FRICTION STIR WELDING: THE PROSPECTIVE WELDABLE ALLOYS FOR DIFFERENT APPLICATIONS

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Abstract: *The Friction Stir Welds mainly depends on three factors Tool pin which is the joining material will be properly mixed during joining. FSW machine is primarily used to control the critical parameters used in the specific range. The tooling fixture needs to be perfectly positioned and locate the workpiece accurately as well as dissipate the heat that is imparted during welding. The significant parameters that must be controlled using the friction stir welding process include the position of the tool pin, Orientation, Axial load, Spindle Speed, and Travel speed of the workpiece. The physics behind the FSW process includes various stages such as the tool pin rotating and plunging into the parent material with a larger amount of heat generation and reaching the plasticized formation. Then the tool approaches the predefined tool path and makes the joining by stirring action by the shoulder of the tool. In recent days this process can also perform joints underwater submerging with dissimilar alloys. Joints are made by using ultrasonic vibrations for pipes under quality monitoring systems were also employed. The real challenges still depend upon the reliability and durability of the weldments.*

Keywords: **Tool pin, Axial Load, Spindle Speed, Travel Speed, Aluminium Alloys, Copper Alloys, Steels, Magnesium Alloys.**

1. INTRODUCTION

Friction stir welding and stir processing are used in industrial applications. It is a solid state welding process by a rotation non-consumable electrode without melting a workpiece for joining. Heat is obtained by friction between the rotating tool and the workpiece material which makes the surface soften by the tool. It is primarily used for the joining of Aluminium and Magnesium materials used by various industries like aerospace, ship building, and railways [1]. This review paper discusses the various modern stir processes and applications in various forms it gets welded and also discusses possibility of welding similar and dissimilar alloys for various applications.

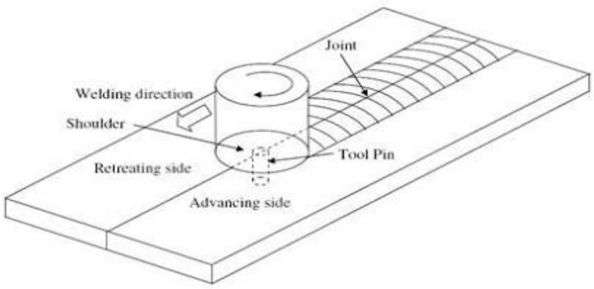

Figure 1: Schematic drawing of friction stir welding [1]

The figure. (1) Shows the schematic drawing of FSW process. The main source of heat is produced between the shoulder and the base alloy which is fixed on the table rigidly by the fixture element. The significant process parameters for making a 100% strength similar to parent material is obtained by selection of input values such as Tool rotational speed, Feed of the table and Axial Load applied by the tool against the base material.

2. WELDING OF DIFFERENT ALLOYS

Magnesium alloys is one of the light weight structural alloy, which makes possible alternate for copper, aluminium & steel alloys in various applications including automotive and marine industries [2]. The alloy has a hexagonal lattice structure and found to be more complications with respect to plastic deformation when compared with the other alloys like copper, steel & aluminium [3]. In the case of magnesium the as cast alloys are used in different applications, and wrought magnesium alloys are used in the manufacture of modern automobile components [4]. Defects and solidification problems like hot cracking, porosity, partial melting zones, segregation of alloys etc are the challenges during welding of Mg alloys [5]. Mg alloys needs suitable welding process for fabricating parts so that defects associated with solidification can be eliminated [6]. High strength can be achieved with moderate cost; ability to join different weld metals & non metals is yet another reason for choosing FSW process for Mg alloy welding [7]. Magnesium alloys have also gained more attention because of their high strength to weight ratio, remarkable stiffness, seismic performance, and easy workability. Sound welds were produced with lower heat on stationary shoulder friction stir welding (SSFSW) at speeds ranging (700–1500 rpm) with a constant welding speed of (50 mm/min). Results with fine equi-axed grains is present, with grain size increases as increasing the tool rotational speed with high joint efficiency of 97% has been achieved at the rotational speed of 1500 rpm [8].

Welding of the aluminium alloys via friction stir welding (FSW) has been successful most of the times [9]. During the process of joining the Al series most of the literature discussed about the defects of joining the alloys. The defect occurred within the AA2219 aluminium alloy during submerged FSW process on underwater was studied by Zhang and Liu [10], and the results showed that the formation of welding defects occurred at both of low and high rotational speeds where the material stirring was unstable. In another study by Liu et al. [11], by optimization of input parameters for underwater FSW process, a dissimilar joint with a strength ratio of ~ 80% was achieved. As it was recorded in another work by Zhang and Liu [12], the main reason for grain size homogeneity of mechanical property in the processed AA2219 aluminium alloy after underwater FSW was significantly increased of the hardness through the stirred region. Sree Sabari et al. [13], work discussed about the minimization in the size of heat-affected zone (HAZ) and thermomechanical- affected zone (TMAZ) during underwater FSW joining of AA2519-T87 aluminum alloy. Heirani et al. [14], discussed the effects of air and water as two cooling mediums on the microstructure and mechanical properties of AA5083 aluminium alloy during FSW process were analysed. The report also discussed on the underwater FSW was determined very effective on increasing the hardness of the stirred zone and also for improving the tensile strength of weldments. Liang et al. [15] discussed the efficiency of water cooling medium temperature on the tensile strength of FSW weldments from AA7055 aluminium alloy. The joint strength up to ~ 150% was increased by employing the underwater FSW and using cooling water medium with a temperature of ~ 60°C.

