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Mechanical Properties of Friction Stir Welded Cast Al–Mg–Sc Alloys

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Received: 9 September 2011 / Accepted: 26 December 2011 / Published online: 12 April 2012
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Abstract Friction Stir (FS) welding promises joints with low porosity, fine microstructures, and low vaporization of volatile elements compared with conventional welding techniques. FS weld was carried out on Vacuum Induction Melted 5 mm thick cast Aluminum-Magnesium-Scandium (Al–Mg–Sc) alloy plates. Microstructural evaluation revealed that due to FS welding, fine and fragmented dynamically recrystallized grains have been formed in the weld nugget. Tensile fracture occurred out side the weld zone. The tensile strength of the welded joint is more than the cast base metal. The hardness of the FS welded joint is less than the hardness of the cast base metal. The minimum hardness was located on the retreating side of the weld. These results clearly show that FSW process is amenable to join cast Al–Mg–Sc alloy.

Keywords Friction stir welding · Mechanical properties · Cast Al–Mg–Sc alloys

1 Introduction

Non heat-treatable aluminum–magnesium alloys with 1–6% Mg have been used in welded structures for a long time now. The advantage of these alloys is their good weldability which allows production of welded joints without cracks and pores, and strength equal to about 90% of the base metal strength in the as-annealed condition. The main disadvantage of these alloys is their low strength compared to precipitation-hardened aluminum alloys. Investigations performed during the last 4 decades have indicated that the strength of Al–Mg alloys can be significantly improved by alloying with Scandium [1–5]. Scandium combines with Al to form a stable L12 phase Al3Sc precipitates. Despite the relatively low solubility of Sc and, hence, limited volume fraction of the Al3Sc phase, it produces a significant strengthening effect. The FS welding process has several advantages when compared with fusion welding processes, mainly with regard to the welding of aluminum alloys. Difficulties related to the sensitivity to solidification cracking and the formation of porosity due to absorption of hydrogen during welding and thermal distortion, which are very common in fusion welding processes [6–7], do not happen in FS welding process. In addition, lower peak temperature results in lower residual stress [8].

FS welding is a promising process that can produce high quality, low cost joints [9]. This welding process is being extensively studied in order to weld various types of wrought aluminum alloys, especially non-heat-treatable aluminum alloys [10–23]. The FS welded joint analysis was reported by various investigators on wrought Al–Mg–Sc alloys [24–26]. The FS welding process schematic diagram is shown in Fig. 1.

In this study, a Cast Al–Mg–Sc was selected as the experimental material to demonstrate the feasibility of
Comparative evaluation of tungsten inert gas and laser beam welding of AA5083-H321

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MS received 8 November 2011; revised 25 June 2012; accepted 18 July 2012

Abstract. In this study, the bead-on-plate welds were made on AA5083-H321 alloy plates using both tungsten inert gas (TIG) welding and laser beam (LB) welding processes to study the enhancement of mechanical properties such as weld yield strength and hardness. The low heat input of laser beam welding effectively reduced the size of the fusion zone and heat affected zone compared to tungsten inert gas welding process. High speed LB welding and fast heating and cooling of LB welding process hinders grain growth compared to TIG welding process. The effect of vaporization of volatile alloying elements is also considered. It seems that magnesium evaporation is relatively less in LB welding compared to TIG welding. Tensile testing of the welded joints revealed that LB welding results in superior mechanical properties. It is concluded that LB welding process is more suitable to join AA5083-H321.

Keywords. Aluminum alloys; laser beam welding; mechanical properties; vaporization.

1. Introduction

Aluminum and its alloys are widely used in the transportation, aircraft, and marine industry where lightweight, corrosion resistance and high fatigue strength are the desired properties. In 5000 series aluminum alloys, the chief alloying element is magnesium (Howard et al 1969), one of the most effective and widely used additives for aluminum. Magnesium up to approximately 5%, as an alloying element in aluminum gives a strong highly weldable alloy. Manganese may be used with magnesium to increase alloy strength. The alloys in this series have good corrosion resistance, as well as high strength, which give them fine qualities for structural members.

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Comparison of Tungsten Inert Gas and Friction Stir Welding of AA 5083- H321 Aluminum Alloy Plates

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Abstract

Aluminum-Magnesium alloy AA5083 is used extensively as a structural material in aerospace, automobile and marine applications. Fusion welding processes such as metal inert gas (MIG) welding and tungsten inert gas (TIG) welding are widely used in fabrication of this alloy. Fusion welding processes generally result in lower joint efficiencies mainly due to defects such as porosity, large columnar grain structure, loss of strain hardening effect in fusion zone and heat affected zone and loss of magnesium due to evaporation. Friction Stir (FS) welding is a solid state welding process which has been proved to solve the above mentioned problems. In this study, Round-cu-Plate (RoP) tests were made on 5 mm thick plates of AA5083 using both tungsten inert gas and friction stir welding processes. Studies using light microscopy revealed that FS welding results in finer grains in the weld zone. Tensile testing of the joints revealed that FS welding results in superior tensile properties compared to TIG welding process. The drop in hardness in the weld zone is higher for the TIG welding. The depletion of magnesium due to evaporation in the fusion zone of TIG welds were found to be significantly higher compared to that in FS welds. It is concluded that Friction Stir Welding process resulted in significantly stronger joints and is more suitable to join AA5083.

