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A Review paper on Friction stir Welding process parameters

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Abstract: Friction Stir Welding (FSW) was invented by Wayne Thomas at TWI (The Welding Institute), and the first patent applications were filed in the UK in December 1991. Initially, the process was regarded as a "laboratory" curiosity, but it soon became clear that FSW offers numerous benefits in the fabrication of aluminum products. Friction Stir Welding (FSW) has become a major joining process in the aerospace, railway and ship building industries especially in the fabrication of aluminum alloys. The process uses a spinning non-consumable tool to generate frictional heat in the work piece. Worldwide, there are now over 135 licensees of FSW and new techniques and applications are being developed daily. This paper looks at the review, on friction stir welding process, various welding variables like tool rotation, transverse speed, tool tilt, plunge depth and tool design, for the welding of aluminum alloys or various dissimilar alloys. Applications, future aspects and several key problems are also described.

I. INTRODUCTION

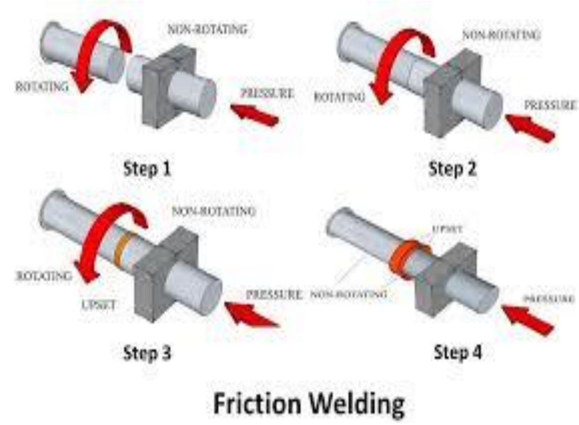
Friction stir welding (FSW) is an innovative welding process commonly known as a solid state welding process. This opens up whole new areas in welding technology. It is particularly appropriate for the welding of high strength alloys which are extensively used in the aircraft industry. Mechanical fastening has long been favored to join aerospace structures because high strength aluminum alloys are difficult to join by conventional fusion welding techniques (Pouget G. et al., 2007). Its main characteristic is to join material without reaching the fusion temperature. It enables to weld almost all types of aluminium alloys, even the one classified as non-weldable by fusion welding due to hot cracking and poor solidification microstructure in the fusion zone (Zimmer Sandra et al., 2009). FSW is considered to be the most significant development in metal joining in a decade and is a green‘‘technology due to its energy efficiency, environment friendliness, and versatility. The key benefits of FSW are summarized in Table 1(Mishra R.S. et al., 2005).

Table 1
Key benefits of FSW are summarized below.

Metallurgical benefits	Environmental benefits	Energy benefits
1. Solid phase process 2. Low distortion of work piece 3. Good dimensional stability and repeatability 4. No loss of alloying elements 5. Fine microstructure 6. Absence of cracking	1.No shielding gas required 2.No surface cleaning required 3. Eliminate grinding wastes 4.Consumable materials saving, such as rugs, wire or any other gases	1. Improved materials use (e.g., joining different thickness) allows reduction in weight 2.Decreased fuel consumption in light weight aircraft automotive and ship applications

II. FSW PROCESS

The working principle of Friction Stir Welding process is shown in Fig. A welding tool comprised of a shank, shoulder, and pin is fixed in a milling machine chuck and is rotated about its longitudinal axis. The work piece, with square mating edges, is fixed to a rigid backing plate, and a clamp or anvil prevents the work piece from spreading or lifting during welding. The half-plate where the direction of rotation is the same as that of welding is called the advancing side, with the other side designated as being the retreating side (Nandan R. et al., 2008). The rotating welding tool is slowly plunged into the work piece until the shoulder of the welding tool forcibly contacts the upper surface of the material. By keeping the tool rotating and moving it along the seam to be joined, the softened material is literally stirred together forming a weld without melting (Rowe C.E.D. et al., 2005).The welding tool is then retracted, generally while the spindle continues to turn. After the tool is retracted, the pin of the welding tool leaves a hole in the work piece at the end of the weld. These welds require low energy input and are without the use of filler materials and distortion.



III. WELDING VARIABLES

FSW involves complex material movement and plastic deformation. Welding parameters, Tool geometry and joint design exert significant effect on the material flow pattern and temperature distribution, thereby influencing the micro structural evolution of material (Mishra R.S. et al., 2005). Therefore, welding speed, the tool rotational speed, the tilt angle of the tool, tool material and the tool design are the main independent variables that are used to control the FSW process. The main process parameters and there effects in friction stir welding are given below Table 2 (FSWTechnical-Handbook).

