Influence of Tool Geometry and Effects of Plunge Depth in Friction Stir Welding Of AA2014

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Abstract ***Friction stir welding (FSW) is a noteworthy technique this is used to fabricate the joints which are difficult to join by fusion welding methods and it gives fabulous results compare to Conventional Welding. In FSW process parameters such as Tool Rotation speed, Traverse speed, Axial Force, Plunge Depth and Tilt angle and tool geometry plays a vital role to obtain the defect free welds, towards this achievement the tool shape, especially the shoulder and pin structure design plays a crucial role. In this paper, equations are made using the MATLAB to find out the geometry of the shoulder and pin changes based on the thickness of the welding plate. This makes it possible to produce specific tool dimensions, by using these equations, a tool was developed. Similarly, the experiments were conducted by varying the plunge depth and correlated the results of microstructure, mechanical properties and fracture features.***

Key words:*Tool Design; Plunge Depth; Defects; MATLAB, properties.*

I. Introduction

Present century, the field of manufacturing concentrated towards the safety, life, quality and cost of the product for better achievements a numerous techniques i.e. friction stir welding was invented by the welding Institute (TWI) in 1991 [6].Friction stirring is a surname of the Friction stir welding and processing (FSW&P).Presently, this technique gives worthy consequences compare to other existing techniques in welding, where the tool

Plays a key role in the process of joining [1]. The tool comprises pin and shoulder. The pin generates the frictional and deformational heating makes the material soften, and the shoulder generates the heat in between the work-piece and contact area of shoulder, expands the region of softened material,and constraints thedeformed material[2].The tool life is dependent on the selection of tool material and its geometry were the pin and shoulder material is same otherwise the tool does not have the significant effect in FSW&P [3]. Plasticized material gets translated in the weld route, and is moved from the leading edge of tool to the trailing edge, where it is forged into the joint and thus creates a through solid phase bonding between the plates [4]. Joint strength is dependent on the geometry of tool such as shoulder length, shoulder diameter, pin height, pin diameter [5]. In the past decades many researches dedicated on the effect of tool pin profiles and plunge depth on the mechanical and microstructures of Friction stir welding joints of several aluminium alloys.

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Very little amount work was carried out on AA2014-T651.The coreidea of this study is to focus on the influence of tool design and various plunge depth with constant welding speed and tool rotational speed on AA2014-T651 weldments.The representation diagram of the FSW as presented in the Fig.1.

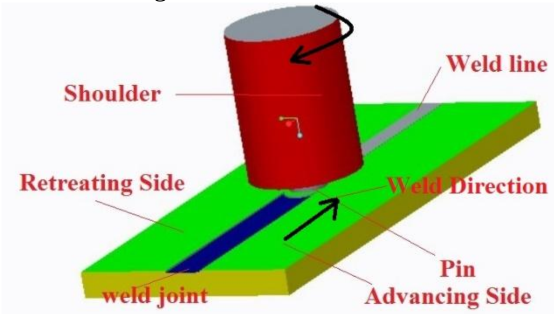

Fig.1 schematic diagram of FSW

II. EXPERIMENTAL PROCEDURE

The experimental work has been carried out on AA2014-T651of 5.5 mm thick sheet and the experimentation was comprises in to two parts like design and fabrication. The tool design was done by using MATLAB and Fabrication was done by using the Computer Numerical Control FSW (CNCFSW).H13 tool steel was chosen as a tool material due their strength, less wear resistance and thermal fatigue behaviour. The piloted experiments were using taper threaded cylindrical tool pin profile on CNCFSW of AA2014 by varying the plunge depth were tool rotation speed and welding speed are constant like 900rpm and 60mm/min. The fabricated joints were shown in Figure 3. The tool dimensions were calculated by using the MATLAB software, the coding details are presented in results phase.

A. *Metallographic testing:*

The sample specimens for microstructure investigation were prepared to the requisitesizes from Friction Stir Joints towards perpendicular to welddirection, and then polished the specimens with different grades of emery papers, finally etched by using Keller’s reagent. Samples microstructures of the weld region is examined with optical microscope.

B. *Mechanical Testing:*

Specimens for tensile test were sliced based on ASTM E8M in the perpendicular direction of the weld joints. Tensile test is carried out by using the computerized universal Testing Machine. Impact test specimens were sliced perpendicular direction of the weld line with ASTM A370 standards. The hardness samples also prepared in a same manner. The microhardness was measured at the weldzone by the help of vicker’s hardness tester with a 100grams load and dwell time of 10 seconds.

