TECHNOLOGY AND RESEARCH DEVELOPMENTS IN FRICTION STIR TECHNIQUE: A REVIEW PAPER

Engineering

KEYWORDS: Friction stir welding, Tool design, Rotation speed, Material properties and Microstructure.

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ABSTRACT

The present research scenario focuses on the friction stir technique to enhance the surface properties and mechanical performance of material. Interwoven to this concept, the present research paper reviews the use of friction stir technique as welding process and surface processing. In the present paper the processing of aluminium and its alloy by friction stir technique has been attempted. The comprehensive review focus the effect of various process parameters like rotation speed, transverse speed, tool design on welding of aluminium alloys and their effect on material properties and microstructure. Furthermore, a new promising advancement in the area of friction stir processing for surface alloying / modification has been proposed.

INTRODUCTION

Aluminium alloys are known to be non-weld able because of poor solidification, porosity in fusion zone and also there is loss of mechanical properties as compared to base metal. Fusion welding of aluminium alloys has low quality, low strength and poor fracture resistance, due to these factors is difficult and expensive to produce sound quality weld on aluminium alloys by conventional fusion processes moreover surface oxidation is also a major problem [1].

Friction stir welding was developed and patented by the welding institute in 1991, it has emerged as a new solid state joining process. This technique opens up the whole new area in welding technique especially for joining of high strength alloys which are being used in aircraft industry, ship building industries and nowadays automobile industries are also accepting it as new joining process. It is a solid state joining process in which material is welded below its fusion temperature. It enables it to weld almost all aluminium alloys because aluminium alloys are difficult to weld by conventional fusion processes. Moreover the fusion welding of aluminium alloys produce defects like hot cracking and porosity etc., which are absent in friction stir welding technique. It is considered to be most significant step toward development of "green technology" that is energy efficient and environment friendly technique. Friction stir joining process is relatively a new welding technique and presently a lot of research is being done in this area. Fig. 1.Shows the schematic of friction stir process in joining the two plates.

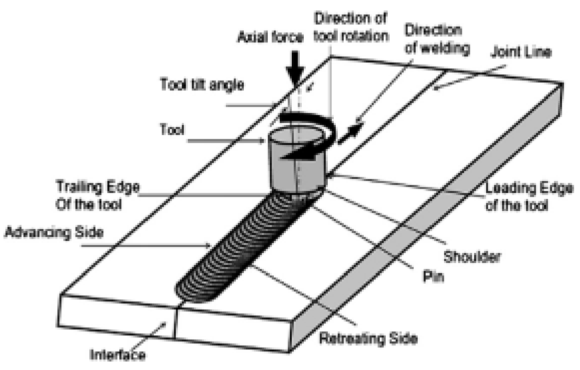

FIG.1. FRICTION STIR PROCESS. [2]

The work piece plates are clamped in backing plate, which is bolted to the bed of friction stir machine table rigidly, which keeps the work piece in compression and rigidly fixed during the welding process. It uses a non consumable tool comprised of shank, shoulder and pin (probe) which is fixed in chuck of milling machine as shown in fig. 2.

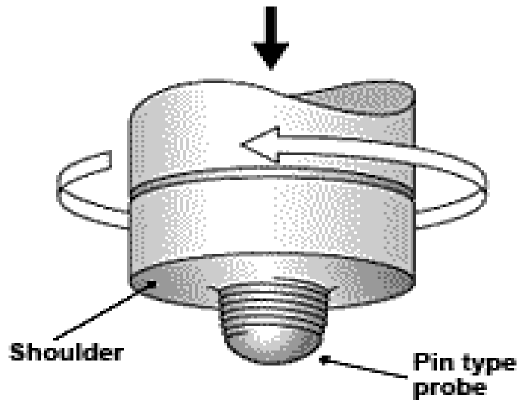

FIG.2. FRICTION STIR WELDING TOOL.

