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Review Article

Friction Stir Welding: Merits over Other Joining Processes

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Abstract

Friction Stir Welding is the one of the most leading joining process used for aluminium and its alloys. The most recent joining process joins materials below the melting point which make it ahead of another joining process. This study is to investigate the comparison of welding of Aluminium plates joined by Gas Metal Arc Welding and Gas Tungsten Arc Welding and Friction Stir Welding. The various advantages have been discussed as compared to other joining techniques. This study also analyses the various types of testing methods used for determines the mechanical properties of weld materials and the material characterization can be obtained by the microstructure of different weld materials for comparing the weld quality by FSW and other processes. It has been found that FSW is more advantages and benefits than other welding techniques.

Keywords: *FSW, TIG, Welding, Merits, Aluminium Alloy*

1. Introduction

Friction stir welding was first time used in 1991 for laboratory research work at TWI, United Kingdom. But the process of joining two aluminium sheets through friction stir welding was so revolutionary that it captured the instant focus of the welding experts and industrialists. Friction stir welding provided the best key solution for all the experts who were facing difficulty for joining aluminium and its alloys at higher temperature (V. Kevorkijan *et al*, 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 friction stir welding and maximum use of resources with minimum waste make friction stir welding process more valuable and more automatic joining process (P. Praveen *et al*, 2005).

In friction stir welding, 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 (J. Kundu, 2016). Mechanism of the friction stir welding process 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.

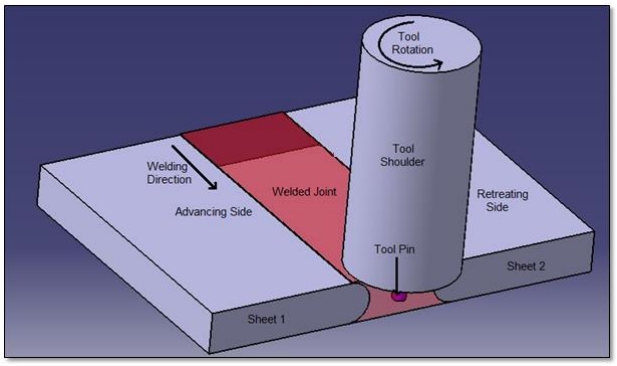

Figure 1: Friction Stir Welding process diagram

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

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process are avoided (V. Kevorkijan *et al*, 2002; J. Kundu, 2016; E. Taban, 2006) In friction stir welding 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.

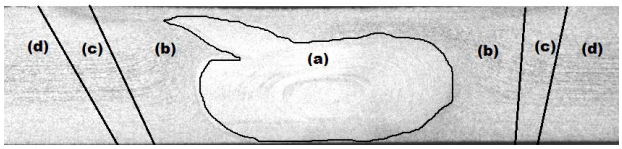

Figure 2: Different welding zones of friction stir welding

3. Literature study on comparison of FSW

Ericsson (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 low and high welding speed has a major influence on the fatigue properties of Friction stir welding joints. The friction stir welds showed higher static and dynamic strength than MIG-pulse welds and TIG welds (M. Ericsson, 2003). Squillace (2004) compared FSW to TIG welding and investigated the modification 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 friction stir welding, 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 (A. Squillace. 2004). Cabello Munoz (2008) compared TIG welding and FSW on aluminium alloy. The result found was hardening precipitates were comparatively 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 (M. Cabibbom 2007). Juan Zhao (2010) compared microstructure and mechanical properties of Al-Mg-Sc alloy welded by TIG welding and FSW (J. 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%. Fahimpour (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. Gurmeet Singh (2017) 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 (G. Singh, 2011).

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). Friction stir welding 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

Provides opportunities for new solutions to old joining problems

The leading-edge technology of Friction Stir Welding allows us to continually identify new joining applications for extrusions, castings, plate, and sheet for customers ranging from railcars to aerospace. Our skilled MTI team is knowledgeable in the materials best suited for FSW and offers solutions to improve product performance, quality, and weld development (J. Kundu, 2016).

Virtually defect-free bonding

As a solid-state process, Friction Stir Welding eliminates many of the defects associated with conventional fusion welding techniques such as shrinkage, solidification cracking, and porosity. The

bond between the two pieces is made solely of the original material, giving it similar strength, bending, and fatigue characteristics of the parent material.

Limitless panel length and width for large projects

The flexibility of our Friction Stir Welding process means we can accommodate the welding of large parts. Our in-house equipment, which we designed and built, can produce friction stir welds up to 55 feet long. This also allows the capability to join aluminium sheets produced at the mill, thereby increasing sheet widths while maintaining plate thickness tolerances (J. Kundu, 20147).

Dual head capability for faster panel welding

Our 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 (J. Kundu, 2016).

Superior mechanical characteristics

Friction Stir Welding 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 (J. Kundu, 2014)

Join dissimilar alloys

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

A green process

Friction Stir Welding 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. Friction Stir Welding also does not emit smoke, fumes, or gases that need to be exhausted on the back end (A. S. Babu, 2013; E. T. Akinlabi, 2012)

Conclusions

Friction stir welding 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, friction stir welding 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 friction stir welding process. Every process is running towards minimum waste and maximum environment-friendly. Friction stir welding bestows the environment-friendly solution for the manufacturing industry.

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