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A Comparison of Welding Techniques of Aluminium Alloys A Literature Review

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ABSTRACT

Welding of aluminum alloys is an important issue because of their increasing applications in industries. The most widely used joining methods for aluminium alloys are Tungsten Inert Gas (TIG), Metal Inert Gas (MIG), Variable Polarity Plasma Arc (VPPA) and Friction stir welding (FSW). However, the high conductivity, high reflectivity, high reactivity and high coefficient of thermal expansion make welding of aluminium alloys difficult. In this paper, the research and progress of a variety of welding techniques for joining Al alloys are reviewed. The aim of the paper is to review the recent progress in the welding of aluminium alloys to provide a basis for follow-up research.
Keywords: Aluminium alloys, welding techniques, TIG, MIG, FSW.

I. INTRODUCTION

Aluminium alloys are of particular interest in the design of lightweight fortification structures in applications such as aerospace, defense, locomotive, automotive and in energy sectors. The outstanding properties of aluminium such as low density, high specific strength, high specific energy absorption capability, good corrosion resistance and good thermal conductivity, formability, machinability, their non-magnetic nature and low cost are the reasons for their wide application.
As a part of the fabrication process, welding is one of the most important manufacturing technologies used in the aluminum alloy industry. The most widely used joining methods for aluminium alloys are Tungsten Inert Gas (TIG), Metal Inert Gas (MIG), Variable Polarity Plasma Arc (VPPA) and Electron Beam (EB) welding. These processes allow us to obtain optimum mechanical properties with minimum distortion due to the high heat intensities provided by these sources. However, the high conductivity, high reflectivity, high reactivity and high coefficient of thermal expansion make welding of aluminium alloys difficult. The high heat input associated with high thermal conductivity and high coefficient of expansion could lead to severe distortion of parts during welding. Careful control of welding parameters is a must to get a sound weld in aluminum alloys.

Compared to the above mentioned fusion welding processes that are routinely used for joining structural aluminium alloys, Friction Stir Welding process is an emerging solid state joining process in which the material that is being welded does not melt and recast. Therefore, when alloys are friction stir welded, phase transformations that occur during the cooling of the weld are of a solid state type. Due to the absence of parent metal melting, the new FS welding process is observed to offer several advantages over fusion welding. Compared to fusion welding processes, there is little or no porosity or other defects related to fusion. In fact, the industrial interest of this study is to evaluate the possible benefits of FSW compared to TIG, MIG considering the lower heat input of the solid-state joining process and the high stability of hardening particles.

Weldability of some aluminium alloys is an issue with the fusion welding processes. The 2000 series, 4000 series, 5000 series, 6000 series and 7000 series of aluminium alloys have different weldabilities. The fusion welding of aluminum alloys offered a great challenge for designers. The difficulties associated to welded joints are mainly related to the presence of an oxide layer, high thermal conductivity, solidification shrinkage, high solubility of hydrogen and other gases into molten state.

Many researchers have compared fusion welding and solid state welding processes for aluminium alloys and successfully represented that solid state welding has been better than fusion welding in terms of mechanical and metallurgical properties. A brief literature survey has been done here in effort to find a scope for further research work in this area.

II. LITERATURE REVIEW

Thomas (1997) focused on this study the relatively new joining technology, friction stir welding (FSW). Friction stir welding can be used to join most aluminium alloys and surface oxide presents no difficulty to the process. On the basis of this study it was recommend that number of lightweight materials suitable for the automotive, rail, marine and aerospace transportation industries can be fabricated by FSW.

Squillace et al., (2004) compared two different welding processes one is conventional tungsten inert gas (TIG) process and second is friction stir welding (FSW). A micro-hardness measurement allows pointing out a general decay of mechanical properties of TIG joints, mainly due to high temperatures experienced by material. In FSW joint, instead, lower temperatures involved in process and severe plastic deformations induced by tool motion allow rising of a complex situation: by a general point of view a slight decay of mechanical properties is recorded in nugget zone, flow arm and thermo-mechanically altered zone (TMAZ), while in heat-affected zone (HAZ), due to starting heat treatment of alloy under investigation, a light improvement of such properties is appreciated. In flow arm and in nugget zone, however, a light recovery of hardness, w.r.t. TMAZ zone, is recorded, due to the re-crystallization of a very fine grain structure.

Wang et al., (2008) reported the effect of welding processes (FSW and TIG) on the fatigue properties of 5052 aluminum-welded joints was analyzed based on fatigue testing. The results show that the fatigue properties of FSW welded joints are better than those of TIG welded joints.

Cabello et al., (2008) made a comparative study on microstructural and mechanical characteristics of fusion welds (TIG) and solid-state welds (FSW) of Al–4.5 Mg–0.26 Sc heat-treatable aluminium alloy. The corresponding mechanical properties are evaluated through micro hardness measurements and tensile tests. The effect of a post-weld heat treatment on both microstructure and mechanical properties is further examined. The results suggest that hardening precipitates are comparatively more affected by the TIG than by the FSW process. This results in a substantial reduction of mechanical properties of TIG welds.

