STUDY OF FRICTION STIR WELDED JOINTS OF SIMILAR ALUMINIUM ALLOYS

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Abstract - The aim of this project is to join two similar Aluminium alloys by friction stir welding (FSW) and to study the characteristics of the welded joints. Friction welding is a solid state joining process which is ideal for welding Aluminium alloys. By the FSW parameters like tool rotation speed, tool feed and design of tool we can increase the strength of the welded area. The principal advantage of friction welding, being a solid state process, low distortion, absence of melt-related defects and high joint strength, even in those alloys that are considered non-wieldable by conventional welding techniques. Furthermore friction welded joints are characterized by the absence of filler-induced problems or defects , since the technique requires no filler, and by the low hydrogen contents in the joints, an important consideration in welding steel and other alloys susceptible to hydrogen damage. Here the tool rotational speed is taken as the variable parameter and the rest of the parameters, i.e., feed, profile, and load are kept constant. Mechanical characterization tests like tensile, impact and hardness tests would be taken and compared amongst the specimens for effectiveness of the weld.

1. INTRODUCTION

Friction stir welding is a solid state welding process performed at the temperatures lower than the melting point of the alloy. The work pieces are rigidly clamped in a fixed position and a specially profiled rotating tool traversed through the joint line produces the friction heating. The tool is crushing the joint line through the joint line produces the friction heating. The tool is crushing the joint line breaking up the oxide by a mechanical stirring and forging of the hot and plastic material the result joint exhibits a finer grain structure than the base metal.

Friction stir welding is a technique that is known for its extra weld strength, and also improvised grain structure. The reason why friction stir welding is preferred over the other conventional welding processes is because that friction stir welds has less heat affected zones compared to those of TIG and other conventional welds.

Infact, TIG is very much a conventional welding process and it is in use for the past 60-70 years or more. It is used for joining metals that form very stable high melting point oxides, that are more difficult to remove through the use of liquid slag. Whereas, friction stir welding is a non fusion process that eliminates unnecessary and undesirable metallurgical changes during melting and subsequent cooling.

The project involves in welding the specimens AA2024 and AA6061 in two different tool rotational speeds, and keeping all other parameters intact. Aluminium is remarkable for the metals low density and for its ability to resist corrosion due to the phenomenon of passivation. Structural components made from aluminium and its alloys are vital to the aerospace industry and are important in other areas of transportation and structural materials. Welding of aluminium alloys is of primary interest in today's modern world.

2. LITERATURE REVIEW

Friction stir welding (FSW) was invented at The Welding Institute (TWI) of UK in 1991 as a solid-state joining technique, and it was initially applied to aluminium alloys. The basic concept of FSW is remarkably simple. A non consumable rotating tool with a specially designed pin and shoulder is inserted into the abutting edges of sheets or plates to be joined and traversed along the line of joint. The tool serves two primary functions, heating of work piece and movement of material to produce the joint. Because of various geometrical features of the tool, the material movement around the pin can be quite complex. During FSW process, the material undergoes intense plastic deformation at elevated temperature, resulting in generation of fine and equalized recrystallized grains. The fine microstructure in friction stir welds produces good mechanical properties. [1]

FSW is considered to be the most significant development in metal joining in a decade and is a "green" technology due to its energy efficiency, environment friendliness, and versatility. As compared to the conventional welding methods, FSW consumes considerably less energy. When desirable, dissimilar aluminium alloys and composites can be joined with equal ease. In contrast to the traditional friction welding, which is usually performed on small axisymmetric parts that can be rotated and pushed against each other to form a joint, friction stir welding can be applied to various types of joints like butt joints, lap joints, T- Butt joints, and fillet joints. [2]

The specimens obtained from the nugget zone demonstrated a super-plastic behaviour at temperatures ranging from 623 to 723K. Recent studies have demonstrated that FSW provides the potential for refining the grain size of a joint material down to the micro level in the friction stir welded zone. The reduction in grain size to the micros level has two significant advantages. First, there will be an increase in the tensile strength with little or no corresponding reduction in the overall ductility at ambient temperature. Second, if the ultra-fine grained 5 microstructure is stable at elevated temperatures where diffusion is reasonably rapid; there will be a possibility of achieving super plasticity. [3]

The friction stirring tool consists of a pin, or probe, and a shoulder. Contact of the pin with the work piece creates frictional and deformational heating and softens the work piece material, contacting the shoulder to the work piece increases the work piece heating, expands the zone of softened material, and constrains the deformed material. Friction stirring pins produce deformational and frictional heating to the joint surfaces. The pin is designed to disrupt the faying, or contacting surfaces of the work piece, shear material in front of the tool, and move material behind the tool. In addition, the depth of deformation and tool travel speed are governed by the pin design. [4]

