A REVIEW ON EXPERIMENTAL ANALYSIS OF MECHANICAL PROPERTIES OF ALUMINIUM ALLOY (AA 2014) FRICTION STIR WELDED T-JOINT

[1]Surendrakumar. B. Agashe, [2]Manish. T. Shete

[1]M-tech Student, [2]Assistant Professor
[1,2]Department of Mechanical Engineering
[1,2]Government college of Engineering, Amravati, Maharashtra, India

Abstract: Friction stir welding plays an important role in the manufacturing and transport industries due to relevant advantages. In this research friction stir welding with the combination of two or three plates (skin and stringer) having thickness 6 mm aluminium alloy AA2014-T6 which makes T-joint will be studied by changing the process parameters such as rotation of tool and welding speed. The three types of joint configuration (T-lap joint, T-butt joint and T-butt lap) is to be welded by using three different tool geometry (cylindrical, conical and pyramidal in shape). The further improved parameters of friction stir welding were determined based on the macro and micro-observations of the T-joint. After performing welding operation, the metallographic examinations and tensile testing were performed to evaluate the welding qualities and mechanical properties of the Friction Stir Welded T-joints.

***Keywords* - Friction Stir Welding, T-Joints configuration, Pin Geometry, Tensile Test, Microstructure Analysis**

1. INTRODUCTION

The friction stir welding is one of the most optimistic joining technology invented by the welding institute situated in the United Kingdom primarily for the aluminium and its alloys [1]. In Friction Stir Welding method a tool pin material needs to be harder than the workpiece material to a continuous causing relative cyclic movement between the tool pin and the workpiece. The tool pin and workpiece together generates heat due to friction as the probe enters the workpiece so as to create a plasticized region in the workpiece material around the probe then the rotating probe is moved along the line of weld, stopping the relative cyclic movement just before the end to restrict the flow of molten metal outside the weld zone, and provide the time to the molten material to solidify [2]. The new joining technology friction stir welding (FSW) process is relatively carried out in the solid phase. Friction stir welding is a continuous welding process having a non-consumable rotating probe of a harder material than the material to be weld. The FSW produces low distortion, solid-phase, and good appearance welds relatively at very low cost [3].

Friction welding is mostly used in various industries such as sub-sea and aerospace. Some variants of friction stir welding which imparts technical opportunities for the shipbuilding and aerospace industries. The techniques are investigated are Continuous Drive, Inertia, Linear, Taper Stitch, Friction Pillar Processing, Friction Transformation Hardening, Third-body Friction Joining, and Friction Surfacing. Friction stir welding is now a prominent process for the manufacturers of aero engine parts. The further progress in friction stir welding work will include a number of useful process variants and deal with the various material combinations of aluminium alloys and other materials which are difficult to weld by traditional processes [4]. The advantage of friction stir welding include the capability to weld the materials which are difficult by the any other fusion welding, for example, welding of AA2000 and AA7000 aluminium alloys. This welding tool can easily be used for up to 1000m of weld length in AA6000 series aluminium alloys. Some other benefits of friction stir welding as No filler wire or rod, No shielding of gas, No certification for welding required, Some lack of imperfect weld preparations can be accepted, No grinding operation, brushing or pickling operation is required in large quantity production [5].

2. TOOL PIN CONFIGURATION:

Welds on AA 2014 aluminium alloy plates will be performed in three different types of Tool configuration

a) Cylindrical Pin tool (Threaded)
b) Conical Pin tool (Threaded)
c) Pyramidal Pin tool

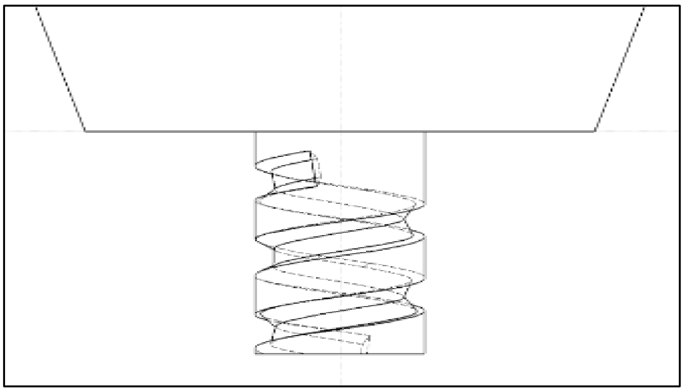

Fig. a) Cylindrical Pin tool (Threaded)