1.1. Tool rotation and Transverse speed

For FSW, two parameters are very important: tool rotation rate (v, rpm) in clockwise or counter clockwise direction and tool traverse speed (n, mm/min) along the line of joint. The motion of the tool generates frictional heat within the work pieces; extruding the softened plasticized material around it and forging the same in place so as to form a solidstate seamless joint (Xunhong Wang et al., 2006). As the tool (rotates and) moves along the butting surfaces, heat is being generated at the shoulder/work-piece and, to a lesser extent, at the pin/work-piece contact surfaces, as a result of the frictional-energy dissipation (Grujicic M. et al., 2010). The welding speed depends on several factors, such as alloy type, rotational speed, penetration depth, and joint type (Sakthivel T. et al., 2009). Higher tool rotation rates generate higher temperature because of higher friction heating and result in more intense stirring and mixing of material. During traversing, softened material from the leading edge moves to the trailing edge due to the tool rotation and the traverse movement of the tool, and this transferred material, are consolidated in the trailing edge of the tool by the application of an axial force (Kumar K., et al., 2008).

Table2
Main process parameters in friction stir welding

Parameter	Effects
Rotation speed	Frictional heat, stirring‖, oxide layer breaking and mixing of material.
Tilting angle	The appearance of the weld, thinning.
Welding speed	Appearance, heat control.
Down force	Frictional heat, maintaining contact conditions.

1.2. Tool tilt and Plunge depth

In addition to the tool rotation rate and traverse speed, another important process parameters are tool tilt with respect to the work piece surface and plunge depth. A suitable tilt of the spindle towards trailing direction ensures that the shoulder of the tool holds the stirred material by threaded pin and move material efficiently from the front to the back of the pin. The tool is usually characterized by a small tilt angle (θ), and as it is inserted into the sheets, the blanks material undergoes to a local backward extrusion process up to the tool shoulder. (Fratini L. et al., 2009). Further, the plunge depth of pin into the work pieces (also called target depth) is important for producing sound welds with smooth tool shoulders.

1.3. Tool Design

Tool design influences heat generation, plastic flow, the power required, and the uniformity of the welded joint. Tool geometry such as probe length, probe shape and shoulder size are the key parameters because it would affect the heat generation and the plastic material flow (Gopala Krishnan S. et al., 2011). The tool is an important part of this welding process. It consists of a shoulder and a pin. Pin profile plays a crucial role in material flow and in turn regulates the welding speed of the FSW process. The shoulder generates most of the heat and prevents the plasticized material from escaping from the work-piece, while both the shoulder and the tool pin affect the material flow. Friction stir welds are characterized by well-defined weld nugget and flow contours, almost spherical in shape, these contours are dependent on the tool design and welding parameters and process conditions used. The commonly used five pin profiles i.e., straight cylindrical, tapered cylindrical and trapezoidal to fabricate the joints, in FSW are shown schematically in following Fig. (Elangovan K. et al 2009).

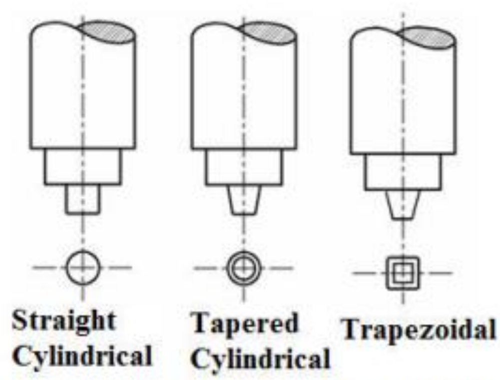


Fig.2. Schematic drawing of the FSW tool.

IV. APPLICATIONS APPLICATION OF FSW

It includes various industries including few of following: - 1. Shipping and marine industries: - Such as manufacturing of hulls, offshore accommodations, aluminum extrusions, etc. 2. Aerospace industries: - for welding in Al alloy fuel tanks for space vehicles, manufacturing of wings, etc. 3. Railway industries: - building of container bodies, railway tankers, etc. 4. Land transport: - automotive engine chassis, body frames, wheel rims, truck bodies, etc.

V. CURRENT STATUS & FUTURE ASPECTS

Friction stir welding technology has been a major boon to industry advanced since its inception. In spite of its short history, it has found widespread applications in diverse industries. Hard materials such as steel and other important engineering alloys can now be welded efficiently using this process. The understanding has been useful in reducing defects and improving uniformity of weld properties and, at the same time, expanding the applicability of FSW to new engineering alloys.

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