A REVIEW ON THE EFFECT OF PIN GEOMETRY AND PROCESS PARAMETERS ON THE CHARACTERISTICS OF FRICTION STIR WELDED AA2024 ALUMINUM ALLOY L-JOINT.

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Abstract : Friction stir welding is a technique which is used for joining aluminum and its alloy which are difficult to weld by traditional welding processes. In this paper we are going to produce friction stir welding of aluminum alloy 2024 in L –joint configuration as less amount of work has been carried out in this area. L-joint with three different tool geometries in two different joint configurations as L-Lap and L-Butt will be produced. The effect of process parameters and the pin geometries like tool rotation, traverse speed, tool tilt angle, shoulder diameter, pin length and pin diameter on the weld quality will be study. Also the temperature at the different locations of weld is being measured with k –type thermocouple. The changes in mechanical properties of the weld will be studied with metallographic testing.

***IndexTerms* - Friction Stir welding, T-joint, lap joint, butt joint, L-joint, mechanical properties, process parameters.**

I. INTRODUCTION

Friction stir welding is a solid state welding techniques which involves joining of metals without filler material. In 1991, Thomas et al, developed the friction stir welding technique at the welding institute of United Kingdom. It was developed for welding of aluminum alloys which were difficult to weld by traditional welding technique [1] [2]. In friction stir welding, the weld is formed by the combined action of the frictional heat between tool and work piece and mechanical deformation due to rotating tool [3]. The plates which going to be joined are butted together on the fixture and the tool with the tilt angle is inserted into the work piece. As the tool is inserted into the upward sheet of the blank, the material from the blank try to came out due to extrusion force. The shoulder of the tool supports the metal which is coming out of the welding zone. Then the rotating tool travel along the abutting plates, the softened material of the two plates mixes together to form the required joint. The weld produced due to the FSW process has higher strength due to the low welding temperature produced at the weld zone [4] [5]. In FSW the concave and convex arc alteration shapes are produced on the surface represents the height will produced the texture on surface which will have changes in roughness of surface. As the welding occur in solid state, the defects are also produced in the welds such as kissing bond and voids due to the effect of intimate contact of materials and in appropriate welding parameters [6]. Many of the research has shown that the weld produced has more advantages than the traditional joining techniques as low distortion and low operation cost. This technique has application in the field of aerospace, railway, land transportation, ship building and marine industry etc. [7] [8].

The research has been going on the butt and lap joints from two decades. Nowadays, the work has been going on the T- joint of the plates and in joining of dissimilar plates of two different alloys or two different material with friction stir welding. Aluminum alloy having series 6XXX has been used in industry purpose and most of the research has been done on it in above field. But the series with 2XXX and 7XXX was less used in research area [9].

II. PROCESS PARAMETERS

The process parameters given below plays important role in producing a sound welding joint. It also affects the heat generation rate, temperature distribution, mechanical properties of the welded joint.

2.1 TOOL ROTATION SPEED AND TOOL TRAVERSE SPEED

These are the two tool speeds to be considered in FSW process that is how fast the tool rotates and how quickly it travels the line of joining of two plates. The relation between the welding speed and heat input is complex such that the increase in the rotational speed or decrease in traverse speed will result in the hotter weld. In order to produce a sound weld the necessary condition is that the tool is hot enough to enable the plastic flow of material and reduces the forces acting on it. Also the very high heat input determines the properties of weld which is going to be produced.

2.2 PLUNGE DEPTH

The plunge depth is the depth at which the pin of the too is inserted inside the surface of welded plate. It is also the critical parameter in determining the weld quality. The plunge depth of the tool is need to be correctly set, if it is greater than the welded plate thickness it will result in pin rubs on the backing plate or if it is lesser than the thickness of the welded plate the weld defects were produced.

Lisheng zuo et al, studied the friction stir welding of AA 7075 material at different welding speeds and rotational speeds. They also studies the effect of process parameters on surface topography. They produced the texture surfaces from the weld and compare the arc structure on to the weld with different rotational speeds. They found that with increasing the rotational speed the arc texture formation on weld will reduces in size. Also the effect of the welding speed on weld quality shows that increase in welding speed will result in less burrs and large spacing in arc texture [10]. X. H. Zeng et al studies the effect of process parameters on material flow in friction stir welding of 6 mm thick plate on which the oxide layers are formed under the pin from the retreating side to the advancing side of the welding direction [11].

Zhenhua Ge et al, studied the effect of the pin length and welding speed on lap joints in FSW process. He tried to develop the relation between the pin length, welding speed and tensile shear strength. He found that the pin with lesser diameter has good effect on the weld. With increasing welding speed, the weld produced with less pin diameter is sound weld and the tensile strength and the micro hardness produced has better results [12]. Chaianya sharma et al, while performing the experiments on FSW welds found that increase in rotary speed and decrease in welding speed reduces zigzag line formation. Grain size of aluminum present in weld nugget decreases on increasing welding speed. Also the ultimate tensile strength, percentage elongation, energy absorbed and joint efficiency decreases with increasing welding speed. The minimum hardness zone shifts from heat affected zone to weld nugget zone on increasing welding speed and decreasing on the tool rotational speed [13].

III. TOOL GEOMETRY

The effects of tool geometry experienced by the tool and weld produced are the heat generation rate, traverse force, torque and the thermo-mechanical environment experienced. The flow of plasticized material in the workpiece is affected by the tool geometry as well as the linear and rotational motion of the tool. Important factors are shoulder diameter, pin geometry including its shape and size.

3.1 TOOL PIN

The shape of the tool pin has effects on the weld produced in FSW. By going through the literature review it has been found that the length of the tool pin should be equal to the thickness of the welded plate. In the research we are going to use three different tool pin configurations (Cylindrical tool pin, pyramidal tool pin and conical tool pin) to produce L-joint.

