THINK INDIA (Quarterly Journal)

ISSN:0971-1260
Vol-22-Issue-4-October-December-2019

Evaluation Of Process Parameters Of Friction Stir Welding Using Dissimilar Materials Of Aluminium Alloys 6061 & 6082

Mr.S.Ravindran
Assistant Professor
Department of Mechanical Engineering
Sri Sairam Engineering College
Chennai, India
ravindran.mech@sairam.edu.in

M.Muthukarthikeyan
Department of Mechanical Engineering
Sri Sairam Engineering College
Chennai, India
muthu.karthik97@gmail.com

S.Mothibalaharish
Department of Mechanical Engineering
Sri Sairam Engineering College
Chennai, India
smbharish@gmail.com

M.Manikandarajan
Department of Mechanical Engineering
Sri Sairam Engineering college
Chennai, India
muthumkraja@gmail.com

S.Manikandan
Department of Mechanical Engineering
Sri Sairam Engineering College
Chennai, India
manikts98@gmail.com

***Abstract*— Friction Stir Welding (FSW) is a solid state welding process in which the relative motion between the tool and the work piece produces heat which makes the material of two edges being joined by plastic atomic diffusion. This method relies on the direct conversion of mechanical energy to thermal energy to form the weld without the application of heat from conventional source. The rotational speed of the tools, the axial pressure and welding speed and the (weld time) are the principal variables that are controlled in order to provide the necessary combination of heat and pressure to form the weld. These parameters are adjusted so that the interface is heated into the plastic temperature range (plastic state) where welding can take place. During the last stage of welding process, atomic diffusion occurs while the interfaces are in contact, allowing metallurgical bond to form between the two materials. The functional behavior of the weldments is substantially determined by the nature of the weld strength characterized by the tensile strength, metallurgical behavior, surface roughness, weld hardness and micro hardness. Al alloy is difficult to weld by traditional methods, due to high thermal conductivity, resulting in defects like porosity, cracks etc. Hence FSW is being increasingly used. The process is especially well suited to butt and lap joint in aluminium since aluminium is difficult to weld by arc process, but is very simple to weld by FSW. In this project the process parameters are to be varied in order to determine and evaluate the influence of the process parameter in the quality of the weldments. Friction stir welding machine is used to be carried out the experiment using AA6061 & AA6082 Aluminium Alloy material. The output factors to be measured using destructive methods. Tensile test, Hardness test and Microstructure of Welded Region are considered for investigation by varying tool speed, tool feed and maintaining constant depth of penetration of weld. The correlation between process parameters and quality of the weld to be analyzed in friction stir welding process and compared with other welding process or techniques. (*Abstract*)**

Keywords—Tensile Test, Hardness Test, Microstructure

I. INTRODUCTION

Welding is a fabrication or sculptural process that joins materials, usually metals or thermoplastics, by causing coalescence. This is often done by melting the work pieces and adding a filler material to form a pool of molten material that cools to become a strong joint, with pressure sometimes used in conjunction with heat, or by itself, to produce the weld. This is in contrast with soldering and brazing, which involve melting a lower-melting-point material between the work pieces to form a bond between them, without melting the work pieces. Many different energy sources can be used for welding, including a gas flame, an electric arc, a laser, an electron beam, friction, and ultrasound. While often an industrial process, welding may be performed in many different environments, including open air, under water and in outer space. Welding is a potentially hazardous undertaking and precautions are required to avoid burns, electric shock, vision damage, inhalation of poisonous gases and fumes, and exposure to radiation. Until the end of the 19th century, the only welding process was forge welding, which blacksmiths had used for centuries to join iron and steel by heating and hammering. Arc welding and oxyfuel welding were among the first processes to develop late in the century, and electric resistance welding followed soon after. Welding technology advanced quickly during the early 20th century. several modern welding techniques were developed, including manual methods like shielded metal arc welding, now one of the most popular welding methods, as well as semi-automatic and automatic processes such as gas metal arc welding, submerged arc welding, flux-cored arc welding and electro slag welding. Developments continued with the invention of laser beam welding, electron beam welding, electromagnetic pulse welding and friction stir welding in the latter half of the century. Today, the science continues to advance. Robot welding is commonplace in industrial settings, and researchers continue to develop new welding methods and gain greater understanding of weld quality and properties. Resistance welding was also developed during the final decades of the 19th century, with the first patents going to Elihu Thomson in 1885, who produced further advances over the next 15 years. Thermite welding was invented in 1893, and around that time another process, oxyfuel welding, became well established. Acetylene was discovered in 1836 by Edmund Davy, but its use was not practical in welding until about 1900, when a suitable blowtorch was developed. At first, oxyfuel welding was one of the more popular