C. Tool Fabrication:

Tool fabrication was done as per the literature i.e. Arbegast et al. and the equation to get the tool geometry based on the workpiece thickness by using MATLAB, were we used MATLAB to simplify the calculations of tool geometry.

III. RESULTS AND DISCUSSION

The tool geometry was calculated by the MATLAB program, were simple equations are generated to calculate the dimensions as per the literature and material properties of the weld joints were evaluated by Tensile strength, Impact strength, Hardness and optical microscope testing devices.

A. Tool Design using MATLAB:

Many papers have been reported various tool designs which can influence the welding quality and addressed that care must be taken in determining geometrical variables such as the shoulder diameter, pin diameter, pin length and pin contour. The tool consists of a typical non-threaded tapered pin shape and flat diameter. These geometrical variables affect the welding force and torque values and pin supplies the thermal energy to the work. The ratios of shoulder and pin diameter. It is observed that increase in tool shoulder will also increases welding force and torque.

As the tool shoulder increases, the required welding force and torque increased, and also pin diameter and pin length effect the welding force and torque values, Were pin supplies the thermal energy to the work and shoulder diameter , pin diameter ratio effects the thermal conductivity of material [7]. The lower ratios of shoulder and pin diameter creates the lower thermal conductivity and it helps to join the low temperature materials. Hence the ratio of shoulder and pin diameters are chosen minimum. Previously many researchers are suggested the tool geometry based on the workpiece thickness.

It is noticed that any increase in work piece thickness if the work piece thickness increases, reduces the thermal input from shoulder des, based on these concept equations were developed and solved by MATLAB. The program as shown in the below.

Plate Thickness (PT) = 1:12 ---------- (1)

(The range was fixed based on the available literature)

Pin Length =Mean (0.90*PT: 0.01:0.95*PT); --- (2)

(Arbegast and Patnaiketal. 2005 suggest 90-95% of PT thickness)

Shoulder Diameter (SD) = 1:20;--------- (3)

(The range was fixed based on the available literature)

Shoulder Height (SH) = Mean (SD*(2:0.5:3)); - (4)

Pin Diameter (PD) =Mean (SD/(2.8:1:3)); ----- (5)

(Where PL=Pin Length mm;

D=Pin diameter at bigger end; d=Pin diameter at small end;

SD=Shoulder diameter;

SL=Shoulder length; SH= Shoulder height)

X=((D-d)/2*L); (X=Pin Taper) ---------- (6)

Theta=tand(X); ---------- (7)

From the above equations we found the tool geometry.

The tool fabrication was done by the help of CNC (computer Numerical control) turning center. The schematic diagram of the FSW tool as shown in the fig.2.

Fig.2 Schematic diagram of Tool Design

B. Plunge Depth:

It was observed that only limited work has been carried out to study the effect of plunge depth/ axial force, which affects the axial force required for plunging, in the current work, an attempt made to understand the effect of plunge depth in the mechanical properties of friction stir welded AA2014-T651. This section we conducted experiments by varying the plunge depths like <90-95%, <90-85%, >95% and observed visual defects by visual inspection method and experimental results were shown inFig.3.

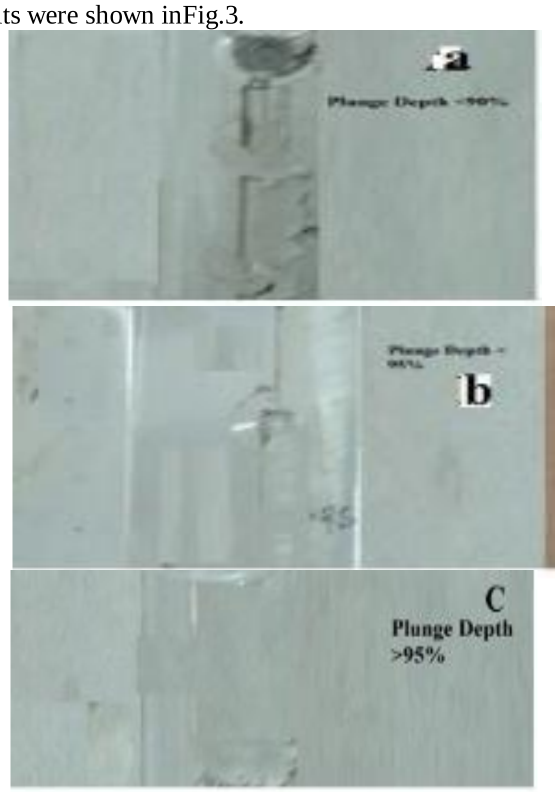

Fig.3Surface morphology of the FSWed Joints Plunge depth <90% (b) Plunge depth <95% (c) Plunge depth >95%

