Optimization of Friction Stir Welding for AA5052 and AA6061: A Review

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Abstract— Friction Stir Welding (FSW) is a solid state joining process that can be applied to a number of materials including aluminium, magnesium, copper and steels. A number of researches have been conducted in Friction Stir Welding of two dissimilar plates of aluminium alloy and a vast literature review has been discussed towards the case study of industries. The basic principles of FSW are described and future scopes are also discussed. Finally, the range of mechanical properties that can be achieved is discussed.

Key words: Friction Stir Welding (FSW)

I. INTRODUCTION

Friction stir welding was invented by a research team led by Wayne M. Thomas at The Welding Institute (TWI) in England (UK) in 1991 and patented in 1999 [1]. Friction stir welding (FSW) is recent technique in welding that utilizes a rotating welding tool to generate frictional heat and plastic deformation at the welding place, resulting in the creation of the joint while the material is in the solid state. Friction welding is a type of forge welding, i.e. welding is done by the application of pressure. Friction generates heat, if two surfaces are rubbed together, enough heat can be generated and the temperature can be raised to the level where the parts subjected to the friction may be fused together. In conventional friction welding, relative rotation between a pair of work pieces is caused while the work pieces are urged together [2]. Typically thereafter once sufficient heat is built at the interface between the work pieces, relative rotation is stopped and the work pieces are urged together under forging force which may be same as or greater than the original urging force. “Friction welding” (FW) is a group of solid-state welding processes using heat generated through mechanical friction between a moving work piece, with the addition of an upsetting force to plastically displace material. It is primarily used on aluminium, and most often on extruded aluminium (non-heat treatable alloys), and on structures which need superior weld strength without a post weld heat treatment. Friction stir welding is a comparatively new solid state joining process. This joining technique is energy competent, atmosphere friendly and flexible. In particular, it can be used to connect high strength aerospace aluminium alloys and other metallic alloys that are very hard to be weld by conventional fusion welding technique. In comparison to established welding technique, FSW strongly reduces the presence of distortion and left over stresses.

FSW is considered to be the highly significant development in the metal joining in a decade and is a green technology due to its energy effectiveness, atmosphere friendliness and flexibility. As compared to the traditional welding methods, FSW consumes considerably very less energy. There is no use of cover gas or flux, thereby making the process atmosphere friendly.

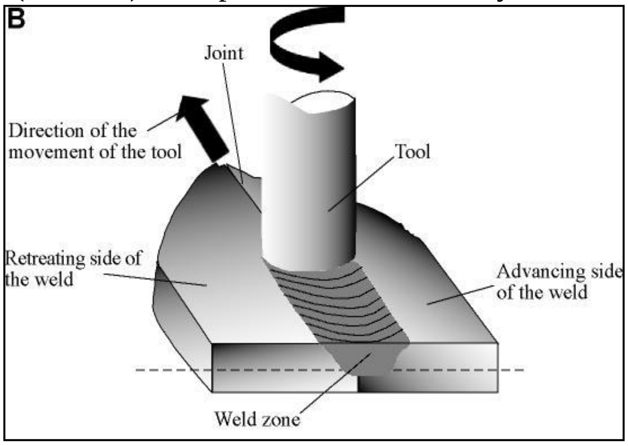

Fig. 1: Process of Friction Stir Welding

II. LITERATURE REVIEW

Friction stir welding has been found as one of the most significant welding process invention from the last two decades. Many researchers investigated and formulated the effect of friction stir welding which has produced structural joints superior to conventional arc welds in Aluminium, Steel, Nickel, Copper and titanium alloy. Research and development efforts over the last decade have resulted in improvements in friction stir welding and the spin-off of a series of related technologies.