ISSN:0971-1260
Vol-22-Issue-4-October-December-2019

welding methods due to its portability and relatively low cost. As the 20th century progressed, however, it fell out of favor for industrial applications. It was largely replaced with arc welding, as metal coverings (known as flux) for the electrode that stabilize the arc and shield the base material from impurities continued to be developed.

N.T. Kumbhar et al has carried out an experiment on Friction Stir Welding of A1 6061 Alloy. Friction stir welding, a solid state joining technique, is widely being used for joining Al alloys for aerospace, marine automotive and many other applications of commercial importance. FSW trials were carried out using a vertical milling machine on Al 6061 alloy. The process of Friction Stir Welding has been widely used in the aerospace, shipbuilding, automobile industries and in many applications of commercial importance. This is because of many of its advantages over the conventional welding techniques some of which include very low distortion, no fumes, porosity or spatter, no consumables, no special surface treatment and no shielding gas requirements. FSW joints have improved mechanical properties and are free from porosity or blowholes compared to conventionally welded materials. At the end of the welding process an exit hole is left behind when the tool is withdrawn which is undesired in most of the applications. This has been overcome by providing an offset in the path for continuous trajectory, or by continuing into a dummy plate for non-continuous paths, or simply by machining off the undesired part with the hole. Large down forces and rigid clamping of the plates to be welded are a necessity for this process, which causes limitation in the applicability of this process to weld jobs with certain geometries.

V. Balasubramanian et al Predicted tensile strength, hardness and corrosion rate of friction stir welded AA6061-T6 aluminum alloy joints. AA6061-T6 aluminium alloy (Al–Mg–Si alloy) has gathered wide acceptance in the fabrication of light weight structures requiring high strength-to-weight ratio and good corrosion resistance. The friction stir welding (FSW) process and tool parameters play major role in deciding the joint characteristics. In this research, the tensile strength and hardness along with the corrosion rate of friction-stir-butt welded joints of AA6061-T6 aluminium alloy were investigated. The relationships between the FSW parameters (rotational speed, welding speed, axial force, shoulder diameter, pin diameter and tool hardness) and the responses (tensile strength, hardness and corrosion rate) were established. The optimal welding conditions to maximize the tensile strength and minimize the corrosion rate were identified and reported here.

L. Karthikeyan et al studied on the Relationship between process parameters and mechanical properties of friction stir processed AA6063-T6 aluminum alloy. In this investigation the surfaces of AA6063-T6 aluminum alloy were friction sir processed and the effects of process variables such as axial force, tool feed and rotational speed were studied. For certain combinations of the process variables, a maximum increase of 46.5% in the ultimate tensile strength, 133% in ductility and 33.4% in micro hardness in relation to the parent material was observed. The micro structural observations revealed a defects constrained structure under an axial force of 10 kN. In addition, a mathematical model was developed to establish the relationship between the different process variables and their mechanical properties. The established model was validated through further experiments. The deviation between the developed model and experiments was within 9% for the process variables yield, tensile strengths and Vickers micro hardness and for ductility, it was around 12%.