The probe of the tool generates the heat and stirs the material being welded but the shoulder also plays an important part by providing additional frictional treatment as well as preventing the plasticized material from escaping from the weld region. The plasticized material is extruded from the leading to the trailing side of the tool but is trapped by the shoulder which moves along the weld to produce a smooth surface finish. Clearly, different materials and different thicknesses will require different profile probes and welds can be produced from just one side or by welding hall the thickness then turning over 10 complete the other side. Welding is carried out around 70 - 90% of the material melting point so it is important that the tool material has sufficient strength at this temperature otherwise the tool can twist and break. [5]

The Vickers hardness, tensile strength 11 and radiography arc considered for investigation by varying tool speed, tool feed and maintaining constant depth of penetration of weld. Experiments were conducted on AA6351 Aluminium alloy in a CNC Vertical Machining Centre. The output factors are measured in I 11'M, Vickers hardness tester and Radiography equipment Results show strong relation and robust comparison between the element strength and process parameters. Hence FSW process variable data base is to be developed liar wide variety of metals and alloys for selection of optimum process parameters for efficient wet& [6]

Tool rotational speed is having significant influence on tensile properties of' the welded specimens and also it is observed that most of the specimens failed in the HAZ region of retreating side. Friction stir welding possess good micro structural and mechanical properties. Main advantage of welding aluminium Alloys are due to their recrystallization property in the welded area [7]

3. METHODOLOGY

The methodology adopted for our project on optimization of friction stir welding parameters for dissimilar aluminium alloys is illustrated in the following ways.

3.1 NEED FOR STUDY

Why Friction Stir Welding…...?

- No consumables & no prior surface cleaning are required
- Good mechanical properties are obtained
- Can be done in simple CNC and lathe machine.

Why Optimization…..?

- To find best process parameters to attain high tensile strength in the welded area in friction stir welding.

Why Aluminium alloys…...?

- Most abundant metal.
- High S-W ratio than other materials.

3.2 MATERIAL SELECTION

The material which is used in our project is two dissimilar aluminium alloys. The major criteria's considered while selecting the materials were, 1. Applications; Based on the applications where the material can be used in the present scenario. 2. Tensile strength; The materials selected should possess contrasting or dissimilar tensile strength to obtain new characteristics 3. Corrosive resistance; the materials are selected based on the fact that one high resistive material can be welded with the other ordinary one to obtain intermediate characteristics.

3.3 TOOL SELECTION

The tool is selected based on the base metal selected. The tool should have high strength and hardness than the materials used. Three types tool that is tried and tested in our experiment are; Cylindrical Tool; in the friction stir welding process, the tool used has a cylindrical profile. It is considered to have a simple design. Cylindrical threaded tool; in the friction stir welding process, the tool used has a cylindrical profile and V-thread on it. Tapered Threaded tool; in the friction stir welding process, the tool used has a tapered profile. It has a taper angle of 15 degree.

3.4 FRICTION STIR WELDING PROCESS

The welding process is carried out using the materials and tools selected for the process. The parameters like tool transfer speed, tool profile and load are fixed and tool rotational speed is varied throughout the process.

4. MATERIAL SELECTION

4.1 ALLOYS USED FOR FSW

An alloy is a metallic or metallic solid solution compound of two or more elements. Complete solid solution alloys give single solid phase microstructure, while partial solution give two or more phases that may or may not be homogeneous on distribution, depending on thermal heat treatment history. Alloys usually have different properties from those of the components elements, as shown in table 5.1.

Table 4.1: Various types of available alloys

Aluminum alloys	Indium alloys	Potassium alloys
Bismuth alloys	Iron or ferrous alloys	Rare earth alloys
Cobalt alloys	Lead alloys	Silver alloys
Copper alloys	Magnesium alloys	Tin alloys
Gallium alloys	Mercury alloys	Titanium alloys
Gold alloys	Nickel alloys	Titanium alloys
Zinc alloys	Zirconium alloys	

The major advantages of FSW are any alloy can be welded with any alloy. So to attain the required objective of welding dissimilar alloys, the ferrous alloys and nickel alloys are used. The major welded by this process by this process is aluminium and its alloy types.

4.2 ALUMINIUM ALLOYS

Aluminium alloys are alloys in which aluminium (Al) is the predominant metal. The typical alloying elements are copper, magnesium elements are copper, magnesium, manganese, silicon and zinc. There are two principal classifications, namely casting alloys and wrought alloys, both of which are further subdivided into the categories heat-treatable and non-heat-treatable alloys. Aluminium alloys typically have an elastic modulus of about 70 GPA, which is about one-third of the elastic modulus of most kinds of steel and steel alloys. Alloys composed mostly of aluminium have been very important in aerospace manufacturing since the introduction of metal skinned aircraft.