Zhao et al., (2010) welded Al–Mg–Sc alloy plates by FSW and TIG welding. The effect of welding processes on mechanical and metallurgical properties of welded joints was analyzed. The results shown that the mechanical properties of FSW welded joint are much better than those of TIG welded joint. Moreover, tensile strength and yield strength of FSW joint are 19% and 31% higher than those of TIG joint, respectively. Due to the low welding temperature during FSW process and the excellent thermal stability of Al_3 (Sc, Zr) particles, the cold working microstructures can be well preserved.

Malarvizhi and Balasubramanian (2011) welded AA2219 aluminium alloy square butt joints without filler metal addition using gas tungsten arc welding (GTAW), electron beam welding (EBW) and friction stir welding (FSW) processes. The effect of three welding processes on fatigue crack growth behavior is reported. Transverse tensile properties of the welded joints were evaluated. It was found that the FSW joints are exhibiting superior fatigue crack growth resistance compared to EBW and GTAW joints. This was mainly due to the formation of very fine grains.

Zhen et al., (2011) made a comparative study of the mechanical and metallurgical properties of Al-Mg-Mn-Sc-Zr alloy weld joints prepared by FSW and TIG welding. The strength of FSW and TIG welded joints decreased as compared to the base metal but strength of FSW welded joints higher than the TIG welded joints. The loss of substructure strengthening and a very little loss of precipitation strengthening of Al3(Sc, Zr) cause the decreased strength of FSW welded joint. But for the TIG welded joint, the disappearance of both the strain hardening and most precipitation strengthening effect of Al3(Sc, Zr) particles contributed to its softening. At the same time, the grains in weld nugget zone of FSW welded joints were finer than those in the molten zone of TIG welded joints.

Anjaneya Prasad et al., (2013) experimented AA6061 joints welded by Metal Inert Gas (MIG) and Friction Stir

Welding (FSW). The FSW was carried out by 3 axis computer numerical controlled milling machine. semiautomatic welding machine MIG 350 carried out the MIG welding with the welding speed of 110mm per min. FSW showed 10-100 times smaller grains than the MIG welding in the microstructure of the weld joints. MIG welding produced the less tensile strength than FSW. The amount of heat input affected the weld material hardness and the width of hardness was determined by shoulder diameter and heat input. The FSW reduced production cost, pre operations and increased the weld quality.

S. Jannet et al., (2013) evaluated the mechanical properties of welded joints of 6061-T6 and 5083-O aluminum alloy obtained using friction stir welding (FSW) with four rotation speed (450, 560, 710 and 900 rpm) and conventional fusion welding are studied. FSW welds were carried out on a milling machine. The performance of FSW and Fusion welded joints were identified using tensile, hardness and microstructure. Better tensile strength was obtained with FSW welded joints. The width of the heat affected zone of FSW was narrower than Fusion welded joints welded joints. Properties FSW and Fusion Welded processes were also compared with each other to understand the advantages and disadvantages of the processes for welding applications of the Al alloy.

Baiju Sasidharanet al., (2014) compared DCSP (Direct current straight polarity) TIG welding and Friction Stir Welding (FSW on aluminium alloy AA2219 Comparative study on Tensile and Micro structural characteristics of welded joints obtained from DCSP TIGW and FSW revealed that the Ultimate Tensile Strength (UTS) of DCSP TIG welded joint was 257.48MPa and the UTS for FSW resulted 287.9MPa, which are 58.5% and 65.4% compared to the parent metal. Percentage elongation for FSW joint has also been found more than that of parent metal. From the microstructure study it is seen that FSW joints are having very less micro porosities compared to DCSP TIG welded joints.

Ashwani Kumar et al., (2014) performed TIG, MIG and FSW welding processes to weld aluminium alloy AA6061. FSW performed on vertical milling machine at 60mm/min welding speed, 0.69 kJ/mm heat input, 635 rpm of tool rotational speed, 16mm tool shoulder dia,7mm pin diameter, 4.7mm pin length, 20 degree tool tilt angle. The heat input in case of FSW is less than that of TIG and MIG welding processes. Among these three welding processes, in FSW heat input are 38% less as compared to TIG welding and 51.2% less as compared to MIG welding process. FSW joint efficiency is 19.4% higher as compared to TIG welded joints and 35.5% higher as compared to MIG welded joints. With the help of FSW as comparison to TIG and MIG, nice welds having higher joint efficiency with less heat input.

S. Navyashree et al., (2015) considered two different welding processes: a conventional tungsten inert gas (TIG) and friction stir welding (FSW) for the joining of commercial aluminium plates of 150X50X6mm of size. The results indicated that the microstructure of fiction weld is different from the tungsten inert gas welded joint. The tensile strength of weld joint in friction stir welding is more instead of tungsten inert gas welding. Hardness test of friction stir welding is more instead of tungsten inert gas where as in parent material also. From the observations in the project it is concluded that: Smooth surface finish can be obtained by using Friction stir welding with a tool having a smooth pin. The microstructure is studied and observed that the heat affected zone (HAZ) is well fused and free from nonmetallic defects.

III. CONCLUSION

This review reveals that the mechanical and metallurgical properties of welded joints are influenced by welding process. FSW joints show comparatively excellent mechanical & metallurgical properties when compared to TIG & MIG joints. Although most of aluminium alloys have been selected for research work. Still comparison of various welding techniques for aluminium alloys of 5xxx series have been selected by very few researchers.

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