S. Rajakumar Influence of friction stir welding process and tool parameters on strength properties of AA7075-T6 aluminium alloy joints. The aircraft aluminium alloys generally present low weldability by traditional fusion welding process. The development of the friction stir welding has provided an alternative improved way of satisfactorily producing aluminium joints, in a faster and reliable manner. In this present work, the influence of process and tool parameters on tensile strength properties of AA7075-T6 joints produced by friction stir welding was analyzed. Square butt joints were fabricated by varying process parameters and tool parameters. Strength properties of the joints were evaluated and correlated with the microstructure, micro hardness of weld nugget. From this investigation it is found that the joint fabricated at a tool rotational speed of 1400 rpm, welding speed of 60 mm/min, axial force of 8 kN, using the tool with 15 mm shoulder diameter, 5 mm pin diameter, 45 HRc tool hardness yielded higher strength properties compared to other joints.

J. Adamowski, C. Gambaro, E. Lertora, M. Ponte, M. Szkodo Analysis Of FSW Welds Made Of Aluminium Alloy AA6082-T6. In many industrial applications steels are readily replaced by non-ferrous alloys, in most cases by aluminium alloys. Some of these materials combine mechanical strength comparable with structural steels and low weight, allowing for a significant reduction of weight. While production of components of aluminium alloys is not very complex, joining of these materials can sometimes cause serious problems. Lack of structural transformations in solid state and excellent thermal and electrical conductivity cause problems in fusion and resistance welding of aluminium alloys. That led to the development of Friction Stir Welding a solid state joining technique in which the joined material is plasticized by heat generated 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 the material of the components to be welded, thus creating a joint. This allows for producing defect-free welds characterized by good mechanical and corrosion properties. This paper summarizes the results of an experimental campaign in which the aluminium alloy AW6082-T6 was FSWelded, using various combinations of process parameters (rotational and travel speed). Mechanical properties of the test welds were assessed by means of static tensile test, bending test. Macro and microstructure of the welds were examined by means of optical observations and Vickers hardness measurement.

Moreira (2008) studied about the Mechanical and metallurgical characterization of friction stir welding joints of AA6061-T6 with AA6082-T6 and investigated about the

ISSN:0971-1260
Vol-22-Issue-4-October-December-2019

aluminum alloy of 6061-T6 with 6082-T6 was carried out. For comparison, similar material joints made from each one of the two alloys were used. The work included microstructure examination, microhardness, tensile and bending tests of all joints. An approximate finite element model of the joint, taking into account the spatial dependence of the tensile strength properties, was made, modelling a bending test of the weldments. This study shows that the friction stir welded dissimilar joint present intermediate mechanical properties when compared with each base material. In tensile tests the dissimilar joint displayed intermediate properties.

II. FRICTION STIR WELDING

Friction-stir welding (FSW) is a solid-state joining process (meaning the metal is not melted during the process) and is used for applications where the original metal characteristics must remain unchanged as far as possible. This process is primarily used on aluminium, and most often on large pieces which cannot be easily heat treated post weld to recover temper characteristics. It was invented and experimentally proven by Wayne Thomas and a team of his colleagues at The Welding Institute UK in December 1991. TWI holds a number of patents on the process, the first being the most descriptive.

A. FLOW OF MATERIALS

Early work on the mode of material flow around the tool used inserts of a different alloy, which had a different contrast to the normal material when viewed through a microscope, in an effort to determine where material was moved as the tool passed. The data was interpreted as representing a form of in-situ extrusion where the tool, backing plate and cold base material from the "extrusion chamber" through which the hot, plasticized material is forced. In this model the rotation of the tool draws little or no material around the front of the pin instead the material parts in front of the pin and passes down either side. After the material has passed the pin the side pressure exerted by the "die" forces the material back together and consolidation of the join occurs as the rear of the tool shoulder passes overhead and the large down force forges the material. More recently, an alternative theory has been advanced that advocates considerable material movement in certain locations. This theory holds that some material does rotate around the pin, for at least one rotation, and it is this material movement that produces the "onion-ring" structure in the stir zone. The researchers used a combination of thin Cu strip inserts and a "frozen pin" technique, where the tool is rapidly stopped in place. They suggested that material motion occurs by two processes:

- Material on the advancing front side of a weld enters into a zone that rotates and advances with the pin. This material was very highly deformed and sloughs off behind the pin to form arc-shaped features when viewed from above (i.e. down the tool axis). It was noted that the copper entered the rotational zone around the pin, where it was broken up into fragments. These fragments were only found in the arc shaped features of material behind the tool.

