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# Investigation on effect of Tool Size & Welding Parameters on FSW Butt Joint – A Review

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**Abstract**: *This review paper discuss about the effect of tool geometry (Tool Pin Profile & Tool Shoulder Diameter) and different friction stir welding parameters like Tool rotational speed, Tool travel speed, Tool force on butt weld joint of different sizes and grades of material. The tool profile plays critical role in determining the end properties of welding joint apart from other parameters like rotational speed, welding speed and axial force. [1] [2] The paper focuses on FSW parameters in different conditions and their effect on mechanical properties and microstructure of weld joint. [2]The careful selection of FSW process parameters can avoid the void formation, micro cracks and other defects.[15]*

***Keywords:*** *FSW, Tool Pin Profile, Tool Shoulder Diameter, Rotational Speed, Travel Speed, Al-Alloy (AZ91D), Tensile Strength*

## 1. INTRODUCTION

Friction stir welding (FSW) was invented by Wayne Thomas at TWI (The Welding Institute) and first patent application were filed in the UK in December 1991.[3] Friction Stir Welding (FSW) is Solid State welding process for joining Aluminum alloy and has been employed in aerospace, rail, automotive and marine industries for joining Aluminum, Magnesium, Zinc and Copper Alloys. [4]

The effectiveness of the obtained joint strongly dependent on several operating parameters .First the geometric characteristic of tool, such as the height and shape of the pin and the shoulder surface finish and diameter. Second, Axial force superimposed on the rotating tool during process, because the pressure generated on the tool shoulder surface and under the pin end determines the heat generated during process. Finally, both tool rotational speed and the welding speed determines the local heat flux during welding process. [5][6]

FSW is relatively new welding process does not release toxic acids or fumes, environment friendly , No filler material or edge preparation is normally necessary. It may have significant advantages compared to the fusion process as follows: Joining of conventionally non-fusion weldable alloys, reduces distortion and improved mechanical properties of weldable alloys joints due to pure solid-state joining of metals. [1][7][16]

FSW Utilizes a rotating tool design to induce plastic flow in the base metal and to essentially “Stir” them together. During the FSW, the tool pin attached with shoulder is inserted between the abutting edges of plates to be joined. As the tool traversed along the joint line, the rotation of shoulder under influence of an applied fixed load heats the metal surrounding the joint and with the rotating action of the pin induces the metal from each work piece to flow together and form weld. The schematic figure representing the principle of Friction Stir Welding is shown in the figure 1. [4][8][17]

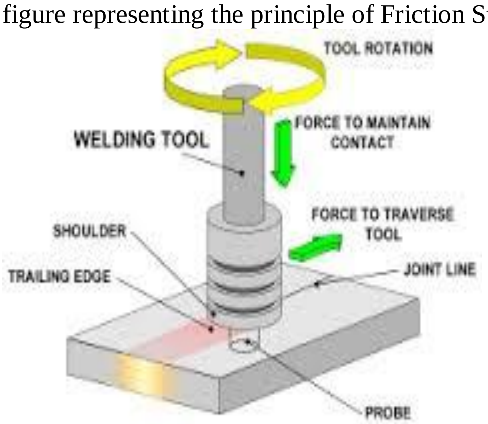


Figure 1: Friction Stir Welding Principle [1]

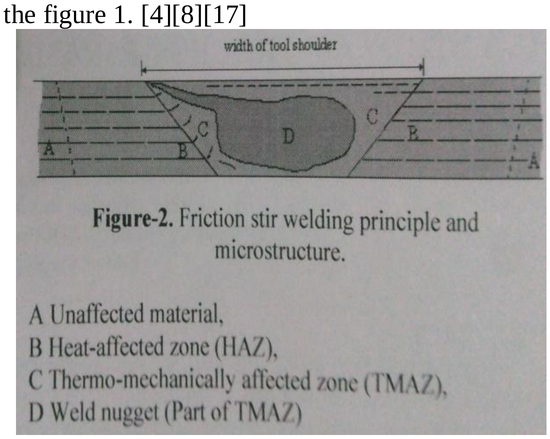


Figure 2: Different Region of FSW Joint [1]