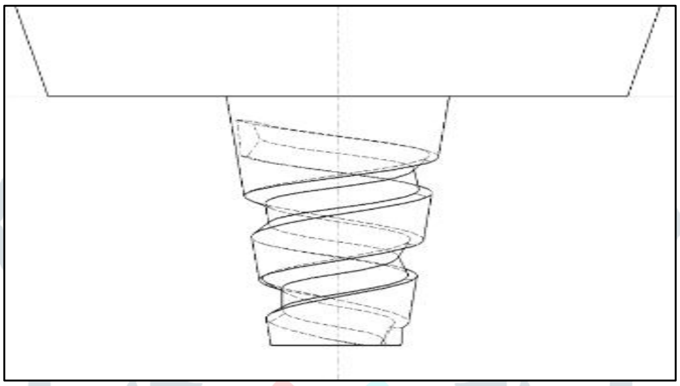

Fig. b) Conical Pin tool (Threaded)

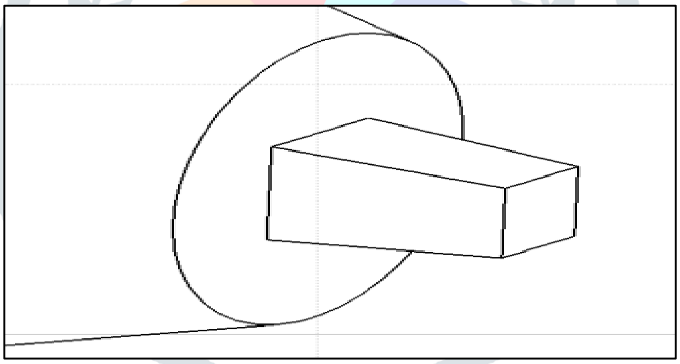

Fig. c) Pyramidal Pin tool.

Heideman et al. invention reveal a friction stir weld tool suitable for heating due to friction and welding together in solid phase to joint at least two plate. The cylindrical pin profile which is projected from the bottom surface of the shoulder of the tool and the axis of the pin is co-extensive with the axis of the cylinder. The other shapes such as frusto-conical, inverted frusto-conical, Spherical and pear shapes pin geometry can also be used for welding. The friction Stir weld tool geometry having at least one spiral groove and at least one counter-spiral groove in the pin Surface [6]. Trapp et al. study focuses on the three features of the selection tool, first is an integral transition geometry Structure between the shoulder face and the probe that has the advantage of Substantially reducing rotary bending fatigue and Subsequent breakage of the tool, second feature of the invention is the selection of a tool material on the basis of mechanical properties Such as the ultimate tensile Strength at the processing temperature of the workpiece material, third feature of the their invention is the introduction of compressive Stress in areas of fatigue cracking at the base and the threaded area of the probe. By using one of these three features the friction Stir weld tool can be made that is capable of welding high Strength materials including aluminum and aluminum-based alloys, copper and copper based alloys, iron and iron-based alloys, titanium and titanium-based alloys, nickel and nickel-based alloys and the combinations of any two alloying materials [7].W M Thomas et al. developed the different tool shapes the Flared-Triflute probe, Skew-stir and Reversal stir. Tri-flute type probes can be designed with any combination of neutral, left or right-handed flute, or ridge groves. In the implied line Stir variant, the axis of the tool is given a slight inclination to that of the machine spindle. Reversal Stir Welding, this illustration applies to both angular and reciprocating [8]. Zhao et al. In this research hook feature which is prone to forming when helical threaded tool pins are used to deteriorate overlap shear load fracture by reducing the welded zone in the upper sheet. This deterioration problem can be controlled by replacing the helical threads with concentric grooves in the tool pin [9]. J.S. Jesus et al. studied three different tools were used respectively a: pyramidal pin, tapered threaded pin and progressive pin. The tool with a tapered and threaded pin was constructed in order to improve the vertical material flow relative to the pyramidal one, while the tool with a progressive pin was designed to help the molten material flow in the fillet zones [10]. Mohammed M. Hasan et al. This paper presents a design study of the welding tool by analyzing the effect of using pin flute radius during the FSW of dissimilar AA7075-T651 and AA2024-T351 aluminum alloys. Five pin tools with different flute radii are 0, 2, 3, 6, and 8 mm were inspected at the speed of 900 rpm and the welding speed of 150-mm/min. The study show that the flute radius actually affects the molten material flow pattern and the quality of weld [11].