- The lighter material came from the retreating front side of the pin and was dragged around to the rear of the tool and filled in the gaps between the arcs of advancing side material. This material did not rotate around the pin and the lower level of deformation resulted in a larger grain size.

The primary advantage of this explanation is that it provides a plausible explanation for the production of the onion-ring structure. The marker technique for friction stir welding provides data on the initial and final positions of the marker in the welded material. The flow of material is then reconstructed from these positions. Detailed material flow field during friction stir welding can also be calculated from theoretical considerations based on fundamental scientific principles. Material flow calculations are routinely used in numerous engineering applications. Calculation of material flow fields in friction stir welding can be undertaken both using comprehensive numerical simulations and simple but insightful analytical equations. The comprehensive models for the calculation of material flow fields also provide important information such as geometry of the stir zone and the torque on the tool. The numerical simulations have shown the ability to correctly predict the results from marker experiments and the stir zone geometry observed in friction stir welding experiments.

B. WELDING PARAMETERS

There are two tool speeds to be considered in friction-stir welding; how fast the tool rotates and how quickly it traverses the interface. These two parameters have considerable importance and must be chosen with care to ensure a successful and efficient welding cycle. The relationship between the welding speeds and the heat input during welding is complex but, in general, it can be said that increasing the rotation speed or decreasing the traverse speed will result in a hotter weld. In order to produce a successful weld it is necessary that the material surrounding the tool is hot enough to enable the extensive plastic flow required and minimize the forces acting on the tool. If the material is too cold then voids or other flaws may be present in the stir zone and in extreme cases the tool may break.

Excessively high heat input, on the other hand may be detrimental to the final properties of the weld. Theoretically, this could even result in defects due to the liquation of low-melting-point phases (similar to liquation cracking in fusion welds). These competing demands lead onto the concept of a "processing window": the range of processing parameters viz. tool rotation and traverse speed that will produce a good quality weld. Within this window the resulting weld will have a sufficiently high heat input to ensure adequate material plasticity but not so high that the weld properties are excessively deteriorated.

ISSN:0971-1260
Vol-22-Issue-4-October-December-2019

III. Fabrication

Façade panels and athode sheets are friction stir welded at AMAG and Hammerer Aluminium Industries including friction stir lap welds of copper to aluminium. Bizerbas meat slicers, Ökolüfter HVAC units and Siemens X-ray vacuum vessels are friction stir welded at Riftec. Vacuum valves and vessels are made by FSW at Japanese and Swiss companies. FSW is also used for the encapsulation of nuclear waste at SKB in 50mm thick copper canisters. Pressure vessels from ø1m semispherical forgings of 38.1mm thick aluminium alloy 2219 at Advanced Joining Technologies and Lawrence Livermore Nat Lab. Friction stir processing is applied to ship propellers at Friction Stir Link, Inc. and to hunting knives by Diamond Blade The welding experiments were carried out in FSW machine which is shown in Figure 3.2. The machine specifications are Motor capacity 12kW / 440V AC drive. Spindle speed: 200 to 2000 RPM.Downward Force: 0.5 to 10 kN. Transverse feed is 10 to 150 mm/min

Fig 1. FSW Machine (Coimbatore Institute of Technology, Welding Research Institute, Coimbatore).

