A Study on the Weldability for fillet joint of light weight alloy 5mm Al 5083 using Hybrid(CW Nd:YAG Laser+MIG) Welding

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KEY WORDS: Aluminum alloy, Shipbuilding, Hybrid (CW Nd:YAG laser + MIG) welding, Leading process, Welding speed, Joint efficiency.

ABSTRACT: *The application of aluminium alloy is increasing for lightweight and high quality transport vehicle. In this study, therefore, it is intended to apply the high speed hybrid welding method for marine grade aluminium alloy (A5083) used for shipbuilding that consists of 3 kW CW Nd:YAG laser and MIG welding process. For this purpose, the characteristics of process parameters (laser & arc combine angle and focal position of hybrid head to specimen)are investigated for hybrid fillet joint. This study also describes determination of heat distribution using finite element model of the T-joint fillet weld using the in-house solver which has been validated for different type of welding problems.*

1. Introduction

Since the weight reduction of vehicles strongly required, the production of high-strength aluminium alloy is continuing to increase. In particular, the aluminium- magnesium (Al-Mg) alloy sheets are widely used in car industries and ship building, replacing steel sheets and fibre reinforced plastic panels, due to their excellent properties such as high strength, corrosion resistance and weldablity. In this study, the laser-arc hybrid welding was applied to develop and apply alternative fusion welding process for aluminium alloy. For this purpose, the characteristics of process parameters (laser & arc combine angle and focal position of hybrid head to specimen)are investigated for hybrid fillet joint. Relation between process parameter and profile of cross section area also investigated with the characteristics of optical aspects of welds formed by hybrid welding(HAZ and weld metal microstructures). Reliability assessment and verification of the welding design and construction criteria for welds formed by hybrid welding are conducted through the experiment.

2. Experimental Procedure

For the experiment, 3 kW Nd:YAG laser was used together with conventional welding equipment consisting of a welding mode DAIHEN Corporation 500A A6442. The MIG torch was connected close to the laser focusing optic at an angle of about 55°. Shielding gas was supplied through a MIG torch located at the side of laser head. Laser beam was irradiated perpendicularly to the surface of specimen. Experimental setup for CW Nd:YAG laser, MIG and hybrid welding is shown in Fig 1. And the other parameters concerning the experimental setup are shown in Table 1. A specimen size of 100 mm wide and 250 mm long & 5 mm thickness were used. The surface of specimen was cleaned using Acetone.

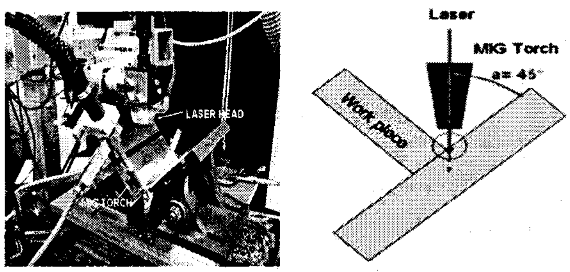

Fig 1. Principle of experimental set-up focal angle of incident for laser & arc

Table 1. Range of welding parameters

Laser welding	MIG welding	Hybrid welding
P_W = 2.76 kW fd = 0 mm Focal length: 223 mm Shielding gas: Ar 30 L/min Ws = 500~1000 mm/min	I = 194 A E = 23.2 V MIG torch angle: 45° WFS: 6m/min Wire diameter: 1.2 mm Polarity: DCEP Shielding gas: Ar 30 L/min Ws = 500~1000 mm/min	*[Laser welding condition + MIG welding condition]* - Leading process: L+M, M+L - Ws = 500~1000 mm/min - LAD = 1, 3, 5 mm

In this study, for the initial test, the angle between Hybrid head and flange angle was kept 45 degrees and incidence position was a contact line. The gap size was approximately zero mm with considering gap tolerance.

3. Numerical Analysis

For the analysis, the system is divided into many elements by fine mesh. The mesh model generated consist of Nodes = 4411 and elements = 4000. The temperature dependent material properties of A5083 have been used. The temperatures of all the wall elements are specified as boundary condition and temperature of the weld zone is given as heat input in (cal/mm) to the weld zone elements. The heat input in the weld zone is dissipated via conduction in to the work piece. A specialized finite element code has been used to analyze this heat conduction process in this Hybrid welding. After the analysis the temperature distribution and the thermal history of the nodes has been determined using which residual stress distribution could be calculated.

4. Result and Discussion

4. 1 Weld beads appearance and geometry

In the case of MIG welding for fillet joints, welding speed about 1000mm/min is too fast to form sufficient weld bead shape. Furthermore, web and flange were not welded completely because of complete fusion. However, the 600 and 700mm/min were quite good for making proper weld bead except proper throat size and leg length. Even if laser welding has benefits for inducing good welds it is really difficult to make good joint design as aspects of structure and strengthen due to not enough throat size and leg length. There were two cases of hybrid welding like laser leading and MIG leading conditions. Many previous research reports, generally, mentioned that laser leading process causes good welds except gap bridging condition. As below figure (exp. No 220906-01), laser leading process has less contamination and spatter because laser induce plasma near the molten pool is effective in stabilizing the arc. In MIG leading case, occurrence of contamination and spatter were increased as compared with laser leading condition. Moreover, it seems to be humping beads because welding speed was too fast with strong arc force and incomplete fusion.