In FSW joints usually there are four regions, namely (i) Unaffected base metal (ii) Heat Affected Zone (ii) Thermo-Mechanically Affected Zone and (iv) Friction Stir Processed (FSP) Zone, shown in the figure 2. The Formation of above regions is affected by the material flow behavior under the action of rotating non consumable tool. At the same time, the material flow behavior is predominantly influenced by the FSW tool-pin profiles, FSW tool-dimensions and FSW process parameters. [18][19][20]

## 2. LITERATURE REVIEW

(1) An experiment was carried out on AA-6061 Al-Alloy “O” & “T6” condition. The size of the AA-6061 Alloy plate taken was 150 mm x 75 mm x 6.6 mm thick duly hardened. Tool of tool material H11 of shoulder diameter 10 mm, Frustum shaped probe with threads varying, pin diameter 5 mm to 3 mm used. The experiment was carried out at two different tool rotation speed (800 & 1000 RPM) and welding speed of (10 & 15 mm/min). After experiment on observation it was seen that tool rotational speed 800 RPM and 10 mm/min & 15 mm/min are optimum parameters for “O” condition AA-6061 Alloy plates. 100 rpm and 10 mm/min are optimum parameters for “T6” condition Al-Alloy plates.[1]

(2) In this experiment five different grades of Al-Alloys rolled pates, AA-1050, AA-6061, AA-2024, AA-7039 & AA-7075 has been used as base material of size 300 mm x 150 mm x 6 mm thick to make square butt joint with threaded cylinder pin profile, non consumable tool of high carbon steel material. Different joints were made using different tool rotational speed and welding speed combinations by indigenously developed machine of 15 HP, 3000 rpm, capacity. Rotational speed from 700 rpm to 1700 rpm used in set of five at step of 100 rpm for all different material with combination of 22, 45, 75, 100, 135 mm/min welding speed and axial force of 5 KN and optimum parameters for AA-1050 – 900 rpm & 135 mm/min for AA-6061 – 1100 rpm & 100 mm/min , for AA-2024 – 1200 rpm & 75 mm/min , for AA-7039 – 1300 rpm & 45 mm/min, for AA-7075 – 1500 rpm & 22 mm/min observed. [4]

(3) In this research work two plates of AA 6061 T6 of dimensions 6 mm x 100 mm x 100 mm were Butt welded by En-24 hexagonal pin of concave shoulder, has diameter of 20 mm and pin length was 5-7 mm and welded at 1070 rpm tool rotational speed and 78, 120 mm/min two different welding speeds. After completion of experiment research work tensile test result shows that weld carried out at 1070 rpm tool rotational speed of 78 and 120 mm/min welding posse’s tensile strength of 108 & 123 Mpa. The Fractrographs of specimen at 1070 rpm & 78 mm/min welding speed having wide and long micro cracks. While, Fractrographs of failed tensile specimen of 1070 rpm & 120 mm/min welding speed having equiaxed dimple structure with fine micro cracks and voids. [8]

(4) The effect of welding parameters studied on structure and properties of weld zone of Al-Alloy 7010 during FSW process. It was observed during study that there is optimum tool rotating speed for given travel speed that gives highest strength and ductility. For given tool travel speed, lower rotating speed results in less tensile strength and ductility. As tool rotating speed increase both strength and ductility increase before attains maximum value and decreasing again at higher rotational speed. This highest strength and ductility again attains when there is increase in rotational speed with increase in tool travel speed. At low heat input (low rotational speed & high travel speed) give poor strength & ductility. At high heat input (high tool rotational speed & high travel speed) leads to improvement in both strength and ductility. With further increase of heat input, melting takes place and both strength ductility starts to reduce parallel.[9]