IV. METHODOLOGY

The experiments were conducted using Friction Stir Welding (FSW) process. For this study aluminium alloys AA6061 were used as the base materials. Various characterization techniques and the mechanical testing procedures were employed to evaluate the welds in detail. The plan of experiments include Procurement of materials, design and fabrication of tools Welding trials and establishment of process parameter windows Comparison of different welding techniques Tensile, hardness and micro structure testing Optimization of the process parameters. 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. Hot-worked tool steel such as AISI H13 has proven perfectly acceptable for welding aluminium alloys within thickness ranges of 0.5 – 50 mm but more advanced tool materials are necessary for more demanding applications such as highly abrasive metal matrix composites or higher melting point materials such as steel or titanium. Improvements in tool design have been shown to cause substantial improvements in productivity and quality. TWI has developed tools specifically designed to increase the depth of penetration and so increase the plate thickness that can be successfully welded. An example is the "whorl" design that uses a tapered pin with re-entrant features or a variable pitch thread in order to improve the downwards flow of material. Additional designs include the Triflute and Trivex series. The Triflute design has a complex system of three tapering, threaded re-entrant flutes that appear to increase material movement around the tool. The Trivex tools use a simpler, non-cylindrical, pin and have been found to reduce the forces acting on the tool during welding.

V. TEST RESULTS & DISCUSSIONS *A. TIG WELDING*

The TIG torch can be air cooled or water cooled and of vastly different shapes and sizes dependant on access to the area to be welded and welding current required. TIG torch for use on equipment without a electric operated valve (normally scratch start systems) can have a finger operated gas valve fitted to the torch head. If the operator is using a foot control unit, the torch will not need a switch fitted. For welding in difficult to get to areas,a flexible head torch can be used and bent to the best position for welding.

Fig 2. Tensile Test Specimens of TIG Welded specimens

Fig 3. Vicker’s Hardness TIG welded Specimens

In Tig Welding, the Similar materials had a tensile strength of 7825.87 N and the dissimilar materials resulted in a tensile strength of 7699.12 N with hardness values of 57.2 and 45.3 respecetively.

ISSN:0971-1260
Vol-22-Issue-4-October-December-2019

B. GAS WELDING

Fig 4. Tensile Test Specimens of Gas Welded Specimens

Fig 5. Vicker's Hardness Gas Welded specimens

In Gas Welding, the Similar materials had a tensile strength of 12435.76 N and the dissimilar materials resulted in a tensile strength of 7689.34 N with hardness values of 37.30 and 37.50 respecetively.

C. FRICTION STIR WELDING

The solid-state nature of FSW immediately leads to several advantages over fusion welding methods since any problems associated with cooling from the liquid phase are immediately avoided. Issues such as porosity, solute redistribution, solidification cracking and liquation cracking are not an issue during FSW. In general, FSW has been found to produce a low concentration of defects and is very tolerant to variations in parameters and materials.

Nevertheless, FSW is associated with a number of unique defects. Insufficient weld temperatures, due to low rotational speeds or high traverse speeds, for example, mean that the weld material is unable to accommodate the extensive deformation during welding. This may result in long, tunnel-like defects running along the weld which may occur on the surface or subsurface. Low temperatures may also limit the forging action of the tool and so reduce the continuity of the bond between the material from each side of the weld. The light contact between the materials has given rise to the name "kissing-bond". This defect is particularly worrying since it is very difficult to detect using nondestructive methods such as X-ray or ultrasonic testing. If the pin is not long enough or the tool rises out of the plate then the interface at the bottom of the weld may not be disrupted and forged by the tool, resulting in a lack-of-penetration defect.

A number of potential advantages of FSW over conventional fusion-welding processes have been identified

1. Good mechanical properties in the as welded condition

2. Improved safety due to the absence of toxic fumes or the spatter of molten material.

3. Easily automated on simple milling machines lower setup costs and less training.

Fig 6. Tensile Test Specimen of Friction Stir Welded specimens

Fig 7. Vicker's Hardness Friction Stir Welded specimens

In Friction Stir Welding, the Similar materials had a tensile strength of 13673.14 N and 9439.14 N. The dissimilar materials resulted in a tensile strength of 12136.19 N and 13782.69 N with hardness values of 46.50 and 45.30 for similar materials and 43.80 and 45.20 for dissimilar materials respecetively.

