joints are made below solidification temperature of the base material and its value lies between 0.4-0.5 times of melting point of the base material.
- The sample no.4 processed at TRS 900 rpm, WS 40 mm/min, offset 0.5 mm with

pentagonal pin profile produce the highest temperature.

- It is clearly observed that the temperature measured about AS is greater than RS side.It is a good sign for intermixing of materials.

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