Development of CO2 Laser-Arc Hybrid Welding Technology in KITECH

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1. Introduction

The laser-arc hybrid welding technology introduced in the late 1970s has many advantages due to its high welding speed, low distortion, deep penetration and gap bridging ability. In recent years, with the development of high power industrial lasers, the laser-arc hybrid welding has been considered to be an effective way to improve the productivity of shipbuilding industry. KITECH (Korea Institute of Industrial Technology) initiated the CO2 laser-arc hybrid welding project in 2003 under support of Korean government and organized the laser hybrid welding consortium comprising research institutes, universities and major heavy industries in 2004. In this project, the investigation of KITECH is oriented to the process development and some fundamental approaches for the simulation, monitoring and evaluation of welding phenomena and weldments have been carried out by collaborative universities. The material and the types of joints were determined upon demand of shipbuilding industries and the objectives of the process development such as welding speed and gap tolerance were also decided in the consortium. The scopes of our investigation are following:

(a) To investigate the influences of process parameters on welds

(b) To develop welding procedures for CO2 laser-GMA hybrid welding of butt and fillet joints in 8mm thickness – shipbuilding A-grade steel.

(c) To select the process parameters to ensure 1.5 m/min welding speed for butt welding with up to 2mm joint gap.

(d) To find the process parameters robust to the joint gap variation (optional).

2. Experimental setup

The laser-arc hybrid welding has three kinds of process parameters: arc welding, laser welding and hybrid welding parameters. To control these parameters and ensure the repeatability, the following equipments were used.

(1) 12kW CO2 laser

(2) Fully digitized inverter arc welding power source (500A)

(3) 3 axis Cartesian manipulator driven by servo motors

(4) 4 axis hybrid welding head

(5) High speed camera and CCD camera to monitor the droplet transfer, molten pool behavior and plasma formation

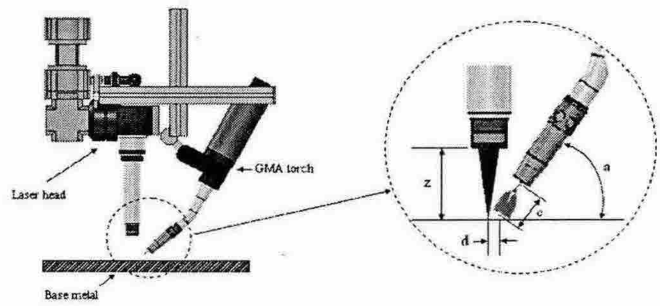


Fig. 1 Experimental setup and parameter definitions for CO2 laser-GMA hybrid welding

The edges of specimens were milled before experiments for BOP(Bean-On-Plate), I-square butt and fillet welding.

3. BOP welding

BOP welding experiment were conducted to select the adequate welding parameters for butt joint welding and analyze the influences of various welding parameters on welding phenomena and bead shape. Table 1 shows the welding parameters selected after extensive investigation for BOP welding. The distance between laser spot and electrode (which is called "separation" in this paper) is an important parameter which can affect the droplet transfer, depth of penetration and undercut formation. The shielding gas composition is also a dominant factor for the welding phenomena. For example, the impinging droplets were deviated by pressure from the laser keyhole in zero separation, as shown in Fig. 2, which results in asymmetric cross-sectional beads. In the cases of more than 6mm separation, the solid walls indicated in Fig. 3 were elongated, which causes undercuts on the boundary of weld bead.