ISSN:0971-1260
Vol-22-Issue-4-October-December-2019

D. MICROSTRUCTURE

TIG WELDING

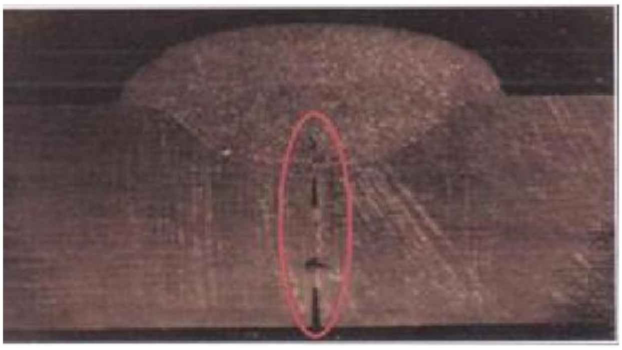

Fig 8.Microstructure of Similar TIG welded specimens

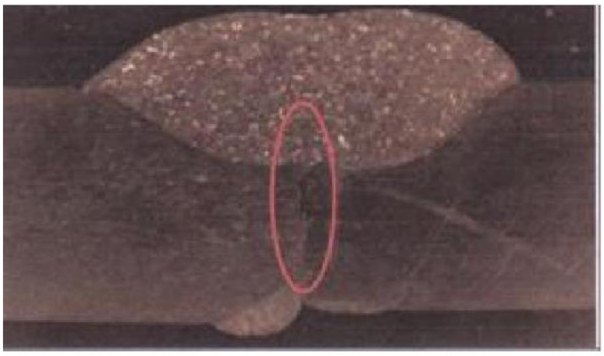

Fig 9. Microstructure of Dissimilar TIG welded specimens

GAS WELDING

Fig 10.Microstructure of Similar Gas welded specimens

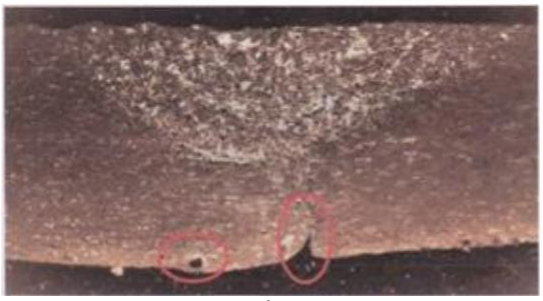

Fig 11. Microstructure of Dissimilar Gas welded specimens

FRICTION STIR WELDING

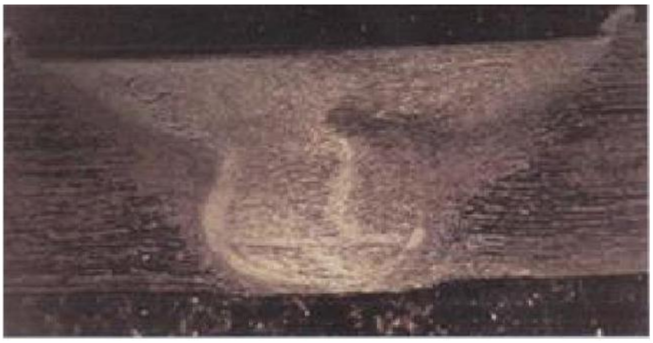

Fig 12.Microstructure of Similar FSW welded specimens

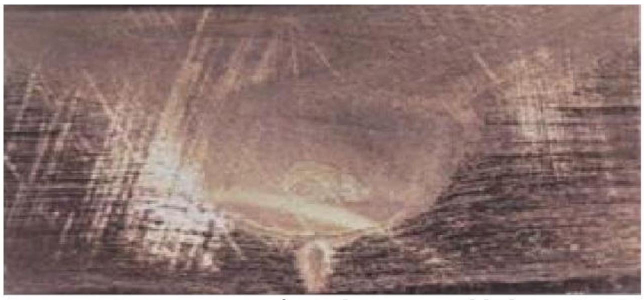

Fig 13.Microstructure of Similar FSW welded specimens

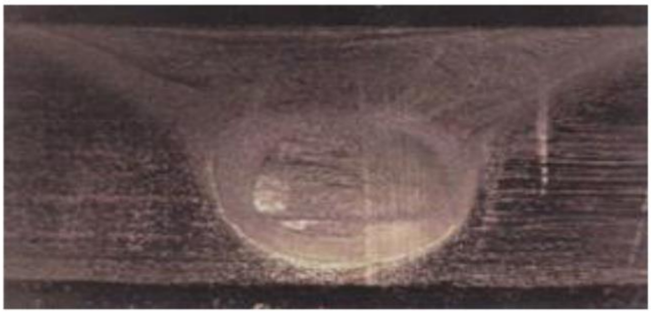

Fig 14. Microstructure of Dissimilar FSW welded specimens

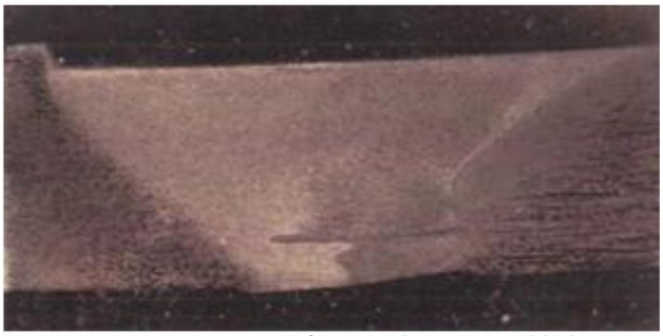

Fig 15. Microstructure of Dissimilar FSW welded specimens

ISSN:0971-1260
Vol-22-Issue-4-October-December-2019

CONCLUSION

Aluminium alloy is difficult to weld by traditional methods, due to high thermal conductivity, resulting in defects like porosity, cracks etc. The process is especially well suited to butt and lap joint in aluminium since aluminium is difficult to weld by arc process, but is very simple to weld by using friction stir welding (FSW). In this project the process parameters of the micro structure analysis, tensile and hardness test states that