3. PROCESS PARAMETERS

a. Spindle Speed

Spindle speed is one of the important parameter considering during Friction stir welding process. Optimum spindle speed is needed to achieve for obtaining sound welded joints [12]. Experiments shows the higher spindle speed leads to an increase in frictional heat generation within the weld zone and lower spindle speed results in poor heat input condition and lack of stirring. At higher tool rotational speed micro level voids are visible in the weld. The distribution of temperature is also effect by the rotational speed of the tool.

b. Welding Speed

Welding speed is also an important parameter that affects the mechanical properties of friction stir welded region of the part. In the welded zone the fatigue property of the weld is increased up to the welding speed of 16 mm/min and then decreases by increases in welding speed. [13-14]. The fine grain size was obtained by the optimum welding speed up to 16-18 mm/min and the grain size increases on increasing the welding speed [15].

c. Axial Force

The axial force plays important role to optimize the above parameters which is necessary to obtain sound weld joint. The wear rate of material to be weld decreases as the axial force of the tool increases and vice versa. Experimentally calculated optimum axial force of the tool exceeds the flow stress of the material which is required to make the defect-free joint. The plunge depth of the pin also depends on the axial force [16].

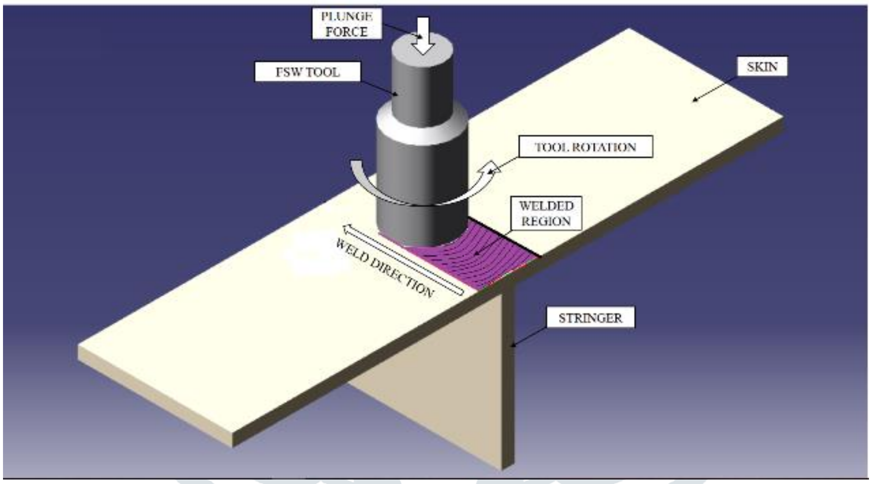

Figure 3.1 Process Parameters

M. Jariyaboon et al. investigates the impact of welding parameters such as rotation speed, welding speed and dwell time on the corrosion behavior of friction stir welded high strength aluminium alloy AA2024–T351. The study shows that the rotation speed plays a major role to control corrosion attack. The localized intergranular attack was observed in the nugget region for low rotation speed, whereas for higher rotation speed the impact of the tool occurred predominantly in the heat-affected zone of the welded part [17]. Lisheng Zuo et al. studied the how the process parameters of welding effects on AA7075 aluminum alloy friction stir weld at different rotational and welding speeds. The surface texture was examine by using the pixel imaging method. The experiment show that the surface arc texture spacing is smaller at the higher rotational speed and larger at the increase of welding speed [18]. X.H. Zeng et al. his analysis shows that the effect of process parameters of the welding on material flow and the formation of defect during friction stir welding investigated on 6 mm thick 2014-T6 aluminium alloy plates. It was found that the 'S' line in the stir zone rotated with the pin and stayed on the retreating side and advancing side at low and high heat inputs, respectively [19]. Zhenhua Ge et al. this study, the effective sheet thickness gradually increases with the increase of welding speed by 4 or 5 mm pins because of the role domination of shoulder effect. The effective lap width first decreases and then increases with the increase of pin length at a welding speed of 60, 90, or 120 mm/min, while it decreases with the increase of the pin length at a welding speed of 30 mm/min. [20].