Table 1 Welding conditions used in experiments

Focal length, z		250mm
Laser head angle		90 deg.
Wire feed rate		12 m/min
Welding voltage		31.5 V
Torch angle, a		59 deg.
Contact tube to work distance, c		18 mm
Travel speed		1.5 m/min
Distance between laser spot and electrode, d		4 mm
Electrode diameter		1.2 mm
Shielding gas	Type	He:50%, Ar:38%, CO2:12%
	Flow rate	50 l/min

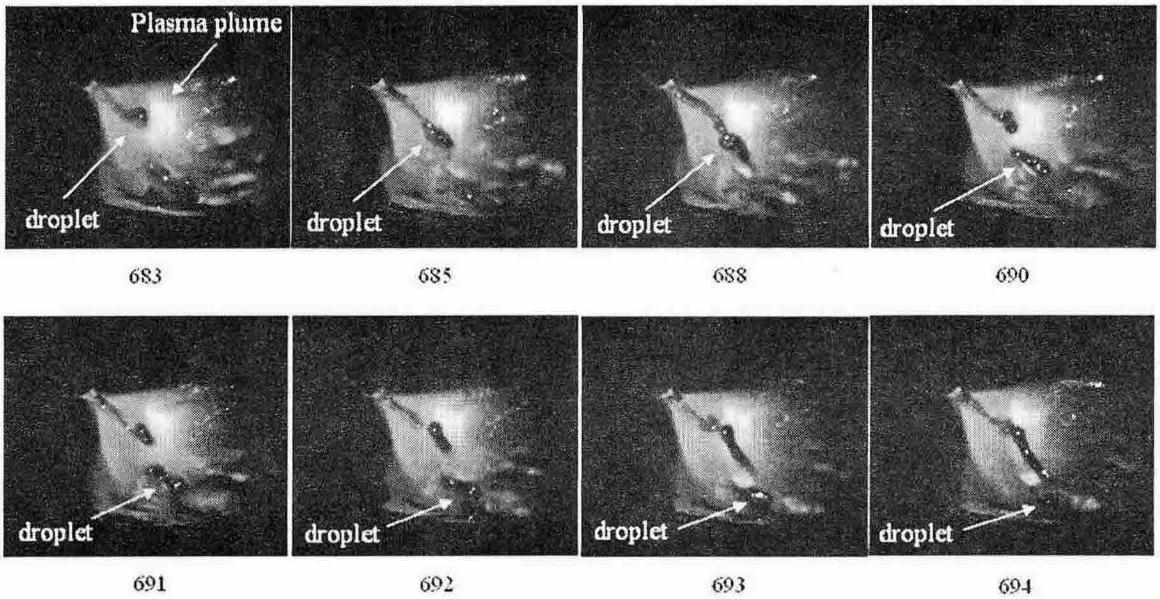


Fig. 2 Phenomena of hybrid welding with zero separation

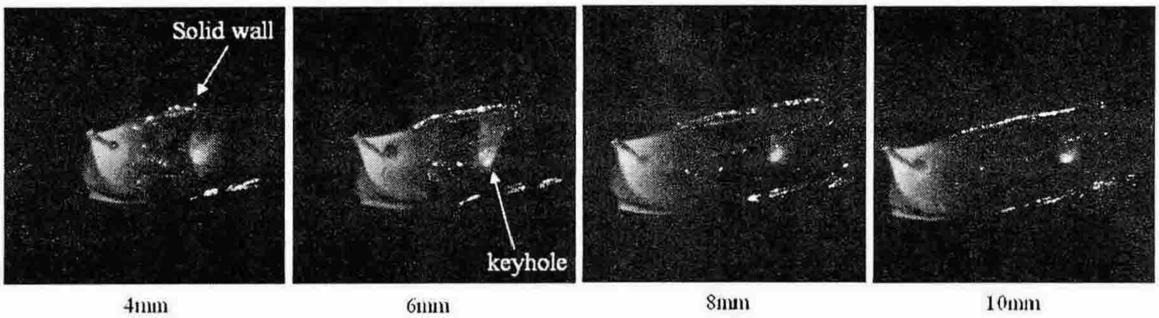
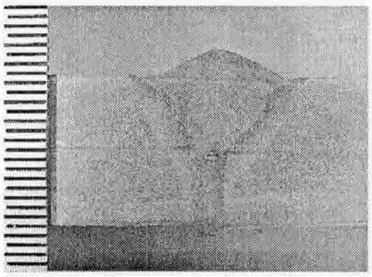