the friction stir welding (FSW) shows to be efficient and better than the other methods of welding considered in this project. FSW ensures excellent weld ability in aluminium alloy of six series compared to other welding techniques such as TIG and Gas welding. The various process parameters of welding techniques are studied and it clearly indicates that FSW is the best welding technique suited for aluminium alloys.

REFERENCES

[1] J. Adamowski, C. Gambaro, E. Lertora, M. Ponte, M. Szkodo, “Analysis of FSW welds made of aluminium alloy AW6082-T6,” Archives of Materials Science and Engineering Volume 28, Issue 8 August 2007 Pages 453-460.

[2] L. Karthikeyan, V.S. Senthil Kumar, “Relationship between process parameters and mechanical properties of friction stir processed AA6063-T6 aluminum alloy,” Materials and Design 32 (2011) 3085–3091.

[3] N. T. Kumbhar and K. Bhanumurthy, “Friction Stir Welding of Al 6061 Alloy,” Asian J. Exp. Sci., Vol. 22, No. 2, 2008; 63-74.

[4] S. Rajakumar, C. Muralidharan, V. Balasubramanian,

“Predicting tensile strength, hardness and corrosion rate of friction stir welded AA6061-T6 aluminium alloy joints,” Materials and Design 32 (2011) 2878–2890.

[5] S. Rajakumar, “Influence of friction stir welding process and tool parameters on strength properties of AA7075-T6 aluminium alloy joints,” Materials and Design 32 (2011) 535–549.

