EFFECT OF FOCAL POSITION ON CO_2 LASER BEAM WELDED AL-MG-MN ALLOY

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ABSTRACT

The mechanical characteristics of the laser beam welded joints mainly depend on the power input and the welding speed. The heat input to the material to be welded depends on many welding parameters, such as welding speed, laser power, and type of the shielding gas used, focal position, gap size and the flow rate. Hence it is very important to select a suitable welding speed and focal position to obtain the required mechanical characteristics for the joints. In this paper, the effect of focal position on the mechanical properties of AA5083-H321 aluminum alloy laser welded joints has been studied. Macrostructural examinations show that the fast heating and cooling cycle produced by the laser welding process leads to a narrow heat affected zone. The mechanical properties of the welded joints were evaluated using tensile test and microhardness test. The results indicate that this alloy can be autogenously laser beam welded with full penetration and minimum surface discontinuities. The optimization of the focal position was achieved.

***Keywords**: Laser beam welding; Aluminum alloys; Joint performance;*

INTRODUCTION

Aluminum alloys have many favorable mechanical properties, namely, a high strength-to-weight ratio, excellent formability, light weight, corrosion resistance etc. Furthermore, the aluminum alloy components are easily recyclable [1]. Aluminum alloys are extensively used in the fabrication of transport vehicle components used in automobile, marine and aerospace applications.

Traditionally, the welding of vehicle components or structures was generally performed using Metal Inert Gas (MIG), Tungsten Inert Gas (TIG) and electrical resistance welding. Compared with MIG and TIG, Laser Beam (LB) welding has the advantage of a substantially higher welding speed, under heavily reduced thermal loads.

Some investigations can be found regarding the study of mechanical properties and formability or the laser welding characteristics of the bead on plate or butt welding processes on aluminum alloys [ ]. The effect of welding speed, focal position, laser incident power, vaporization of volatile elements on various automotive aluminum alloys were reported in the literature [ ].

Recently, 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 CO_2 laser [32]. It has been reported that many welding parameters, such as welding speed, laser power, and type of the shielding gas used, focal position, gap size and the flow rate influence the mechanical properties of laser beam welded joint.

The focal plane position is the placement of the focal spot or minimum waist diameter to the workpiece surface. Straying outside the depth of focus in relation to the workpiece is unwise because small deviations cause large variations in beam diameter, especially with low F numbers, where the beam divergence angle is large [19]. Focusing the laser beam above the workpiece (positive defocusing) produces more plasma that defocuses the beam and reduces the irradiance on the surface, but the keyhole is inherently more stable at positive defocusing [30]. The placement of the laser beam focus on or below the surface of the workpiece can optimize the laser beam coupling to the material and increase the irradiance inside the weld pool [15 & 20].

The present study investigates the influence of the focal position on the mechanical properties of the AA5083-H321 aluminum alloy welds commonly used in the fabrication of marine structures.

EXPERIMENTAL PROCEDURES

In the present work, LB welding was applied to 5 mm thick plates of non- heat treatable aluminum alloy AA 5083-H321 plates using CO_2 laser. A diffusion cooled slab 3.5 kW CO_2 laser welding system was used. Bead-on-plate welds with full penetration were performed. The welds were made using a CO_2 laser on the aluminum plates at a speed of 3.5 m/min. Helium was used as shielding gas with a flow rate of 20 liters/min. The experiments are conducted using LB incident power value of 3.5 kW.

After welding, the joints were cross-sectioned perpendicular to the welding direction for metallographic analysis and tensile tests using an EDM cutting machine. The mechanical properties of the joint were measured by tensile tests. The configuration and size of the transverse tensile specimens were prepared according to ASTM-E8 standard.

The cross-sections of the metallographic specimens were polished with alumina suspension, etched with Keller's reagent for about 10 seconds, and observed by optical microscopy. Micro structural characterization of the weld was performed using conventional metallographic techniques, optical microscopy, and scanning electron microscopy.

Table.1 Mechanical properties of AA5083-H321.