4.2.1 CHARACTERISTIC OF ALUMINIUM

1. The difference in melting points of the two metals and their oxides. The oxides of iron all melt to or below the melting point of the metal; aluminium oxides melts at 2060c some 1400c above the melting point of aluminium. This implication for the welding process.
2. The oxides film on aluminium is durable, highly tenacious and selfhealing; this gives the aluminium alloys excellent corrosion resistance, enabling them to be in expected application without additional protection.
3. The co-efficient of thermal expansion of aluminium is approximately twice that of steel which can mean unacceptable bucking corrosion resistance, enabling them to be used in exposed application without additional protection.
4. The coefficient of thermal conductivity of aluminium is six times that of steel. The result of this is that the heat source for welding aluminium needs to be far more intense and concentrated than that for steel.
5. Aluminium has high electrical conductivity, only three-quarters that of copper but six times of steel. This is disadvantages when resistance spot welding where the heat for welding must be produces by electrical resistance.

5. TOOL SELECTION

5.1 FRICTION STIR WELD TOOL

FSW applications require a tool that can withstand temperatures of approximately 900-1000°C at high z- and x-axis loads. The tool must produce consistent weld properties and maintain high abrasion-resistance. The tool has two primary functions one is localized heating and the other one is Material flow. In the initial stage of tool plunge, the heating results primarily from the friction between pin and work piece. Some additional heating results from deformation of material. The tool is plunged till the shoulder touches the work piece. The friction between the shoulder and work piece results in the biggest component of heating. From the heating aspect, the relative the pin and shoulder is important. And the other design features are not critical. The shoulder also provides confinement for the heated volume of material. The second function of the tool is to stir and move the material.

5.2. TOOL DESIGN

The design of the tool is a critical factor as a good tool can improve both the quality of the weld and the maximum possible welding speed. It is desirable that the tool material is sufficiently strong, tough, and hard wearing at the welding temperature. Further it should have a good oxidation resistance and a low thermal conductivity to minimize heat loss and thermal damage to the machinery further up the drive train. Tool geometry is the most influential aspect of process development. The tool geometry plays a critical role in material flow and in turn governs the traverse rate at which FSW can be conducted.

The standard dimensions of the tool are,
Shoulder diameter : 18 mm
Shoulder length : 18 mm

Pin diameter : 6 mm
Pin length : 5.7 mm

6. WELDING EXPERIMENTATION PROCESS

The friction welding experimentation process starts with cutting the aluminium work pieces according to the required dimensions. After the pieces are cut, each piece from each aluminium alloy is selected and welding is done. The detailed process is discussed below fig 6.1.

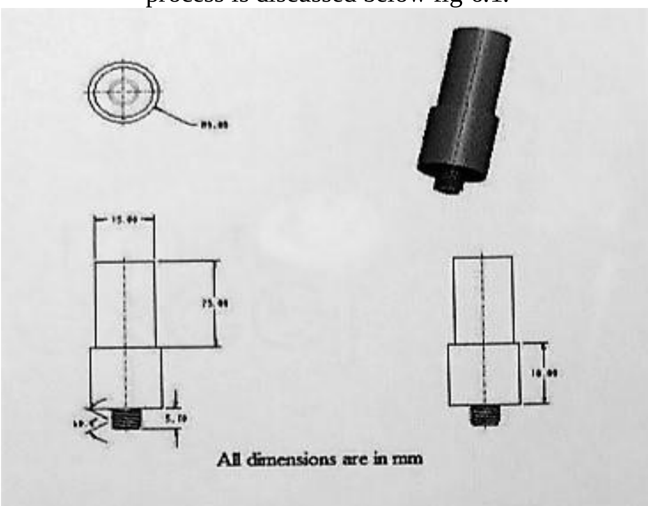

Figure 6.1: 2D Drawing of cylindrical threaded tool

Figure 6.2: Tool used for friction stir welding process

7. WELDING EXPERIMENTATION PROCESS

The friction welding experimentation process starts with cutting the aluminium work pieces according to the required dimensions. After the pieces are cut, each piece from each aluminium alloy is selected and welding is done. The detailed process is discussed below fig 7.1.

Figure 7.1: Setting of work piece in CNC

PROCESS DETAILED

1. The work piece of dimensions 100*50*6mm is cut on AA2024 and AA6061 Using power axe saw.
2. Then the work piece is milled to the tolerance limits.
3. Then the work piece is milled to the tolerance limits.
4. Then the work piece is milled to the tolerance limits.
5. The work piece is mounted firmly on the bed and checked for flatness.
6. The CNC program is fed into the control panel of the machine.
7. The suitable collect size is chosen for the tool.it is then fitted to the CNC spindle.