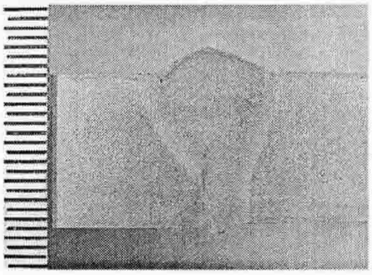
Fig. 3 Phenomena of hybrid welding with variable separation from 4mm to 10mm

4. Butt welding with joint gap

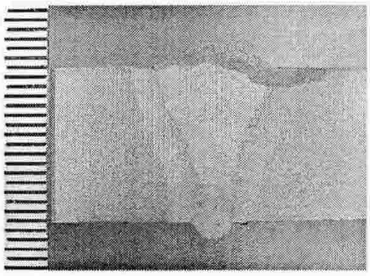
For butt welding with joint gap, the arc welding parameters were controlled as the welding speed and laser parameters were fixed. The wire feed speed should be increased to bridge joints gap but the increased arc pressure due to high welding current may cause the geometrical imperfections such as undercut and underfill. The welding voltage and CTWD (contact tip-to-work distance) were controlled to avoid such imperfections. In butt welding with up to 1mm joint gap, the sound beads could be achieved by control of wire feed speed and welding voltage. The CTWD control was inevitable for welding with 1.5mm joint gap, which can increase complexity of hybrid welding head. The CTWD control and 1.4mm diameter welding wire were used together to fill 2.0mm joint gap and avoid the underfill. Fig. 4 shows some cross-sectional bead shapes for various gaps.



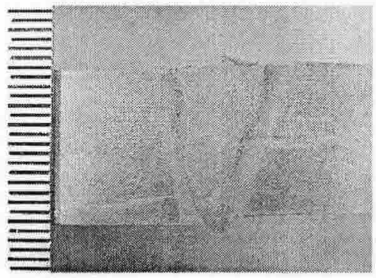
(a) no gap, 340A, 31.5V



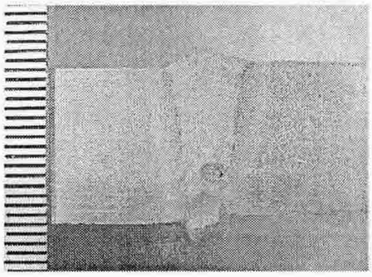
(b) 0.5mm gap, 340A, 25V



(c) 1.0mm gap 420A, 300V



(d) 1.5mm gap, 440A, 25V, CTWD 32mm



(e)2.0mm gap, 1.4mm dia. wire, 420A, 20V, CTWD 34mm

Fig. 4 Bead cross-sections for butt welding with variable joint gap up to 2mm

5. Fillet welding

The parameter optimization for fillet welding is still going on. The influence of welding parameters on the welding phenomena, gap bridging ability and bead shapes will be investigated. Fig. 5 shows one of cross-sections made by hybrid fillet welding.

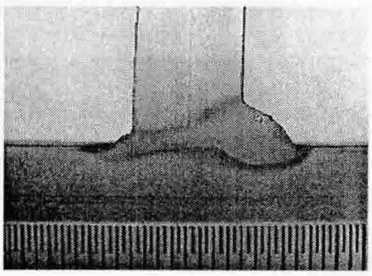


Fig. 5 Bead cross-section for fillet welding

6. Conclusion

The hybrid welding procedures were successfully developed for butt welding with joint gap and the procedure for fillet welding is also being developed. The sound weld bead without geometrical imperfections could be achieved in butt joint with up to 2mm joint gap. Moreover Nd:YAG laser-GMA hybrid welding and laser-controlled arc hybrid welding will be covered by this project. It is anticipated that Nd:YAG laser-GMA hybrid welding can increase flexibility of the process due to optical fiber transmission and laser-controlled arc hybrid welding can increase gap bridging ability without CTWD control.