4. JOINT GEOMETRIES

Welds on AA 2014 aluminium alloy plates will be performed in three configurations of T-joints

a) T-Butt Joint
b) T-Lap Joint
c) T-Butt lap Joint

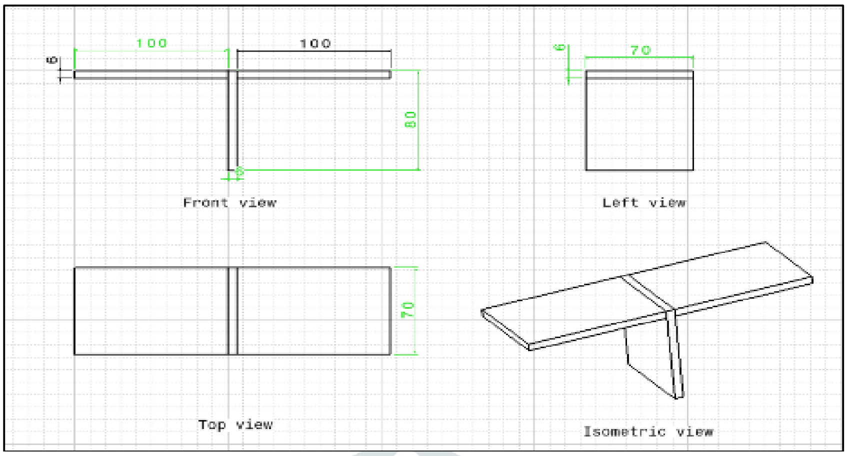

Figure. 4.1 T -Butt Joint

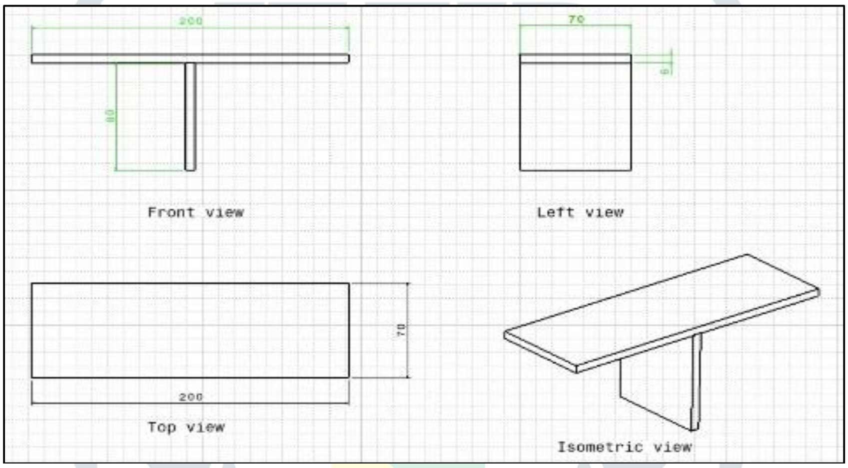

Figure 4.2 T-Lap Joint

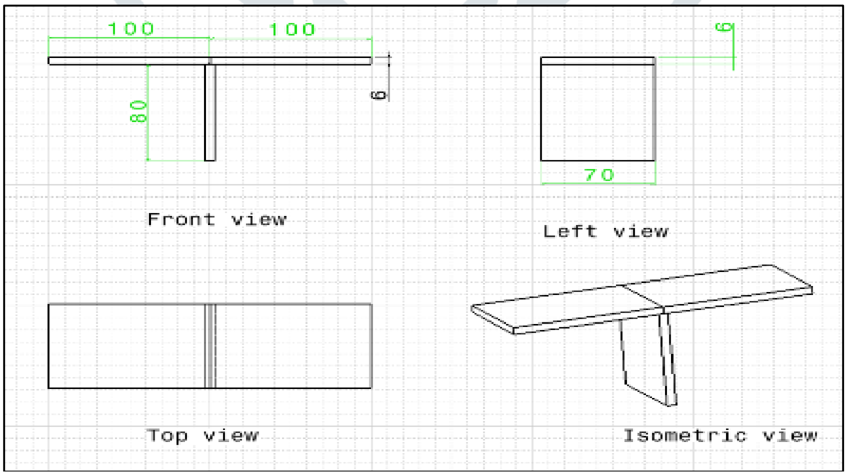

Figure 4.3 T-Butt lap Joint

R.S. Mishra et al. his study found that the most convenient joint configurations for Friction Stir Welding are butt and lap joints of two plates with the same thickness are placed on a backing plate and clamped rigidly to prevent the two plates from being forced apart. In a simple lap joint, two plates or sheets which is lapped are clamped on a backing plate. A rotating tool with the pin is plunged vertically starts from the upper plate and penetrates into the lower plate just before the bottom surface of the plate and the rotating tool moves along the line in the direction which is to be weld and join the two lap or but weld plates [21]. L. Fratini et al. investigated the two different configurations, by superposing the upper sheet, i.e. skin, with rolling direction respectively parallel and perpendicular to welding direction. A H13 steel tool has been used with a 4 mm diameter and a 4 mm height of the pin, the shoulder diameter of 15 mm which is nearly four times the pin diameter. The tool axis is tilted by the angle of 3° and with a plunge of 4.2 mm, other main process parameters are rotational speed set equal to 1040 rpm and feed rate set equal to 150 mm/min according to the study [22].

4. EXPERIMENTAL ANALYSIS:

There are number of testing and testing procedures to find out the changes in mechanical properties of friction stir welded joints such as Tensile test, Bending Test, Impact Test, Hardness test and the physical property like Microstructure analysis of weld zone by using suitable tools and equipment.