EXPERIMENTAL WORK

The process consists of four experiments by varying the tool rotational speed at two different levels. The evaluated parameters and the four experiments are given below:

SI. NO	MATERIAL	SPEED (rpm)	FEED (mm/min)
1	2024	750	25
2	2024	1250	25
3	6061	750	25
4	6061	1250	25

EXPERIMENT 1 (2024, 750rpm, 25 mm/min, CYLINDER THREADED (CT) TOOL)

The speed is set at 750rpm and the feed is selected as 25mm/ min .the tool chosen for this experiment is cylindrical threaded type. The process is carried out by moving the tool along the joining axis of the two aluminium alloys for required parameters. Then burrs are removed and then it is grinded for good surface finish as shown in fig 8.2.

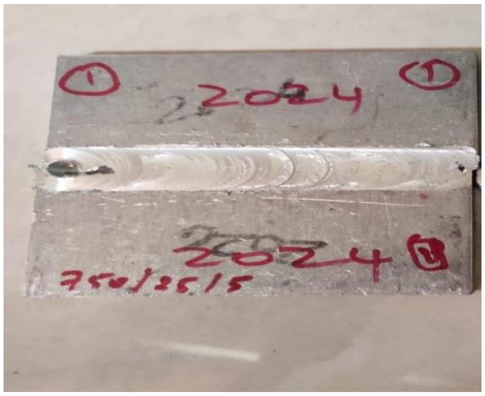

Fig 7.2

EXPERIMENT 2 (2024, 1250 rpm, 25 mm/min, Cylindrical Threaded (CT) Tool)

The speed is set at 1250 rpm and the feed is selected as 25 mm/min. the tool chosen for this experiment is cylindrical threaded type. The process is carried out by moving the tool along the joining axis of the two aluminium alloys. Thus the friction welding is carried out in the aluminium alloys for required parameters. Then burrs are removed manually and then it is grinded for good surface finish as shows in fig 8.3.

Fig 7.3

EXPERIMENT 3 (6061, 750 rpm, 25 mm/min, Cylindrical Threaded (CT) Tool)

The speed is set at 750 rpm and the feed is selected as 25 mm/min. the tool chosen for this experiment is cylindrical threaded type. The process is carried out by moving the tool along the joining axis of the two aluminium alloys. Thus the friction welding is carried out in the aluminium alloys for required parameters. Then burrs are removed manually and then it is grinded for good surface finish as shows in fig 8.4.

Fig 7.4

EXPERIMENT 4 (6061, 1250 rpm, 25 mm/min, Cylindrical Threaded (CT) Tool)

The speed is set at 1250 rpm and the feed is selected as 25 mm/min. the tool chosen for this experiment is cylindrical threaded type. The process is carried out by moving the tool along the joining axis of the two aluminium alloys. Thus the friction welding is carried out in the aluminium alloys for required parameters. Then burrs are removed manually and then it is grinded for good surface finish as shows in fig 8.5.

Fig 7.5

Fig 7.6 (a)

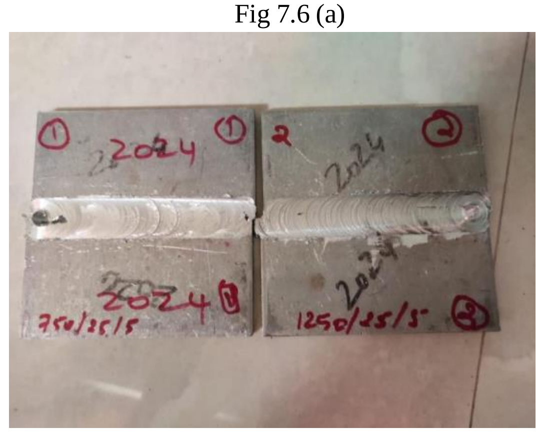

Fig 7.6 (b)

8. CONCLUSION

1. Thus, friction stir welding process has been successfully carried out on dissimilar aluminum alloys of AA2024 and AA6061.
2. The welding and mechanical properties of these dissimilar alloys are examined.
3. The best parameters for the speed, feed and tool profile are chosen among 3 levels. It is found out using Taguchi method.
4. For the best hardness nature of the welded area, the suitable parameters are 1400rpm, 20mm/min and cylindrical threaded tool profile.
5. The percentage contribution of speed is 50%, feed rate is 44.5% and tool profile is 46.8% for the hardness property using ANOVA.
6. For the best tensile nature of the welded area, the suitable parameters are, the suitable parameters are 1000rpm, 20mm/min and square tool profile.
7. The percentage contribution of speed is 76.8%, feed rate is 77.3% and tool profile is 31% for the hardness property using ANOVA.
8. From the experiment carried out, we conclude that speed is the major factor influencing the mechanical properties like tensile strength and hardness.
9. The best parameters are given by experiment and theoretical work. This can applied for friction stir welding of AA5052 and AA6061 in aerospace and marine applications.

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