ELSEVIER
Available online at www.sciencedirect.com
SciVerse ScienceDirect
Physics Procedia 41 (2013) 140 – 143
Physics Procedia

Lasers in Manufacturing Conference 2013

Autogeneous laser and hybrid laser arc welding of T-joint low alloy steel with fiber laser systems

A. Unt[a*], E. Lappalainen[a], A. Salminen[a,b]

[a] *Lappeenranta University of Technology, Laboratory of Laser Processing, Tuotantokatu 2, Lappeenranta 53850, Finland*
[b] *Machine Technology Centre Turku Ltd, Lemminkäisenkatu 28, FI-20520 Turku, Finland*

Abstract

This paper is focused on the welding of low alloy steels S355 and AH36 in thicknesses 6, 8 and 10 mm in T-joint configuration using either autogeneous laser welding or laser-arc hybrid welding (HLAW) with high power fiber lasers. The aim was to obtain understanding of the factors influencing the size of the fillet and weld geometry through methodologically studying effects of laser power, welding speed, beam alignment relative to surface, air gap, focal point position and order of processes (in case of HLAW) and to get a B quality class welds in all thicknesses after parameter optimization.

Keywords: fiber laser; autogeneous laser welding; hybrid laser arc welding (HLAW); T- joint, low alloy steels; weld quality

1. Motivation / State of the Art

The possible applications of autogeneous laser welding and hybrid laser arc welding (HLAW) in fields of shipbuilding, transport and aerospace industries are currently extensively researched, since combination of cost-efficient, highly productive process together with fairly mobile and flexible welding equipment have risen high expectations for improved quality and economic feasibility. [1] [2] Mainly the studies have been addressing the influence of welding speed, laser power and other basic process parameters on weldability, butt joint being typical joint configuration. [3] Several researchers have studied HLAW welding of T-joint with CO_2 laser based systems [4] [5] [6], the orientation of the beam and arc in HLAW and influence of the air gap on processes have been estimated [5] [7] [8] [9]. Recent research has investigated the welding of medium

* Corresponding author. Tel.: +3584 0152 3580; fax: +358 5 624 3082 .
E-mail address: anna.unt@lut.fi .

doi:10.1016/j.phpro.2013.03.062

thickness T-joints [7] and eccentric fillet joints [10] made by fiber laser based systems. Present article shows and discusses the shape features of one side single pass T-joints made with autogeneous laser and HLAW processes. Systematic knowledge of factors affecting process stability is valuable for industry.

2. Experimental

2.1. Materials

Low alloy steel Ruukki Laser S355MC (SFS-EN 10025-2) and ship building steel AB AH36 (ABS standard) plates were joined in T-joint configuration in PA (1F) welding position using either autogeneous laser welding or HLAW processes. The thicknesses and material of the web and the flange were the same. Plates were laser cut to pieces of 350 x 100 mm (length x width) and grid blasted. The filler wire used was ESAB OK AristoRod 12.50 with 1 mm diameter, which is typical filler material for this base material in arc welding. Table 1 shows chemical compositions of test materials and filler wire.

Table 1. Chemical composition of test materials (wt. %)

	C	Si	Mn	P	S	Nb	V	Cr	Ni	Cu	Al	N	Ceq
AH36	0.18	0.03	0.7	0.035	0.035	0.02-0.05	0.05 – 0.10	0.2	0.40	0.35	min. 0.015	-	-
8 mm S355MC	0.057	0.02	0.78	0.006	0.004	0.030	0.006	-	-	-	0.031	-	0.2
10 mm S355MC	0.052	0.02	0.76	0.007	0.004	0.025	0.007	-	-	-	0.036	-	0.19
OK AristoRod 12.50	0.06 – 0.14	0.7 – 1.0	1.3 – 1.6	0.025	0.025	-	0.03	0.15	0.15	0.35	0.02	-	-

2.2. Process

The experiments were made with two different laser systems where continuous wave (CW) IPG Photonics Yb-fibre lasers were used as laser power source. First set of experiments was made with YLR-5000-S laser combined with ESAB Aristo LUD 450 arc power source. Second set was made with YLS-10000 laser source and Kemppi ProMig 530 arc power source. The welding head used was Kugler LK190 mirror optics laser welding head with Binzel MAG torch. Approximate focal point diameter of the laser beam was 0.5 mm, resulting from 300 mm focal lens, 125 mm collimation lens and ø200 µm process fiber. Air gap of 0.5 mm used in some of the set-ups was made by steel strips placed between the plates at the start and end of each weld. Only pulsed arc was used, synergy setting was constantly on, thus arc current and voltage were varied in accordance with feeding speed of filler wire. Constant parameters were tilt angle of the arc welding torch, 45 degrees, travel angle of the torch, 58 degrees, process distance 3 mm and free wire length 15 mm. The experimental set-ups and process variables are shown in Table 2.

