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Tool Influence on Friction Stir Welding-A Review

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Abstract—*Friction stir welding (FSW) is a giant step in ever constant endeavor of welding technology. FSW was proved to be an efficient method for Aluminum and its alloys, which are difficult to weld with the conventional techniques. The unique properties of friction stir welds make possible some completely new structural designs with significant impact to ship design and construction. Improvements in construction cost, durability and welding distortion have been demonstrated in Europe and Japan. In the present work an attempt has been made to review the studies on the influence of tool parameters on weld quality. A significant effect of the welding tool, its pin profile, shape and dimensions is observed and reported.*

Keywords: *Friction Stir Welding, Aluminum and its alloys, Welding Tool, Tool Parameters.*

Introduction

Friction stir welding (FSW) is a fairly recent welding technique, invented by The Welding Institute (TWI), Cambridge, UK. This technique utilizes a nonconsumable rotating welding tool to generate frictional heat and deformation at the welding location, thereby affecting the formation of a joint, while the material is in the solid state. The principal advantages of FSW, being a solid-state process, are low distortion, absence of melt-related defects and high joint strength, even in those alloys that are considered nonweldable by conventional techniques.

A non consumable rotating tool is employed of various designs, which is manufactured from materials with superior high temperature properties to those of the materials to be joined. Mainly the probe of the tool is applied to the faces of the work pieces and rotated, there by generating frictional heat, which creates a softened plasticized region around the immersion probe and at the interface between the shoulder of the tool and work piece. The shoulder provides additional frictional treatment to the work piece, as well as preventing plasticized material from being expelled from the weld. The strength of the metal at the interface between the rotating toll and the work piece falls to the low the applied the sheared stress as the temperature raises, so, that plasticized material is extruded from the leading side to the trailing side of the tool. The tool is then steadily moved along the joint line giving a continuous weld.

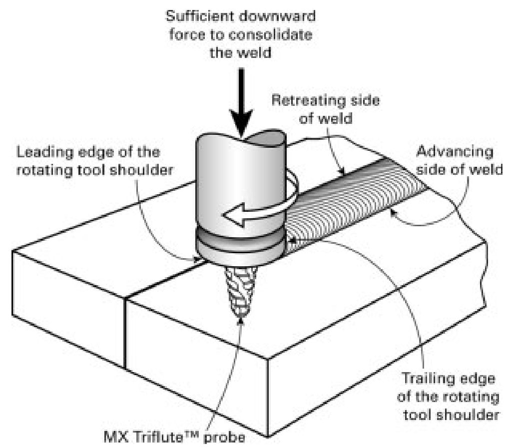

Fig. 1: Principles of friction stir welding

1.The importance of the friction stir welding tool

1.1 The function of Tool

The welding tool, its pin profile, shape and dimensions plays a vital role in making the weld joint. In Friction Stir Welding, the stress distribution of tool pin is affected by the thermo mechanical characteristics of the work piece. The friction stirring tool consists of a pin, or probe, and a shoulder.

Contact of the pin with the workpiece creates frictional and deformational heating and softens the workpiece material; contacting the shoulder to the workpiece increases the workpiece heating, expands the zone of softened material, and constrains the deformed material. Naturally, there are important effects to the tool during welding: abrasive wear, high temperature and dynamic effects. Therefore, the good tool materials have the following properties:

- Good wear resistance,
- High temperature strength, temper resistance,
- Good toughness.

So as we can see there are two important fields of friction stir welding tool design: tool material and geometry.

1.2. Tool material

Friction stirring is a thermomechanical deformation process where the tool temperature approaches the solidus temperature of base metal. Production of a quality friction stir weld requires the proper tool material selection for the desired application. Thus, it is undesirable to have a tool that loses dimensional stability, the designed features, or worse, fractures.

The following characteristics have to be considered for material choice:

- Ambient and elevated temperature strength,
- Elevated temperature stability,
- Wear resistance,
- Tool reactivity,
- Fracture toughness,
- Coeficient of thermal expansion,
- Machinability.

There are several tool materials to use depending on the base material.

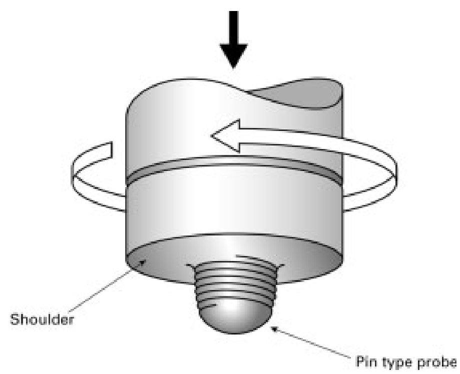

Fig. 2: Cylindrical threaded pin type probe

1.3 Tool geometry

Each of the friction tool parts (pin and shoulder) has a different function. Therefore, the

best tool design may consist of the shoulder and pin constructed with different materials.

The workpiece and tool materials, joint configuration (butt or lap, plate or extrusion), tool

parameters (tool rotation and travel speeds), and the user's own experiences and preferences are factors to consider when selecting the shoulder and pin designs.

