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Review Article

Friction Stir Welding: Merits over other Joining Processes

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Abstract

Friction Stir Welding (FSW) is the one of the most leading joining process used for aluminium and its alloys. This most recent joining process joins materials below the melting point which make it ahead of any other joining process. This study is to investigate the quality of weld produced using GMAW and GTAW and FSW. Various advantages of FSW over other joining techniques have been discussed in this article. This study also discusses the different types of testing methods used for determining the performance of welded joints. Material characterization through microstructure analysis is important for comparing the weld performance produced using FSW and other processes. It has been found that FSW is more advantages and beneficial than other welding techniques for the joining of aluminium and its alloys.

Keywords: *FSW, GTAW, Welding, GMAW, Aluminium Alloy*

1. Introduction

FSW was used first time in 1991 for research work in laboratory at TWI (The Welding Institute), United Kingdom. But the joining of two aluminium sheets through FSW was so innovative that it attracts the welding experts and industrialists. FSW gave the best key solution for all the experts who were facing difficulty for joining aluminium and its alloys at higher temperature (Kevorkijan, 2002). Aerospace industry and modern automobile industry got new opportunities to have a relook for better use of the most available metal on earth. In present, the flow of expertise in FSW and maximum use of resources with minimum waste make FSW process more valuable and more automatic joining process (Praveen & Yarlagadda, 2005).

In FSW, a rotation tool with a pin is inserted in the weld line until the tool shoulder touch upper surface of plates. Frictional heat is induced between tool shoulder and welding plates which increase the temperature up to re-crystallization temperature and the inserted pin intermix the plasticize material to make solid-state welding. The used welded sheets may be of same or dissimilar materials (Kundu & Singh, 2016). Mechanism of the process of FSW is shown in figure 1.There are two sides of the welding, during clockwise rotation of the tool and forward feed, the left side is called advancing side and the right side is called retreating side.

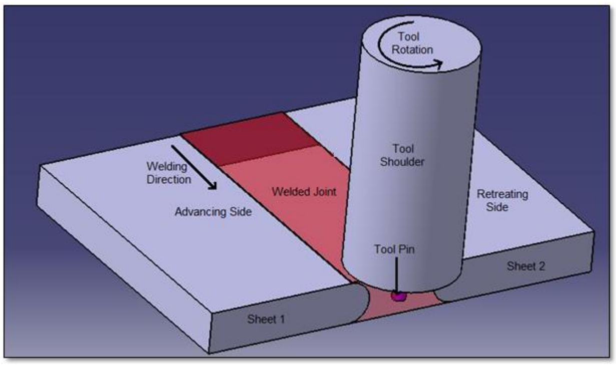

Figure 1: FSW process diagram

During welding joint zones are formed named as (a) nugget zone, (b) thermo-mechanical affected zone, (c) heat affected zone, (d) Base material which has been represented in figure 2. The Central zone is nugget zone (NZ) where intermixing of material is taken place. Thermo-mechanical affected (TMAZ) is a zone of maximum deformation without intermixing. Heat affected zone experiences the temperature variation without any deformation.

The solid state welding produces welded joint without melting of material sheets; therefore, a number of defects e.g. porosity, cracking, blow holes which appear during conventional fusion welding process are avoided (Kevorkijan, 2002; Kundu & Singh,

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2016a; Taban & Kaluc, 2006). In FSW high temperature below the melting point is attained through friction between tool shoulder and joining sheets as well as frictional heat produced by tool pin and the semi-solid material through the plastic flow of materials under the tool shoulder.

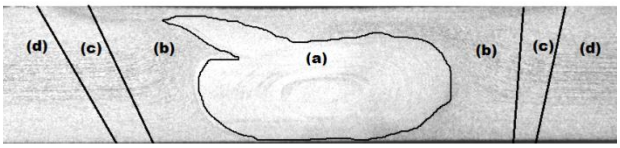

Figure 2: Different welding zones of FSW

3. Literature study on comparison of FSW

Ericsson & Sandstrom (2003) estimated the welding speed affect the fatigue properties of friction stir weld and compare it with MIG and TIG welding on Al-Mg-Si alloys. They concluded that extreme the fatigue properties of FSW joints majorly influenced by low and high welding speed. The friction stir welds showed higher dynamic and static strength than TIG welds and MIG-pulse welds (Ericsson & Sandstrom 2003). Squillace et al. (2004) compared FSW to TIG welding and investigated the alteration of microstructure and pitting corrosion resistance in AA2024-T3 butt joints aluminium alloy. According to the conclusion, a gradual decrease in mechanical properties in TIG welding is due to the heat subjected to the material. However in FSW, the material experienced less heat compared to TIG and the joining occurs due to severe plastic deformations induced by the tool motion; a slight decay in mechanical properties was found out in nugget zone, flow arm, TMAZ while in HAZ mechanical properties were slightly improved (Squillace. 2004).