P. Prasanna [3] provided the Optimization and validation of process parameters in friction stir welding on AA 6061 aluminium alloy using gray based taguchi method. This states that the specimens of the size of 200mm × 100mm × 5mm were machined from AA6061 aluminium alloy plates. The two plates of AA 6061 aluminium alloy were Friction stir welded in the butt configuration by using conventional vertical milling machine. The two plates were placed side by side and clamped firmly to prevent the abutting joint faces from being forced apart. In this study, there are four major controllable factors each one at four levels namely rotation speed (600, 700, 800, 900rpm), welding speed (10, 14, 16, 19mm/min), pin tool length (5.3, 5.5, 5.7, 5.9mm), tool pin offset distance (0.1, 0.2, 0.3, 0.4mm). The ANOVA summary results of the gray relational grade indicates that pin tool length, transverse speed, rotational speed and tool pin offset distance are the relatively significant FSW process parameters respectively, for affecting the multiple performance characteristics. Raj Kumar V. [4] provided the friction stir welding on aluminium alloy AA5052-AA6061 using cylindrical pin tool rotated at constant speed 710 rpm and at two different feed rates 28 and 20 mm/min. The tensile tests and hardness was measured and found that cylindrical pin profile shown excellent bondage between both alloys. It was observed that the sample B was outperformed sample A on certain fronts corresponding to better ductility. Aval [5] looked into the microstructures and mechanical properties in similar and dissimilar friction stir welding of AA5086-O and AA6061-T6 using thermo-mechanical model and experimental observations. The authors concluded that the hardness in AA5086 side mainly depends on recrystallization and generation of fine grains in the weld nugget whereas hardness in the AA6061 side varies with the size, volume fractionand distribution of precipitates in the weld line. It was observed that grain refinement in the stirred zone for all samples. In addition, the finer grain size distribution was achieved within the AA6061 side where higher strain rates were produced. Mohamadreza Nourani [6] provided the Taguchi Optimization of Process Parameters in Friction Stir Welding 0f 6061 Aluminium Alloy: A Review and Case Study. This states that study is intended to present a straightforward and computationally efficient methodology for optimizing the process parameters of friction stir welding of 6061 aluminium alloy. In particular, it is shown how to minimize the heat affected zone distance to the weld line in the joined parts using a Taguchi optimization method and a temperature-field finite element model. Contributions of the process parameters on both criteria were found to be comparable in the conducted case study; namely, the tool rotational speed showed the highest significance, followed by the normal force and the welding transverse speed. Yong-Jai KWON [7] executed friction stir welding between 5052 aluminium alloy plates with a thickness of 2 mm. The experiments were conducted on rotational speed of 500-3000 rpm under a constant welding speed of 100 mm/min. It found that at 1000, 2000 and 3000 rpm, the welds show very smooth surface morphologies. At 500, 1000, and 2 000 r/min, onion ring structure was clearly observed in the friction-stir-welded zone (SZ). In addition, the onion ring structure region becomes wider as the tool rotation speed is increased. Douglas [8] provided the effects of applied load on 6061-T6 aluminium joined employing a novel friction bonding process. States that temperature tests and micro structural examinations show that for the current tool geometry, the advancing side of the tool produces a majority of the frictional heat, while the retreating side of the tool mainly serves to forge the plasticized material downward into the work piece. There is a trade-off between complete bonding across the joint interface and penetration of the tool into the work piece. The assembly must be subjected to the friction bonding process on the both sides rather than one single side only, as was performed in this study, to ensure both complete bonding of the aluminium and the fuel without disturbing the fuel at the interface. However, the UTS is only slightly decreased from the parent metal, and the ductility of the processed material is significantly increased due to the generation of fine recrystallized grains. Selvaraj [9] followed up the friction stir welding on 6mm thick sheet of aluminium alloys AA6061-T6 (150 mm × 75 mm × 6 mm) using various rotational (300-2000 rpm) and welding speeds (300, 900, and 1,800 mm/min). The interface temperature range was measured for defect-free weld during FSW of AA6061 aluminium alloy was 400–525 °C. It was observed that the yield strength for welding speed of 300 mm/min and rotational speed 400 rpm was 172 MPa, which was 63.2 % of yield strength of base metal and yield strength for rotational speed 1,800 mm/min and 1,200 rpm is 205 MPa which was 75.4 % of yield strength of base metal. The tensile test results shown that when welding speed increased from 300 to 1,800 mm/min, the yield strength was increased by 12.2%. When welding speed increases, strength of the joint increases significantly. The yield strength for rotational speed of 400 rpm and 1,200 rpm for a constant welding speed of 300 mm/min were 172 and 173 MPa. It also investigated the effect of rotational speed on the strength of the FSW joints was not significant. Elatharasan G. [10] optimized the process parameters (rotational speed, welding speed and axial force) with respect to ultimate tensile strength, yield strength and displacement of FSW of AA6061 - AA7075 using Response Surface Methodology. The optimal result of ultimate tensile strength, yield strength and displacement was found i.e.198.540 MPa, 184.020 MPa and 2.09 mm respectively. In addition, it analyzed that Ultimate Tensile Strength (UTS) of joints were increases with increase in tool rotational speed & welding speed and UTS decreases due to increase in axial force. Displacement of joints decreased with increase in tool rotational speed and welding speed. D.M. Rodrigues [11] dealt with influence of friction stir welding parameters on the micro structural and mechanical properties of AA 6061-T4 thin welds. States that in present work friction stir welds produced in 1 mm thick plates of AA 6061-T4 aluminium alloy, with two different tools were analysed and compared concerning the microstructure and mechanical properties. For each tool, the welding parameters were optimized in order to achieve non-defective welds. Assuming a relation between the welding parameters and the energy input per unit of length of the weld a conical shoulder with a inclination cavity and 10 mm in diameter and a scrolled shoulder with 14 mm in diameter. The conical shoulder geometry is very traditional and has already been used in numerous applications. Friction stir welds were performed parallel to the rolling direction of the plates using a conventional milling machine. Shibayanagi T. [12] investigated that the welded two dissimilar aluminium alloy AA5083 and AA6061 by friction stir seam welding at various rotational speed ranging from 300 to 2000 rpm, welding speed ranging from 100 to 500 mm/min and tilt angle of 3°. The researchers analyzed the result by using SEM-EDS and found that Mg concentration fluctuated in a corresponding fashion to the laminated structure, and this clarified the state of heterogeneous mixture at the friction stir welded joints. Furthermore, authors found coarse grain structure when annealing was done at 773K. From the SEMEDS analysis, it became clear that the heterogeneity in Mg concentration within the nugget was disappearing and this suggested the possibility that diffusion-induced grain boundary migration has some connection to the anomalous grain growth.

III. FUTURE PERSPECTIVES

There are three categories for FSW variable like-FSW set up, work pieces and tool variables. Set up variable include-rotating speed, transverse speed and axial force. Work piece variables include materials of work piece and dimensions of work piece like- length, diameter and hardness etc. Tool variables are tools diameter, tools geometry, tilt angle of tool and tool wear rate. This Study considers about work piece, tool and set up variables. There is scope for considering more factor levels, interactions; to optimize a selected set of parameters. The following suggestions may improve useful work:

1) Tool variables can also be optimized by Taguchi approach.
2) Level of factor can be increased for further study.
3) Different material and different optimization technique can be applied to find the interaction between selected set of parameters.
4) A comparison between different optimization techniques can also be studied to check the better among them.
5) Some response like impact strength, wear rates etc. can also be calculated of the weld obtained.

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