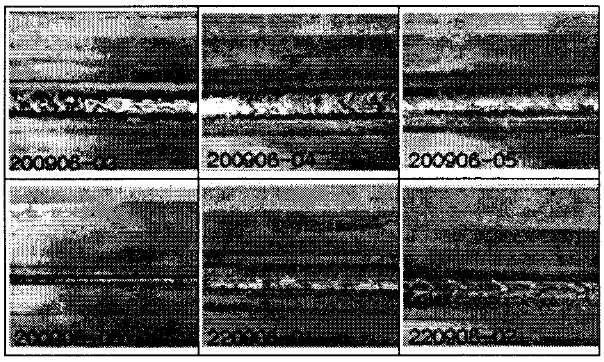

Figure 2. Bead shapes of fillet joints by each welding process; No.200906-03 MIG in 1000mm/min welding speed, No. 200906-04 MIG in 700mm/min welding speed, No. 200906-05 MIG in 600mm/min welding speed, No. 200906-06 Laser welding, No. 220906-01 Laser-arc hybrid welding, No. 220906-02 Arc-laser hybrid welding.

From the results of cross section, all the specimens had incomplete penetration, because of MIG pulsing which occurs due to the energy of heat input only used for wire melting. Therefore, those specimens are hardly welded. From the structural strength point of view, the leg length and throat size for fillet joints are very important. However, the laser welding of fillet joints, especially, was not sufficient for leg length and throat size of fillet joints. There were almost zero throat sizes and unclear leg lengths. In the comparison between MIG processes and Hybrid welding processes, the throat size of MIG case are slightly bigger than Hybrid case due to the less surface tensile force and viscosity of melted aluminium. Even though hybrid processes have smaller throats than MIG processes there were better penetrations.

In the hybrid welding case, the interaction of laser beam and arc induced a quite good penetration for fillet joints than other cases. And also a chink between web and flange induct molten pool moving because of the less viscosity and density of the chink part. However, as below figure(exp. No 220906-02-2), MIG leading process has many pores.

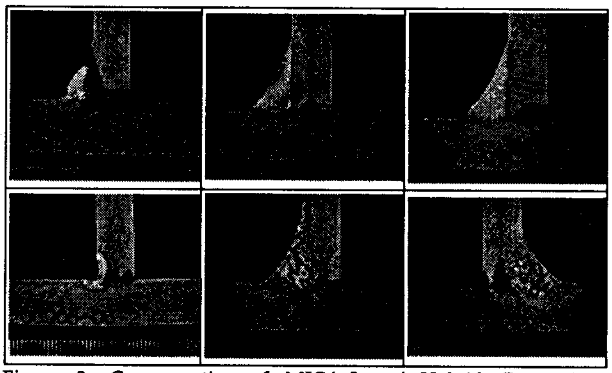

Figure 3. Cross section of MIG/ Laser/ Hybrid (Laser+Arc, Arc+Laser) fillet joints No.200906-03 MIG in 1000mm/min welding speed, No. 200906-04 MIG in 700mm/min welding speed, No. 200906-05 MIG in 600mm/min welding speed, No. 200906-06 Laser welding, No. 220906-01 Laser-arc hybrid welding, No. 220906-02 Arc-laser hybrid welding.

4. 2 Simulation of welding heat distribution

Peak temperature experienced at specific position during welding in one of the important factors that determines the material microstructure and therefore mechanical properties of the welded joint. Fig. 4 shows the maximum temperatures and temperature contour obtained from the numerical modeling of Laser welding, Laser leading and Arc leading Hybrid welding.

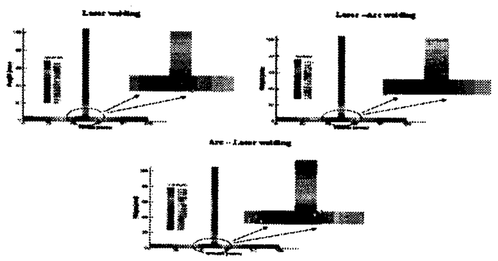

Figure.4 Thermal distribution of the Nd:YAG Laser welding, Laser-Arc welding, Arc-Laser welding

Fig. 5 show the temperature history of all the 3 case. The duration of remaining at high temperature or the cooling rate varies in all the 3 cases. This variation will have effect on the micro structural formation and results in different joint mechanical properties and distortion behavior of T-fillet joint of all the three cases.

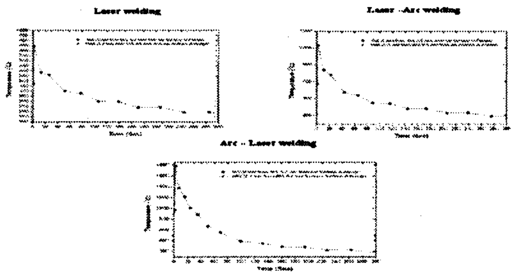

Figure.5 Thermal history in Nd:YAG Laser welding, Laser-Arc welding, Arc-Laser welding.

5. Conclusion

Nd:YAG laser and MIG arc hybrid welding on fillet joints of 5mm Al 5083 alloy are considered as follows.

1.Although the welding speed of laser is high enough complete the productivity demand, in fillet joints case, not enough throat size and leg length are the main quality problems.

2.Compared with laser welding and MIG, penetration depth in laser-arc hybrid welding is greatly increased due to improvement of laser beam absorption. Furthermore, laser beam produces a stabilized arc in hybrid welding and have smaller throats than MIG processes but there were better penetrations.

From the numerical simulation the maximum temperature value and the cooling time for all the three cases has been found different and its effects on the microstructure distribution has been observed and validated experimentally.

6. References

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