Khodaverdizadeh (2013) compared TIG welding and FSW on aluminium alloy. The result found that hardening precipitates were relatively more affected by the TIG welding than FSW process. This causes a reduction of mechanical properties for TIG welds joints which can be overcome by a suitable post weld heat treatment (Cabibbo, 2007). Zhao *et al.* (2010) compared microstructure and mechanical properties of Al-Mg-Sc alloy welded by TIG welding and FSW (Zhao, 2010). The result shows that tensile strength, yield strength and hardness of FSW joints are much better than TIG welded joints; the strength coefficient of FSW joints is up to 94%. Cavaliere (2013), investigated on corrosion behaviour of aluminium 6061 alloys joined by FSW and gas tungsten arc welding. They found the grain size of FS weld joint have finer and equiaxed than GTAW weld joints. So that resistance against corrosion is greater for FSW grains than the GTAW grains. In both cases, chances to corrosion attack were greater at the joint region than the base metal.

Singh *et al.* (2011) investigated mechanical properties of the welded joints evaluated and it was found that friction stir welded joints have superior mechanical properties as compared to TIG welded joints. From the microstructure analysis, it was observed that fine and equiaxed grains were observed in the friction stir welded joints and coarse grains were observed in TIG welded joints. SEM analysis also carried out to know the fracture behaviour of the tensile tested joints.

4. **Merits over other joining processes**

In fact, TIG is very much a conventional welding process and it is in use since 60-70 years or more. It is used for joining metals and alloys which form very stable high melting point oxides (aluminum, magnesium, stainless steel, which contains high % of Cr), which are difficult to remove through the use of liquid slag (produced by molten flux or coating). FSW is a non-fusion welding process which eliminates undesirable metallurgical changes during melting and subsequent cooling. The benefits of

FSW over TIG and MIG as well are:

- Significantly smaller HAZ
- Higher weld strength (in both static & fatigue weld properties) - by at least 10-15%
- Distortion is significantly lower (in comparison to MIG, it can be lower by a factor of 2 - 3 at times, of thin sheet metal)
- There are no solidification defects
- There is no addition of an external consumable
- The weld ductility is much higher
- It is a cleaner and greener process
- Most importantly, when calculated on a cost of the weld, it is also cheaper in the long run due to significantly cheaper operating costs.

5. Benefits of FSW

New solution to old joining problems

The FSW is an innovative technology which makes us able to frequently discover new joining applications for extrusions, castings, plate, and sheet for customers ranging from railcars industry to aerospace industry. The knowledgeable and skilled team, in the materials best fitting for FSW and provides solutions to advance product performance, quality, and weld development (Kundu & Singh 2016).

Virtually defect-free bonding

Because FSW is a solid state welding process so it eliminates the defects such as porosity, solidification cracking, shrinkage etc which commonly associated with conventional welding processes. There is no filler material is used in FSW which provide the bond between the two pieces is made exclusively of the original material, so it gives similar bending, strength, and fatigue characteristics of the parent material.

Limitless panel length and width for large projects

The flexibility of FSW process means it can facilitate the welding of large parts. The vertical milling machine can be upgraded as a setup of FSW by design a proper fixture. Well designed and upgraded vertical milling machine can join the thicker material up to any distance (Kundu & singh 2017)b.

Dual head capability for faster panel welding

The large panel production machine is equipped with dual upper and lower weld heads for extrusions or panels that require a top and bottom welded assembly. Welding a large panel or part assembly on both sides saves time and money (Kundu, 2016).

Superior mechanical characteristics

FSW produces a weld with high weld strength and toughness, plus a fine grain structure that resists fatigue stress. Due to the low heat and small heat-affected zone, there is a minimal distortion of the joined parts, reducing the costs associated with preparing the part for subsequent use (Kundu, 2014)c.

Join dissimilar alloys

FSW may be used to weld dissimilar alloys – even combinations not compatible with conventional welding methods

A green process

FSW is environmentally friendly, with a process that features low energy input and requires no consumables, flux, filler material, or shielding gases to run, like conventional welding methods. FSW also does not emit smoke, fumes, or gases that need to be exhausted on the back end (Babu, 2013; Akinlabi, 2012).