Very important factor of the tool design that the material flow has adequate direction

and quantity during welding. Generally, the greater volume of material to stir better weld

quality is obtained, but it has strong correlation with other technological parameters (rotational speed, welding speed). Horizontal material flow certainly occur during welding, but if some oxide occurs on the base material surface, the vertical material flow will be very

significant and this is especially true at lap joint welding. If vertical flow doesn't occur

during welding, the surface oxide will remains in the joint line and remains the creation of

the joint. Figure 3.a shows the horizontal material flow, figure 3. b shows the vertical material flow around the tool:

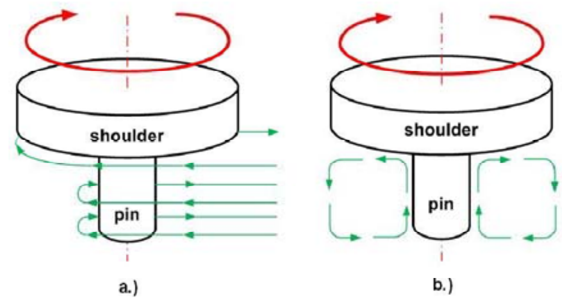

Fig. 3. a.) Horizontal material flow, b.) vertical material flow

2. Design of tool shoulders

Tool shoulders are designed to produce heat to the surface and subsurface regions of the

workpiece. The tool shoulder produces a majority of the deformational and frictional heating in thin sheet, while the pin produces a majority of the heating in thick workpieces. So one of the most important parameter of the shoulder is the diameter because it has significant effect to the amount of frictional heat.

3. Basic variants for the Flared – Triflute probes

K.Elangovan, et.al worked on the influences of tool pin profile and tool shoulder diameter on the formation of friction stir processing zone in WA6061 Aluminum alloy states that compared to the fusion welding processes that are routinely used for joining structural aluminum alloys, Friction Stir welding process is emerging solid state joining process in which the material being welded does not melt and recasp. The welding parameters such as, tool rotational speed, welding speed, axil force ect., and tool pin profile play a major role in deciding weld quality. Five different tool pin profiles with three different shoulder diameters have been used to Fabricated joints.

Jeong-Luh Lin, et.al Worked on "Stress analysis of FSW Tools Under Torsional and Bending loads". In this study One of the tool is made from the same one-piece material with a probe of round pin attached to a scrolled shoulder, while the other is a two-pieces tool with a pin inserted into a separate ring which acts like a shoulder and form similar pin on shoulder configuration like the first one. A comprehensive way of judging the strength of these tools have been established by comparing the stresses in these two tools when they all subjected to the same loading conditions.

H.S. Patil, et.al worked on "Experimental study on The Effect of Welding speed

and tool pin profiles on AA602-o aluminium Friction Stir welded butt joints". The aim of this research study is to investigate the effects of different tool pin profiles on the weld quality of AA6082-o aluminum . Triflutes and taper screw threaded pin are used as

tool pin profiles in this research. The appeared results explain the variation of stress as a function of strain and the effect of different pin profiles on yield strength, ultimate, tensile strength and elongation.

OlivierLorrain, et.al worked on "Understanding the material flow path of friction stir welding process using unthreaded tools". According to them most of studies in literature used threaded pins since most industrial applications currently use

threaded pins. However, initially threaded tools may become unthreaded because of the tool wear when used for high melting point alloys or reinforced aluminum alloys. In this study, FSW experiments were performed using two different pin profiles. Both pins are unthreaded but have or do not have flat faces. The primary goal is to analyze the flow when

unthreaded pins are used to weld thin plates. Cross-sections and longitudinal sections of welds were observed with and without the use of material marker (MM) to investigate the material flow. Material flow with unthreaded pin was found to have the same features as material flow using classical threaded pins: material is deposited in the advancing side (AS)

in the upper part of the weld and in the retreating side (RS) in the lower part of the weld; a rotating layer appears around the tool. However, the analysis revealed a too low vertical motion towards the bottom of the weld, attributed to the lack of threads. The product of the plunge force and the rotational speed was found to affect the size of the shoulder dominated zone. This effect is reduced using the cylindrical frustum pin with flats.

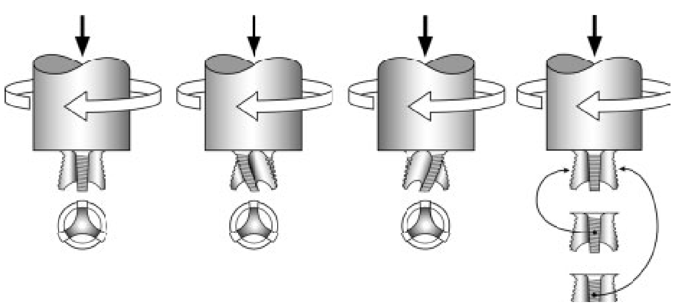

Fig. 4: Basic variants for the Flared – Triflute probes

Conclusions

Numerous factors must be considered for designing the tool of friction stir welding. The technological parameters have significant effect on the tool and its life, it is important to createconformity among them. There is a growing demand on weld materials with high melting temperature, high strength and hardening, and the key is the tool design and the tool itself.

The significant improvements can achieve with Triflute shaped probes that will give acceptable weld quality.

Finally it can be concluded that, among all profiles in the tool with cylindrical profile with threads is prefarale because the maximum stress distribution and displacement is very less.

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