Keywords

Al-Mg alloys; TIG welding; FS welding; Grain Refinement; Evaporation.

Introduction

In the TIG welding process, the arc and the weld are protected from atmospheric contamination by a gas shield, and an electric potential is established between the electrode and the work piece causing a current flow, which generates thermal energy in the partially ionized inert gas. Defects like, porosity, loss of strain hardening in the fusion zone, as-cast coarse microstructure, hot cracking in fusion zone due to segregation of alloying elements during solidification, results in the decrease of mechanical properties. FS welding is a solid-state joining process that enables welding hard-to-weld metals such as high-strength aluminum alloys. Friction-stir welding was developed and patented by The Welding Institute (TWI) in 1991 [1]. Since then the research efforts to understand the micro and macro mechanics of the process are continuous. During FS welding, no melting occurs, and as a result the process is performed at much lower temperatures than conventional welding processes. This has a direct impact on the safe application of the FSW to the environment.

In the conventional TIG and laser welding processes, dendritic structure develops in the fusion zone that leads to a drastic decrease in strength which is one of the major mechanical properties [2]. The FS welding process is a solid-state welding process, therefore the solidification microstructure is absent in the welded metals and the presence of brittle inter-dendritic and eutectic phases is avoided [3, 4].

The mechanical properties of various aluminum alloys during MIG, TIG and FSW were studied and their performances were investigated [5-8]. Taban and Kahuc [9] studied the microstructure and mechanical properties in Mg, TIG and FSW welded joints for 5083-H321 aluminum alloy. Zhou et al [10] investigated the fatigue properties of Mg-Pulse and FSW joints in 5083 Al-Mg alloy.

Though research work of comparative study of FSW with other welding techniques have been reported, it appears that systematic study and detailed comparison between FSW and TIG welding for AA5083-H321 aluminum alloy has not been reported yet. In this work, a study of the mechanical properties of BoP FS welded joints of AA5083-H321 alloy was carried out. For comparison, TIG BoP welds of the same alloys were also performed and tested. Tensile tests and Micro hardness measurements of weld joints and base materials were performed in order to determine the influence of each welding process on the mechanical properties. Microstructure was examined and correlated with the macroscopic mechanical behavior.
Effect of Welding Speed on CO₂ Laser Beam Welded Aluminum-Magnesium Alloy 5083 in H321 Condition

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Keywords: Laser beam welding, Aluminum alloys, Joint performance, Welding speed, Intermetallic compound.

Abstract. Laser beam welding of aluminum alloys is expected to offer good mechanical properties of welded joints. In this experimental work reported, CO₂ laser beam welding at 3.5 kW incident power was conducted autogenously on 5 mm thick 5083-H321 aluminum alloy plates at different welding speeds. The mechanical properties and microstructural characteristics of the welds are evaluated through tensile tests, micro-hardness tests, optical microscopy and scanning electron microscopy (SEM). Both yield stress and tensile strength of the laser beam welded joint at the optimum welding speed were 88 % of base metal values. Experimental results indicate that the tensile strength and hardness of laser beam welds are affected by the variation of the intermetallic compounds.

Introduction

Al-Mg alloys with Mg levels ~ 3 % are extensively used in large welded constructions such as storage containers, vessels for land and marine transportations. In particular, the AA5083 alloy plates in the soft and work hardened tempers are used in the construction of marine vessels such as ships, catamarans, high speed crafts. The main reason for the versatility of the AA5083 alloy is that it provides the best available combinations of high strength (both at ambient and cryogenic temperatures), light weight, corrosion resistance, bendability, formability and weldability.

Low welding speeds, large heat-affected zones and fusion zones, high shrinkages, variations in microstructures and properties, evaporative loss of alloying elements, high residual stress, and distortion joints of MIG and TIG welding processes have caused attention to be drawn toward laser welding [1] due to its numerous advantages such as a narrow affect weld zone, low contamination risk by unwanted components during welding, good quality of joints, lowest porosity in the fusion zone, low heat-affected zone and no-cracks, ease of automation, and high production speed.

The quality of the weld joint is affected by different laser processing parameters. There are many laser welding parameters affecting the welding quality such as laser power, welding speed, focal position, shielding gas flow, and laser pulse frequency. The ideal weld bead can be formed by selecting the process parameters properly. When the process parameters are incorrectly chosen, many defects appear such as an unstable weldpool, substantial spatter, tendency to drop-through for large weld pools, sag of the weld pool, undercut, porous oxide inclusions, loss of alloying elements, liquation, and solidification cracking.

Laser welding studies related to aluminum-magnesium alloys 5052, 5754 and 5083 were conducted by many researchers [2-6]. The influence of laser power on the properties of butt welding of laser welding of AA5083 was analyzed using a 2.5 kW high power CO₂ laser [3]. Recently, for comparative evaluation of TIG and LB welding, LB welding was done in the 3.5 kW CO₂ laser beam welding machine [5].