Proof Stress, MPa	Tensile Strength, MPa	Elongation, %	Hardness, Hv1
261	292	26.4	77

Table.2.Welding conditions used

Laser output power, kW	3.5
Shielding gas consumption	Helium
Gas flow rate, l/min	20
Focal position, mm	0 (on the surface), -1mm, -2mm and -3mm below the surface
Welding speed, m/min	3.25, 3.50, 3.75, 4.25

RESULTS AND DISCUSSIONS

3.1.1. Effect of Focal position on Macrostructure:

The macrographs of the four laser beam welded joints at the four different focal points were shown in Figures 3 to 6. It has been observed that all the four welds containing pores in the weld zone. The size of the pore is increasing when the focal point is moving away from the surface of the plate. The weld is partially penetrated in the case of focal point below 2 mm of the surface of the plate.

In the previous section, the focal point was adjusted to be at the top surface of the specimen which means zero defocusing distance. In order to clarify its effect on both penetration depth and mechanical properties, the defocusing distance was varied between -3 and 0 mm. Full penetration was obtained when the laser beam was focused on the surface. However, acceptable weld profile was obtained with shifting the focal point below the specimen's top surface by 1mm. Increasing the defocusing distance out of this range resulted in a remarkable decrease in penetration depth. This is due to sharp decrease in the laser beam power density at the specimen's top surface. The laser welds with focusing distances 2mm and 3mm below the top surface were not fully penetrating the plate.

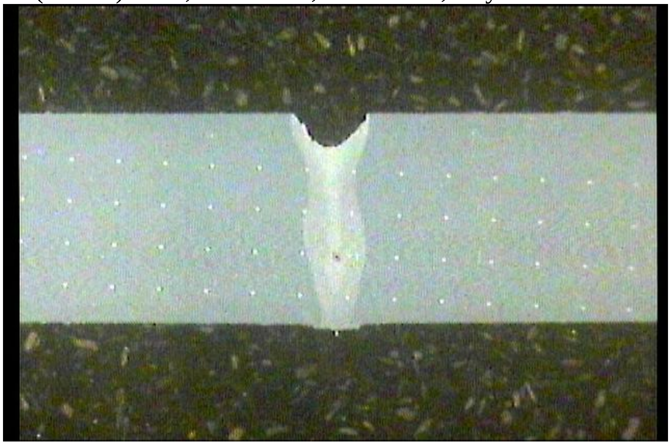

Fig.1. Macrograph of LBW with the focal point on the surface of the plate

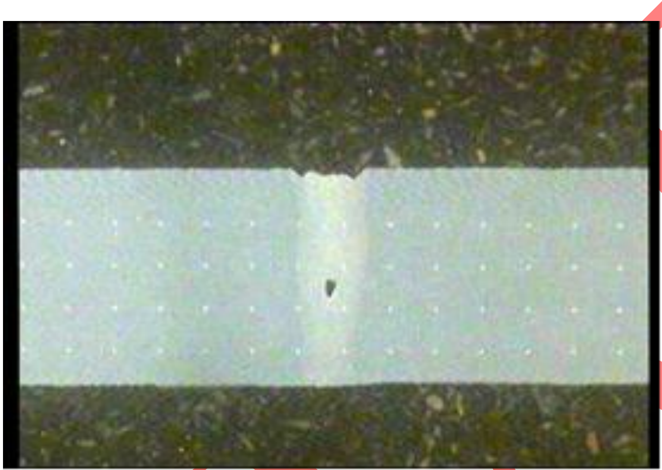

Fig.2. Macrograph of LBW with the focal point 1 mm below the surface of the plate

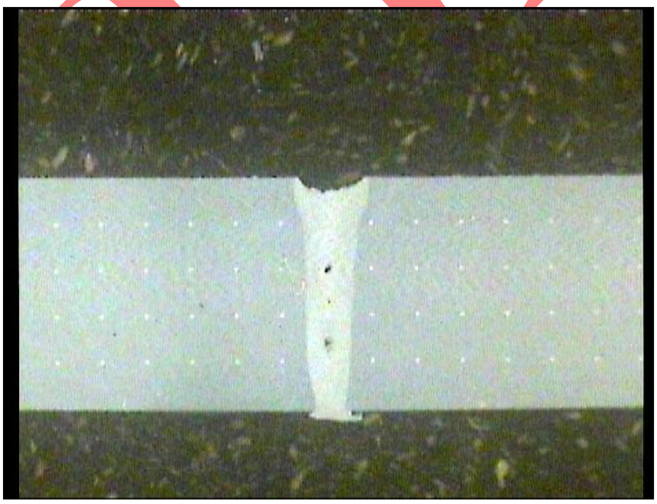

Fig.3. Macrograph of LBW with the focal point 2 mm below the surface of the plate