Fig.3 (a).Shows the large cannel defect besides the weld line, were the joints fabricated at <90% of plunge depth, it causes insufficient flow of material and heat. Similarly, at condition 2 i.e. plunge depth <95% shows the little cannel defect compare to condition 1. Finally, at condition-3 i.e. plunge depth >95% produce better joints compare to other conditions due to sufficient heat and material flow generated in between the tool and butting edges and it represented in Fig.(c).

C. Microstructure:

Microstructure analysis of fabrication specimens were done by the help of optimal microscope. Keller’s regents were applied for getting the clear morphology.

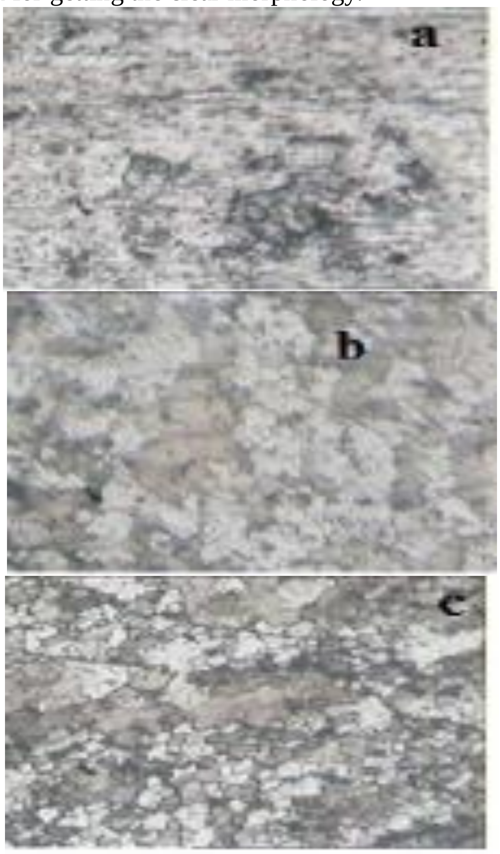

Fig.4 Morphology structures (PL-Plunge depth; OM-Optical Microscope)Condition-1, (b) Condition - 2 (c) Condition- 3.

The fine grains were obtained at condition-3, here the joints are fabricated by the plunge depth more than are equal to 95%. The sufficient heat and stirring may causes to slice the material and produce fine grains at weld zone.

D. Mechanical Properties:

Mechanical properties of the fabricated weld joints by taper threaded tool pin profile of the FSW joints are shown in Table-I. Mechanical properties were changed by the heat, heat input could increase the material flow and also the pin applies an additional downward force which will be beneficial to accelerate the plasticized material flow. The highest values of tensile strength, hardness and impact strength were obtained at condition three i.e. plunge depth were taken 95% of plate thickness it helps to obtain the required heat and plasticization of material.

Table I: effect of plunge depth on mechanical properties

Plunge depth	Tensile Strength (Mpa)	Impact Strength (J)	Hardness (HV)
Taper threaded tool pin			
Plunge Depth <90%	144	4	75
Plunge Depth <95%	131	6	98
Plunge Depth >95%	373	9	119
Base metal	463	13	150

IV. CONCLUSIONS

The effect of various plunge depths on microstructureandmechanical properties of CNCFSW of aluminum alloy was explored. The major inferences drawn are as below.

The mechanical properties of the aluminum alloy weldments were affected by the plunge depths.

Among the three different plunge depths, the plunge depth >95% condition exhibits better results due better thermal conductivity.

Defects free welds were obtained for the plunge depth >95% condition exhibits better results due better stirring and axial force.

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DATA AVAILABILITY

The raw data required to reproduce these findings cannot be shared at this time as the data also forms part of an ongoing study.

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