Conclusions

FSW emerged out a new and advanced version of conventional friction welding. The advanced version filled the gap of joining the aluminium alloys and pure aluminium material which are very difficult to weld with conventional techniques like TIG, MIG etc. Moreover, FSW provides a quality weld and it is a green technology. Two dissimilar materials can be easily joined as compared to other techniques. The quality of weld can be easily achieved in the FSW process. Every process is running towards minimum waste and maximum environment-friendly. FSW bestows the environment-friendly solution for the manufacturing industry.

References

A. S. Babu and C. Devanathan (2013), An Overview of Friction Stir Welding, International Journal of Research in Mechanical Engineering & Technology, vol. 3, no. 2, pp. 259–265.

A. Squillace, A. De Fenzo, G. Giorleo, and F. Bellucci (2004), A comparison between FSW and TIG welding techniques: Modifications of microstructure and pitting corrosion resistance in AA 2024-T3 butt joints, Journal of Materials Processing Technology, vol. 152, no. 1, pp. 97–105.

B. H. Babu and K. Madhivanan (2015), Experimental Analysis of Process Parameters on Friction Stir Welding of Aluminium 6061 Alloy, International Journal of Advanced Research Treands in Engineering and Technology, vol. II, no. Xxii, pp. 78–83.

E. Taban and E. Kaluc (2006), Microstructural and mechanical properties of double-sided MIG, TIG and friction stir welded 5083-H321 aluminium alloy, Metallic Materials, vol. 44, no. 1, p. 24.

E. T. Akinlabi and S. A. Akinlabi (2012), Friction Stir Welding Process : A Green Technology, International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering, vol. 6, no. 11, pp. 63–65.

G. Singh, K. Singh, and J. Singh (2011), Effect of process parameters on microstructure and mechanical properties in friction stir welding of aluminum alloy, Transactions of the Indian Institute of Metals, vol. 64, no. 4–5, pp. 325–330.

H. Khodaverdizadeh, A. Mahmoudi, A. Heidarzadeh, and E. Nazari (2012), Effect of friction stir welding (FSW) parameters on strain hardening behavior of pure copper joints, Materials and Design, vol. 35, pp. 330–334.

J. Kundu and H. Singh (2016), Friction stir welding of dissimilar Al alloys: effect of process parameters on mechanical properties, Engineering Solid Mechanics, vol. 4, no. 3, pp. 125–132.

J. Kundu and H. Singh (2016)a, Friction stir welding of AA5083 aluminium alloy : Multi-response optimization using Taguchi-based grey relational analysis, Advances in Mechanical Engineering, vol. 8, no. 11, pp. 1–10.

J. Kundu and H. Singh (2016)b, Friction stir welding: multi-response optimisation using Taguchi-based GRA, Production & Manufacturing Research, vol. 4, no. 1, pp. 228–241.

J. Kundu and H. Singh (2016), Friction Stir Welding : A Novel Joining Technique, International Journal of Emerging Trends in Research, vol. 1, no. 9, pp. 23–27.

J. Kundu and H. Singh (2017)c, Friction stir welding process : An investigation of microstructure and mechanical properties of Al Alloy AlMg4 . 5Mn joint, Engineering Solid Mechanics, no. 1, pp. 145–154.

J. Zhao, F. Jiang, H. Jian, K. Wen, L. Jiang, and X. Chen (2010), Comparative investigation of tungsten inert gas and friction stir welding characteristics of Al-Mg-Sc alloy plates, Materials and Design, vol. 31, no. 1, pp. 306–311.

M. Cabibbo, H. J. McQueen, E. Evangelista, S. Spigarelli, M. Di Paola, and A. Falchero (2007), Microstructure and mechanical property studies of AA6056 friction stir welded plate, Materials Science and Engineering A, vol. 460–461, pp. 86–94.

M. Ericsson and R. Sandström (2003), Influence of welding speed on the fatigue of friction stir welds, and comparison with MIG and TIG, International Journal of Fatigue, vol. 25, no. 12, pp. 1379–1387.

P. Cavaliere (2013), Friction stir welding of Al alloys: Analysis of processing parameters affecting mechanical behavior, Procedia CIRP, vol. 11, pp. 139–144.

P. Praveen and P. K. D. V Yarlagadda (2005), Meeting challenges in welding of aluminum alloys through pulse gas metal arc welding, Journal of Materials Processing Technology, vol. 164–165, pp. 1106–1112.

V. Kevorkijan (2002), Economic benefits of the substitution of traditional cast iron and steel by aluminium and magnesium based material in automotive segment, Journal Metallurgical & Materials Engineering (formally Journal Metalurgija), vol. 8, no. 3, pp. 251–258.