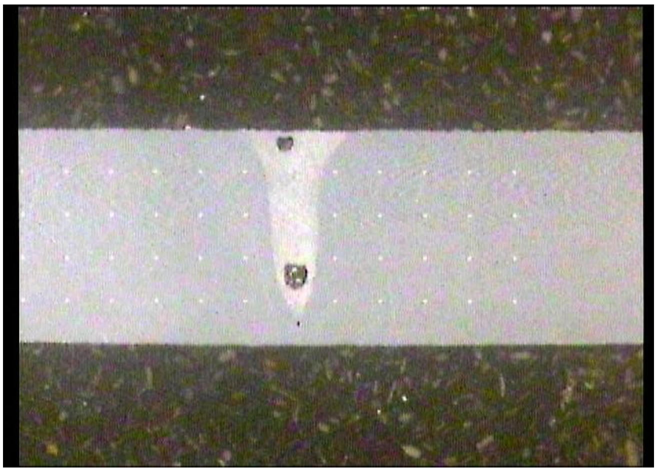

Fig.4. Macrograph of LBW with the focal point 3 mm below the surface of the plate

3.3.2. Effect of Focal position on Porosity:

Porosity is a very important parameter to evaluate the quality of a welded joint since it is recognized to be one of the major concerns during laser welding of aluminum alloys and it has been widely documented to be harmful to the tensile properties of the welds. Pore formation is attributed to the entrapment of gas bubbles due to imperfect collapse of the keyhole either caused by insufficient laser beam energy or because of the turbulent flow in the weld pool generated by too high a laser intensity.

All the welds performed at 2500 W exhibited porosity less than 3 % corresponding to tensile strengths well above 80 % of the base metal. Only a small decrease of the tensile strength has been observed as far as the welding speed was slowed down, probably due to aforementioned larger loss of magnesium. The tensile strength drops below 80 % when porosity is higher than about 5 % because of a reduction in cross-sectional area. The highest levels of porosity have been achieved when operating at 2000 W, when the incident laser power is likely insufficient to keep the keyhole steadily open, thus determining its collapse and the consequent bubble entrapment. [Ancona]

Previous studies[ ] have reported that the main reason for porosity formation in the laser welding of aluminum alloys is the entrapment of gas bubbles, including vaporized alloying elements, shielding gas and environmental air, caused by the instability and collapse of the keyhole during welding. Therefore, if a higher vaporized ratio of low boiling point elements occurs during the welding process, more metal vapor will be trapped in the weld pool, and the formation of bubbles will be increased, resulting in a greater porosity. The average content of the highly volatile Mg element retained in the weld may provide an indication of evaporative loss.

3.5.2 Effect of Focal position on Tensile Properties:

The tensile properties of the welded joints with various focusing points were given in Table.5. The welds with focal position at 2mm and 3mm below the surface tensile properties were better than the other two. This is because of the combined strength of the partially penetrated weld as well as part of the base metal.

The threshold power density for keyhole formation is lower at negative defocusing than at positive defocusing [23]. Therefore, the weld pool size at negative defocusing is larger than that for the same extent of positive defocusing at a given power and spot size. By slightly focusing the beam below the surface of the material, welding speed could be increased at the same penetration depth than the beam focused at the material surface [35].

CONCLUSIONS

5 mm thick plates of aluminum alloy AA5083-H321 were autogenously bead-on-plate welded using the CO_2 laser beams with full penetration. The mechanical properties of the laser beam welded joints were less than the mechanical properties of the base metal.

The best mechanical properties were obtained when the laser beam was focused on the top surface and also 1 mm below the top surface.

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