M.W. Mahoney et al. he studied the performance on the friction stir welds to determine mechanical and physical properties of the welded part in the longitudinal direction i.e. within the weld nugget formed zone and transverse to the line of weld. During performance of the welding, temperatures in the weld zone remained below the melting point and so that no cast or resolidification structure was developed. The longitudinally oriented specimens test the weld nugget of the welded part only. Compared to the base metal, results of the welded sample parts show a reduction in yield and ultimate strengths in the welded region, while elongation of weld was similar to the base metal [23]. Hakan Aydın et al. investigated the tensile properties of the joints have a tendency to increase with the precipitation hardening of the base material. The tensile test of all parts were carried out perpendicular to the welding direction to determine the tensile properties of the welded joints. Tensile properties of each joint were examined by using four tensile specimens which is prepared from the same joint [24]. M. Peel et al. In this paper, he reports the results of microstructural, mechanical property and residual stress investigations of four aluminium AA5083 friction stir welds produced under varying conditions. In this study he found that the mechanical properties of weld influenced by the thermal input. The study provides the information about the microstructural and mechanical property measured on the 3 mm thick plate of AA5083 aluminium alloy. The four samples to be weld by using three traverse speeds and two different tool geometries [25]. L. Fratini et al. investigated mechanical properties and physical properties of the welded joints by means of Vickers micro hardness measurements, T-pull tests and the bending tests. Indentations have been equally spaced, in both parallel and perpendicular direction to the skin, with a distance of 500 μm each other. By using relevant device T-pull static tests have been calculated. The skin between two thick steel plates allows to pull away from the stringer, plate coming out from a slot in one of two steel plates [26].