Table 2. Experimental set-ups and parameters

Material	Process	Laser	Arc source	Shielding gas	Laser power (kW)	Welding speed (m/min)	Air gap (mm)	Focal position (mm)	Laser angle (°)	Leading process	Beam position (mm)	Arc position (mm)
6 mm AH36	Laser, HLAW	YLR-5000-S	ESAB Aristo LUD 450	Ar + 5% CO_2	4.56	1.5 – 2	0.5	-2, -1, 0, +2	6, 8, 10	Laser	0	0
8 mm AH36	Laser, HLAW	YLR-5000-S	ESAB Aristo LUD 450	Ar + 5% CO_2	4.56	0.8 – 1	0.5 and 0	+2	6	Laser	0	0
8 mm AH36	Laser, HLAW	YLS-10000	Kemppi ProMig 530	Ar + 5% CO_2	4.56, 5, 5.56, 6	0.5 – 2.5	0.5 and 0	-2, +2	6	Laser	0, 0.5	0
8 mm S355MC	Laser, HLAW	YLS-10000	Kemppi ProMig 530	Ar + 5% CO_2	5.56, 6	0.75-1.75	0.5 and 0	-2	6	Laser, arc	0.5	0, 1
10 mm S355MC	Laser, HLAW	YLS-10000	Kemppi ProMig 530	Ar + 5% CO_2	5.56, 6, 8, 8.4, 9, 9.5	0.75 – 2.5	0.5 and 0	-2	6, 10	Laser, arc	0.2, 0.5, 0.8	0

The welds were evaluated visually for defects, then, macro pictures of cross sections of the selected joints were made. Penetration, composition of the joint area and dimensions and shape of the fusion zone and heat affected zone, also relation of those to each other and overall dimensions of the seam were evaluated. Vickers hardness tests were carried out for selected specimens in different welding energy levels. The Vickers hardness values were measured near surface, root and midsection of the joint.

3. Results and Discussion

Several welds were of good visual quality having smooth top surface and root side. Macrograph photos for each thickness are enclosed, displaying typical features specific for investigated technique. Full penetration welds were achieved in 6 mm thickness with both tested processes with 4.56 kW laser power, whereas sound welds in 8 mm were obtained only with HLAW and 0.5 mm air gap in power levels higher than 6 kW. Experiments without pre-adjusted air gap also delivered good quality welds regardless of partial penetration (~ 75 % of thickness). The percentage amount of arc energy of total energy input was influencing the shape of the weld and penetration.

References

[1] Gerritsen C, Weldingh J, Kristensen K. Development of Nd:Yag Laser-MAG hybrid welding of T joints for shipbuilding, NOLAMP, Lulea, 2005.

[2] Staufer H, Kammerhuber C, Egerland S. Applying the Solid State Laser-GMA Hybrid Process for Single-Sided Full Penetration Welding of Bulb Bar Profiles in Shipbuilding, International Congress on Advances in Welding Science and Technology for Construction, Energy & Transportation Systems, Antalya, Turkey, 2011.

[3] Cao X, Wanjara P, Huang J, Munro C, Nolting A.Hybrid fiber laser–Arc welding of thick section high strength low alloy steel. *Materials & Design* 2011, **32**:6, p. 3399-3413.

[4] Nielsen S. Hybrid welding of thick section mild steel, in Proceedings 8th NOLAMP Conference, Copenhagen, 2001.

[5] Fellman A, Salminen A, Kujanpää V. The comparison of the effects of welding parameters on weld quality and hardness of T-butt joints welded with CO2 laser, Nd:YAG laser and CO2 laser - GMA hybrid welding, ICALEO 2004, San Francisco.

[6] Cho M, Farson D, Lim Y, Choi H. Hybrid laser/arc welding process for controlling bead profile, Science and Technology of Welding & Joining, 2007 12: 8, p. 677-688.

[7] Murakami T, Shin MH, Nakata K. Effect of welding direction on weld bead formation in high power fiber laser and MAG arc hybrid welding. 2010 Transactions of JWRI. **39**:2, p. 175-177,

[8] Yao Y, Wouters M, Powell J, Nilsson K, Kaplan A. Influence of joint geometry and fit-up gaps on hybrid laser-metal active gas (MAG) welding,*Journal of Laser Applications*, 2006, **18**: 4, p. 283-288.

[9] Weldingh J, Kristensen J. Hybrid YAG-Laser/MAG welding, quality and stability. Proceedings 9th Conference on Laser Materials Processing in the Nordic Countries, 2003, Trondheim, Norway, pp. 15-24.

[10] Karlsson J, Kaplan A. "Analysis of a fibre laser welding case study, utilising a matrix flow chart. *Applied Surface Science* 2011 **257**:9 p. 4113-4122.