(5) Al-Alloy Sheets of thickness 4,5,6,7 & 8 mm were used in this experiment having alloying elements in this alloy 4.2 wt% Mg & 0.42 wt% Si. A non-consumable tool made up of high carbon steel material to make Butt Joint with five different welding tool with Flat Cylindrical Shoulder Diameter 18, 21, 24, 27, & 30 mm chosen. On conventional milling machine tool rotational speed of 400, 700, 1000, 1300 & 1600 rpm is used with welding speed of 0.5, 1.0, 1.5, 2.0 & 2.5 mm/sec. Response Surface Method is used to reduce the experimental work. During experiment it was observed that for plate thickness of 6 mm best welding speed is 1000 rpm with combination of 1.5 mm/sec welding speed and 25 mm shoulder diameter to have maximum yield strength with best welding quality. [10]

(6) In this experiment Al Alloy AZ91D plates of size 6 mm x 150 mm x 100 mm were use to make Butt joint by different sets of parameters of tool pin profile, rotational speed and welding speed. The Taguchi Orthogonal L9 array was used to optimize the process. The Universal Milling machine with vertical milling attachment, with clamping attachment used to carry out FSW process. After completion of experimental work and tensile test, it was observed that TSCP tool with rotational speed of 710 rpm and 28 mm/min welding speed having maximum tensile strength of 76.1667 Mpa. With this combination of parameters, plates were joined properly but during microscopic view inside crack observed. With other combinations of parameters no satisfactory tensile strength achieved and welding also not done properly, plates were also not joined at abutting surfaces and cracks observed wherever welding was done.[11]

(7) In this study a sheet of Magnesium AZ31B alloy with 120 mm length, 60 mm width and 6 mm thickness was used. ANOVA was used to investigate the significance of process parameters on performance characteristics. During investigation it was observed that the parameter pin length plays a major role on the performance characteristic and predecessor is rotational speed. The optimal parameters are 1200 rpm rotational speed, 4.5 mm pin length and 2 inch/min welding speed

 

. Also, the ANOVA results emphasis that parameter pin length contribution was 45.09% and has more influence on quality performance of weld. [12]

(8) Weldability of Friction Stir Welding of AZ91D Magnesium Alloy thixomolded sheet with 2 mm thickness was evaluated by different tool rotational speed and welding speed. Tool rotational speed of 1240-1750 rpm and welding 50 mm/min was found optimum parameters to make good quality square butt joint. Tool size were 12 mm shoulder diameter, 3 mm pin diameter and 2 mm pin length. Higher travel speed or lower rotating speed leads to improper bonding in the weld joint. The Tensile strength of Stir Zone showed 330-360Mpa, a much higher than that of base metal of 250 Mpa. Hardness of Stir Zone increased slightly with decreasing mean grain size. [13]

(9) The Investigation was carried out on 4 mm thick x 70 mm width x 140 mm long Mg-Alloy AZ91D plates at tool rotational speed between 115-377 rad/s and travel speed between 32-187 mm/min. It is observed that Square butt joint with good quality was obtained under 187 mm/min of travel speed and tool rotational speed range of 115-131 rad/s. It is seen by optical and scanning electron microscope that original base metal dendrite grain structure became eliminated and replaced by very fine and equiaxed grain in the stir zone. Temperature of weld zone could be roughly estimated to the range of 370 C to 550 C by microstructure observation of Mg-Al Phase. [14]

(10) An Experiment was performed on 6 mm thick Al-Si-Mg Alloy with constant tool rotational speed and varying welding speed with die steel tool (Pin Length-5.7 mm, Pin Dia.-4.7 mm at Bottom, Shoulder Dia.-15.6 mm) to fabricate FSW Square butt joint. Tensile test were carried out using 25 KN Electromechanically controlled universal testing machine, and it is observed that an increase in welding speed, first increase ultimate tensile strength, yield strength and micro hardness of joint which than decrease with further increase of same after achieving maximum value. An optimum combination of welding and rotary speed (120 mm/min & 635 rpm) was obtained to produce sound and defect free FSW joint with maximum mechanical properties. Formation of void and zigzag line defect observed at 190 mm/min welding speed. [15]

## 3. CONCLUSION

Tool selection plays major role on weld quality and then rotational speed, welding speed and other parameters.

It has been observed that during FSW, original base metal grain structure became completely eliminated and replaced by very fine equiaxed grain in stir zone.

Mechanical Properties like tensile strength and hardness are improves due to refinement of the grain structure in the stir zone.

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