R.A.S. Castro et al. The main goal of his work is to characterize the residual stress field in T-joints which is made of two AA6056 aluminium alloy sheets in the flanges and AA7075 aluminium alloy sheet in the web. The residual stress field obtained at the transition zone between the heat affected and thermo-mechanically affected zones modeled by a logarithmic curve. According to the study maximum tensile stress obtained in the order of 100 MPa while the compressive stress reached the value of -40 MPa [27]. J.-Q. Su et al. evaluate the changes in metallographic structure of Friction stir welded aluminum alloy AA7050-T651. The microstructural formation in each region was an important function of the local thermo-mechanical cycle formed during friction stir welding. [28]. G. Zhou et al. performed the friction stir welding of T-joints on 3 mm thick AA6061-T4 aluminium alloy sheet and relates the influences of welding parameters on the microstructures of the weld zone, defect formation, hardness and tensile strength of the welded region were determined specifically. It is found that the macrostructures and microstructures are similar in the weld of different process parameters. The microstructure features in the skin and the butt-joint weld have the same patterns [29]. Richard Fonda et al. Analysis of an AA2195 aluminium alloy friction stir weld reveals microstructural features changes in the weld zone and the variations of machine force during welding indicate that these textures of weld zone may arise from the oscillation of an off-centered tool axis. This type of tool rotation produces a periodic extrusion of material around the tool pin and below the surface of the shoulder, giving rise to the machine force variations, observed flow features, and change of the local shear texture orientations of the welded parts [30]. Mostaan Lotfalian Saremi et al. studied the influence of welding parameters on metallurgical structure and mechanical properties of the friction stir welded joints. For this application, tensile strength, micro-hardness, macro-structure and microstructures of the joints were evaluated. The optimum results were evaluated at the 1130 rpm rotation speed and 12 mm/min travel speed, with the UTS of 156 MPa. [31]. Husain Mehdi et al. this paper examines an over view of the modelling method of reverse dual rotation friction stir welding by interpreting governing mathematical equations and finite element formulation of heat transfer and material flow for different material like Mild steel and Aluminum alloy [32]. Yanying Hu et al. In this study aluminum alloy 6005-T6 sheets of 300-mm length 9 100-mm width 9 3-mm thickness were used to perform FSLW experiments. The material flow mechanism under the effect of pulsatile revolutions is described by a heuristic model, giving an insight into the coupling flow field between the shoulder-driven zone and pin-driven zone [33]. C.Bitondo et al. works on the effect of the Friction Stir Welding (FSW) process parameters on the physical and mechanical properties of AA2198-T3 aluminium alloy weld part is to be investigated. The influence of the heat transfer transient phase on the mechanical properties of the weld examine by Analysis of variance method (ANOVA), the desirability function technique and main effect plots were used to determine the required process parameters and set the relevant value for each parameter for the friction stir weld. A regression equation was derived from the analysis to predict each output characteristic of the weld [34].

Mohammad Hasan Shojaeefard et al. research the Al–Mg and CuZn34 alloys were lap joined by using friction stir welding process during which the aluminum magnesium alloy sheet was placed on the CuZn34 plate and the welding parameters were examined by using Taguchi L9 orthogonal array design of experiments. The parameters such as revolution of tool, tool axis tilt angle and welding speed of the tool were taken as a important parameters of friction stir welding. The best welding parameters were determined with the help of tensile shear strength test of the specimen of friction stir welded joint. ANOVA results showed that tool rotational speed is the most affective factor for producing the sound weld [35]. Faiz F. Mustafa et al. investigated the effect of friction stir welding (FSW) T-joints for 3mm AA6061-T6 aluminum alloy plates on mechanical by using the nine different tool shapes that were designed according to Taguchi orthogonal array without changing the welding parameters such as tool rotation speed, welding speed, tool tilt angle, plunge depth, and pin diameter. Four different geometrical shape such as shoulder diameter, pin diameter, pin angle, and the groove pin shape with three levels for each parameter have been used. The test were performed at the optimum condition of welding parameters to compare the theoretical and experimental results of the friction stir welding. In addition, the analysis of variance (ANOVA) technique was apply by using the statistical to calculate the factors which affect the welding [36].

CONCLUSION

Friction stir welding technique is already being applied in many aluminium alloys for lap or butt welding of two parallel plates. The researchers a still working on the various types of joint which can be weld by the friction stir welding technic. The studies on the friction stir welding of aluminium alloys with T-joint configuration is new in the research. The 2xxx series of aluminium alloy will be used for making T-joint weld which has relevant applications in manufacturing industries of aerospace and transportation. From the literature survey on friction stir welding process we set the objective to work on the friction stir welding of AA2014 aluminium alloy for T-joint configuration. Three tool geometries (cylindrical, conical and pyramidal) will be used for FSW of T-joint. To design and analyse the tool geometry behavior with the help of (catia & ansys) software. To evaluate the change in mechanical and physical properties of the friction stir welded joints by changing the process parameters such as spindle speed, welding speed and different tool geometry.

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