The rotating tool is plunged into the work piece in with controlled feed, it continuous to plunge until the shoulder of the tool touches the upper surface of work piece, and it exerts the downward force on it. Now tool is made to move along the line of seam to be joined. During the FSW, heat is generated due to friction between tool and the work piece and movement of tool makes material to deform plastically around the tool [3]. Frictional heating along with plastic deformation produce immense heat which cause recrystallisation and grain refinement in friction stirred zone [4]. Material processed by FSW consist of three different zone namely nugget zone (NZ), thermo mechanically affected zone(TMAZ), and heat affected zone (HAZ) as in fig. 3.[5]

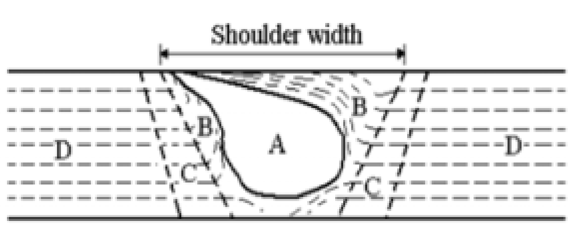

FIG.3. DIFFERENT ZONES IN WELDED JOINT: A-STIRRED ZONE, B-THERMO-MECHANICALLY AFFECTED ZONE (TMAZ), C- HEAT AFFECTED ZONE (HAZ) AND D-BASE METAL [6]

WELDING PARAMETERS

There are various welding parameters like tool rotation speed, traverse speed, plunging force, tool profile which affects the weld properties such as hardness, tensile strength, yield strength and surface properties namely grain structures. Tensile strength was increase with increase in weld speed and decrease in tool rotation speed. Heat input increase as tool rotation speed increase which cause more intense stirring and mixing of material, but higher stirring speed causes void in lower part of weld thus decreasing tensile strength, increase in temperature cause increase in grain size [7]. So, optimum values of tool and weld speed is to be chosen for perfect weld. Tool pin profile plays an important role in material flow, which in turn affects the welding process. Fig. 4.Various shows various pin profiles, plane tapered, threaded and flat surfaces. Flat surfaces are associated with eccentricity and cause pulsation stirring action. Which in turn cause uniformly distributed very fine distributed strengthening precipitates such as Si particles in base metal matrix and in turn yields higher strength and hardness.

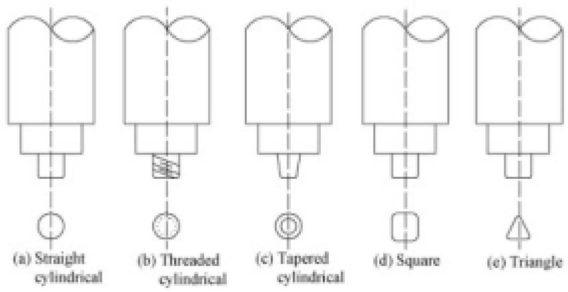

FIG.4. REPRESENTING DIFFERENT TOOL PIN DESIGN

Similarly shoulder design also affects the welding. Different features on shoulder increase and deformation and pushes material from the end to the probe [8]. Plunging force also affects the quality of weld as low force may result into poor consolidation of metal in weld and higher value of force can cause excessive thinning of welded part.

RECENT RESEARCH ON FSW AND FSP:

Selected research papers are related to FSW and the effect of various FSW parameters on the mechanical and micro-structural behavior of aluminium alloys.

MICROSTRUCTURE AND MECHANICAL PROPERTIES:

SAITO et al. studied the effect of FSW on 1050 aluminium alloy and concluded that grain refinement in FSW zone is 1-2μm and 2-4μm is achieved in rolled and annealed samples respectively [9]. Ma and Mishra studied the effect of friction stir welding process on A356 and it was found that there is grain refinement, elimination of porosity and homogeneity in stirred zone [10]. Santella et al. studied the effect on mechanical properties of aluminium alloys A319 and A356 and their study shown reduced porosity and dendritic microstructures and the uniform distribution of second-phase particles [11]. Ma and Sharma critically analyzed microstructure modification by FSW on as-cast Al-Si-Mg and concluded that the FSP brakes and uniformly distributes the Si particles in aluminium matrix and the FSW zone has shown micro structural refinement [12]. Bauri et al. analyzed the effect of FSP on microstructure and properties of Al-TiC and evaluated that one pass of FSP was enough to break the segregated particles and further second pass resulted in complete homogenization and defect free FSP zone and there is increase in hardness after each pass with improved strength [13].Singh et al. analyzed the effect of post heat treatment(T6) on microstructure and mechanical properties of Friction stir welded A7039 aluminium alloy and experimented that the post weld heat treatment lowers the mechanical properties like yield strength and ultimate tensile strength but with improved % elongation [2]. Yadav and Bauri evaluated that FSP result in grain refinement with equiaxed fine grains with well defined grain boundaries and strength with improved ductility [14]. Parida et al. analyzed that weld zone contained refined grains as compared to HAZ and hardness value in HAZ is less than base metal showing increased ductility [15]. Sinhmar et al. experimented FSP of AA7039 aluminium alloy and evaluated that there is decrease in avg. grain size i.e. from 44.3μm to 4.5μm, accompanied with decrease in ultimate tensile strength and yield strength but with gain in ductility and decrease in hardness than base metal [16].