Wang et al. [16] discussed the metal fluidity effects depending on the tool rotational speed during the underwater FSW treatment of an AA7055 aluminium alloy. By increasing the tool rotational speed and subsequent enhancement of material fluidity, the weakened became sharpened and filled the stirred zone properly that caused the better tensile property. Papahnet al. [17] studied the underwater FSW process of AA7075- T6 aluminium alloy plates and showed a decreasing trend in the peak temperature near to about 40% as compared to the air FSW treatment. The induced higher cooling rate led to more brittleness of processed underwater weldments. In the research by Tan et al. [18] on the underwater FSW joining of AA3003 aluminium-manganese alloy, for the size of recrystallized grains and the number of secondary phase particles inside the weld nugget by decreasing the temperature of submerged cooling medium.

Dissimilar underwater FSW joining of AA6061 and AA7075 aluminium alloys was studied by Bijanrostami et al. [19]. Accordingly, the processing parameters were optimized as tool rotational speed of 1853 r/min and traverse velocity of 50 mm/min with a maximum tensile strength of ~ 238 MPa and elongation of ~ 41%. Zhao et al. [20] discussed the dissimilar case study between AA6013 aluminium alloy and AZ31 magnesium alloy. Zhao et al. [21] also discussed the FSW process was found more effective as compared to the air ambient joining in producing of dissimilar weldments with superior tensile strength.

Copper is very common material for industrial application but the welding of copper by fusion welding process is very difficult because it generate oxide at melting temperature, high thermal conductivity and higher expansion coefficient. Cu has an F.C.C. crystal structure, with good corrosion performance and high thermal conductivity [22]. The difficulties are encountered in fusion welding of Cu-alloys with conventional joining processes, which are: Insufficient penetration due to the high conductivity, High distortion, Change of colour due to oxidation, Loss of strength in fusion zone (FZ) due to the evaporation of Zn, particularly in high Zn content alloys, Loss of strength at the weld surface due to the formation of ZnO and formation of weld surface irregularities.

However, the higher heat input requirement for FSW of Cu means that the FSW must be conducted at lower welding speeds and/or higher rotational speeds. This is particularly valid for pure Cu and not for Cu-alloys, which have lower heat conductivity than pure Cu [23].

Figure 2: Welding of Copper by friction stir welding

The heat input required for FSW of Cu-alloys is much higher than those required for other materials because of the higher dissipation of heat through the workpiece, particularly for pure Cu, this is not expected to hinder FSW of these alloys. This shortcoming can be overcome by conducting the FSW at lower welding speeds and/or higher rotation rates. The complete dynamic recrystallization was generally observed in the Stir zone (SZ) of friction stir welded single phase and quasi-single phase pure Cu and Cu-alloys, producing fine and uniform equiaxed grains [24]. Welding of copper by friction stir welding is shown in figure 2.

Friction stir welding on steel is concentrated because of the major use of steels in industries rather than other metals. The Friction stir welding of low alloy steels plates and mechanical and metallurgical properties of low alloy steel plate of 3 mm thickness having 0.2% carbon was investigated at three different speeds [25]. Friction stir welding was used for the welding of high strength steel with a high carbon content, which has been considered as an alternative for the counterpart containing rare metals such as Ni. The chemical composition of the sample used in this study was designed in consideration of the two concepts; (1) the carbon equilibrium is the same as that of the conventional 780 MPa grade high strength steel, and (2) Ni does not have to be used. Based on these considerations, the composition of the sample was determined to be 0.45%C-0.22%Si-0.8%Mn-bal.Fe [26].

Friction stir welding behaviour and friction stir spot welding behaviour of thermoplastics were studied by [25]. Thermoplastics were polyethylene, PA66 and PPS. Friction stir welding behaviour of thermoplastics was quite different from those of metals. Material flow area was very small compared with that of metal. Appropriate friction stir welding condition for polyethylene was obtained at room temperature; however heating of joint was required to get appropriate condition for PA66 or PPS. Large shrinkage was occurred after friction stir welding which sometimes caused fracture of joint because of large thermal expansion coefficient. Friction stir spot welding might be suitable compared with friction stir welding for thermoplastics [25].

3. CONCLUSION

Although many challenges need to be addressed before FSW can be fully implemented for welding dissimilar materials in broader industry sectors, it brings opportunities and hope to industry that welding of conventionally non-wieldable dissimilar materials is possible; just as the invention of FSW technology impacted the Al alloy welding industry. Aerospace, marine, and transportation industries which need high strength lightweight structures are likely to benefit from dissimilar FSW [28]. This paper discussed about the major alloying element that can be welded by FSW and challenges and difficulties in welding other special alloys by FSW.

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