V. Balasubramanian et al, studies the effect of axial force and tool pin profiles on FSW zone formation in AA6061 aluminium alloy. He used the five different tool pin profiles (straight cylindrical, tapered cylindrical, threaded cylindrical, triangular and square) to fabricate the joint. The formation of FSW zone has been analyzed macroscopically. Tensile specimen has been failed at retreating side or advancing side of the weld. While comparing results, he found that the square tool pin profile produces sound weld than other tool shapes [14] [15]. Xiaopeng et al, formed the T-joint of AA6061 –T4 plates with three different tool geometries by FSW. Hardness profiles of sample welds are obtained and the formation mechanism of defects in FSW T-joint has been discussed with macro and micro observations [16] [17].

J.S. Jesus et al, studied the T-butt and T-Lap joint configuration using three different tool pin profiles. It has been found that the pyramidal tool pin produces tunnel defects, kissing bond, oxides line in joint and weld with tapered pin shows kissing bond defects. He also concluded that the T-butt joint shows better performance than the T- lap joints [18]. J. A. M. Ferreira et al, studied the effect of three different tool geometries on quality of AA5083-H111 T welds. The fatigue results obtained by FSW T-joints shows higher strength than conventional T joints made by MIG. Sujoy Tikedar et al, developed a mathematical model to conduct experiments to study the mechanical properties of FSW on AA1100 with three different tool geometries. Tensile strength and micro hardness for different process parameters been recorded for different welded sample [19].

Faiz F. Mustafa et al, designed the nine different tool shaped based on Taguchi orthogonal array without changing the process parameters, to study the effect on the mechanical properties of FSW T-joints for 3 mm thick AA 6061. They used the S/N ratio technique for analyzing results obtained from experiments using statistical software (Minitab @ 16) [20]. H Zhao et al, fabricated the lap joint to study the effect of pin geometries on the hook structure and weld strength and failure mode. A hook like structure is formed when helical threaded pins are used. This hook feature can be removed by pin with concentric grooves [21].

3.2 SHOULDER DIAMETER:-

The diameter of the shoulder is important parameter as most of the heat generated in the weld zone is due to the contact of shoulder with the upper surface of the plates to be joined. Literature regarding the shoulder diameters shown that the ratio between the shoulder diameter and the pin diameter is approximately three. Experimental results shown in literature that the tool with optimal shoulder diameter has higher strength of the welded joints.

Krishna Kishore Mugada et al, studies the effect of increasing shoulder diameter on temperature by using k-type thermocouple at four different locations on the weld. Also they developed the analytical model to predict the maximum temperature during welding. On the basis of that they measured strain, strain rate, z-parameter for all shoulder diameter at four different locations [22]. K. Elangovan et al, studied that the larger diameter shoulder has large contact area so it produces more heat due to which the thermo mechanically affected zone and heat affected zone are larger in size which in turn the tensile properties are deteriorated. If the diameter of shoulder is less than the weld does not produced sound due to low frictional heat produced. He concluded that the 18 mm shoulder diameter tool pin produces sound and defect free joint [23].

IV. EXPERIMENTAL ANALYSIS

The changes in microstructure and mechanical properties can be studied with the different test available. The available test are tensile test, bending test, hardness test, fracture analysis can be performed on friction stir welded L-joint. The following literature shows the studies corresponds to above test.

G. Zhou et al, found that the macrostructure and microstructure are similar in FSW weld specimen when process parameters are different. Two lower hardness zones are found in skin and one lower zone is found in stringer. Tensile strength has been examined along skin and stringer plane directions showing results in range of 170-180 MPa. Tunnel defects are found in the stringer direction which reduces the ultimate tensile strength in return it causes the joint to fracture at the bonding interface [24]. Huijie Liu et al, produces a friction stir welded joint using AA 2219 T-6 Aluminum alloy. The results given by them shows that the recrystallized grains of weld nugget zone in the joint has larger size at the middle and the smaller size at the lower part. Voids are formed in the region where welding speed is quite high. The tensile strength of the joint firstly increases to maximum at initial condition and as the welding speed increases the tensile strength rapidly decreases [25].

S Rajakumar et al, tried to develop an empirical relationship between welding parameters and the tensile strength of the joint. Statistical tools are used with 95% confidence level to develop the above relationship. A sensitivity analysis has been carried out to measure the errors produced during the measurement of tensile strength on estimated parameters [26]. A. Heidarzatch et al, studied the tensile properties of friction stir welded AA6061-T4 aluminum alloy joint by developing a mathematical model with help of response surface methodology. Microstructures of joints were examined using optical and scanning electron microscope. He concluded that the optimal parameter needed to get maximum tensile strength were 920 rev/min, 78mm/min, 7.2 KN [27]. Yong Zhao et al, studies the T-joint made using the AA 6013 T4 Aluminum alloy. It shows the result as joint with maximum tensile strength can be obtained without defect when traverse speed is 100mm/min. it also states that the tensile properties of the skin are affected by kissing bond defect and the tunnel defect affects the properties of stringer [28**].**

V. CONCLUSION

Friction stir welding is been applied so far on lap, butt and T-joint with different series of materials.
The study on L-joint using friction stir welding is new research in this area. Researcher are working to produce new joints using friction stir welding. The series 2xxx of aluminum alloy has relevant application in aerospace industries and can be applied to form L-joint. From the above given literatures we can set our objective to work on aluminum alloy 2024 to make L-joint on friction stir welding. The tools and joint configurations are to be designed in Catia software. To analyse the joint geometry Ansys software is used. The joint can be produced with change of welding parameters (tool rotation speed, tool traverse speed, axial force) and with different tool geometries (Cylindrical, conical and pyramidal).

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