PROCESS PARAMETERS:

Elangovan and Balasubramanian analyzed the effect of FSW welding parameters on FSW processed zone in AA2219 aluminium alloy and concluded that square pin profile at 1600 rpm produces defect free and superior tensile properties. Further Elangovan et al. studied the effect of tool pin profile and axial force on FSW zone in AA6061 aluminium alloy, evaluated that square pin profile produced fine uniformly distributed very fine strengthening precipitates and fine grains in FSP zone, concluded that square pin profile produce pulsating stirring action and optimum value of axial force produce sound weld else low axial force result in poor plasticization and consolidation of material under tool shoulder and excessive higher value can result in excessive thinning of metal in welded zone[17,18]. Grover et al. concluded that tensile strength, micro hardness and impact strength decrease with increase in rpm due to high heat evolved in it and increases with increase in weld speed, also as pin diameter increases there is increase in impact strength and micro hardness as there is more area under recrystallization comes due to it[19]. Singh et al. analyzed that defect free weld was produced on AA6082-T651 aluminium alloy at optimum tool rotation speed up to 700 rpm and weld speed up to 35 mm/ min. above it defects like pin hole are observed which may be due to insufficient heat generation and metal transformation, and tensile strength increase wit increase in tool rotation speed and weld speed increase but up to certain value then starts decreasing because at higher tool rotation speed voids are formed in lower part of stirred zone and there is reduction in hardness in weld zone [20]. Sharma et al. studies the effect of process parameters on mechanical and microstuctural properties of AA7039 aluminium alloy and evaluated that increase in tool rotation speed and decreased weld speed reduces the tendency of zigzag line formation, and with increase in weld speed there is decrease in ultimate tensile strength, %elongation and joint efficiency, location of hardness zone is affected by process parameters as it shifts from heat affected zone to nugget zone with decrease in tool rotation speed and increase in weld speed and when high tool speed and low weld speed is applied to FSW then fracture occurred at heat affected zone adjacent to TMAZ[7]. Mohanty et al. concluded that among different tool profiles, straight cylindrical tool with 5mm diameter produced highest tensile strength for low deformation resistance [6], hence use of tapered and trapezoidal toll does not necessarily enhance weld properties but there can be reduction in plunging force, micro hardness of nugget and TMAZ was slightly higher than base metal. Kumar et al. analyzed the FSW on dissimilar aluminium alloy AA5052-AA6061 and concluded that FSW between these alloys has shown brilliant weldabilty. And with cylindrical threaded pin has shown superior weld quality at high tool rotation speed and low weld speed [21].

CONCLUSION AND FUTURE TRENDS:

Aluminum and its alloys are widely used in aerospace industries, automobile industries due to low density but these materials have low strength and welding of these alloys with conventional fusion process result in poor weld strength, porosity in weld and defects like cracking. All the above shortcomings can be overcome by use of friction stir technique. This technique result into increase in weld strength with grain refinement and decrease in porosity. Also along with welding surface properties and mechanical properties are also enhanced. Which makes this process best suited for aluminium alloys welding and processing.

In this direction, the role of surface alloying of reinforcement materials into the matrix of base material (Stainless steel and Aluminum) to enhance the surface and mechanical properties is still at the experimental stage and has not been explored in detail. The present author proposed here an innovative method for surface alloying by friction stir surface processing (FSSP). Yet, many more issues need to be discussed in detail before before the technique can be embraced in the industry.

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