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The influence of shielding gas in hybrid LASER–MIG welding

Giovanni Tani, Giampaolo Campana *, Alessandro Fortunato, Alessandro Ascari

Department of Mechanical Construction Engineering, University of Bologna, Viale Risorgimento 2, 40136 Bologna, Italy

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Abstract

Hybrid LASER-GMAW welding technique has been recently studied and developed in order to meet the needs of modern welding industries. The two sources involved in this process play, in fact, a complementary role: fast welding speed, deep bead penetration and high energy concentration can be achieved through the LASER beam, while gap bridgeability and cost-effectiveness are typical of the GMAW process.

Particularly interesting, in this context, is the CO_2 LASER–MIG welding which differs from the Nd:YAG LASER–MIG technique for the high powers that can be exploited and for the good power/cost ratio of the process.

This paper is a part of a wide study on the hybrid CO_2 LASER–MIG welding and investigates the influence of the shielding gas both on the stability of the process and on the dimensional characteristics of the weld bead. Two different parameters have been taken into consideration in order to develop this analysis: the shielding gas composition and the shielding gas flow.

The experiment, performed on AISI 304 stainless steel plates, has been planned exploiting design of experiment techniques. The results have been analyzed through a statistical approach in order to determine the real influence of each parameter on the overall process.

Keywords: Hybrid welding; Shielding gas; GMAW; Laser; Stainless steel welding

1. Introduction

Hybrid Arc-LASER welding technology has been thoroughly studied and successfully applied [1–3] in the last few years. In particular hybrid LASER Nd:YAG–GMAW process meets the needs of automotive industry thanks to its easy implementability on anthropomorphic robots, while LASER CO_2–GMAW is suitable for shipbuilding industry, but also for transport and aerospace industry applied to panels manufacturing, thanks to its characteristic high powers. On the other side the two welding sources, coupled to perform an hybrid welding process, require a fine tuning of both sets of technological parameters in order to obtain a stable, repeatable and productive process.

According to this, many studies have been carried out regarding power-related parameters [4,5] such as coupled arc voltage and LASER beam power and on source positioning related ones [6] such as defocus position and distance between the sources, in order to trace out the basics regarding the applicability of the process. More specific studies have been carried out considering plasma interaction [7] and molten pool fluid dynamics [8] with the aim of tuning the complex equilibrium which stands behind this kind of processes.

The aim of this work is therefore to investigate the influence of shielding gas composition and flow on the whole process. In order to accomplish this goal the planning of the experiment and the analysis of the results have been performed by means of design of experiment techniques. This approach allowed to clearly underline the real influence of the studied parameters on the stability of the process and on weld bead geometry.

2. Experimental setup

The equipment used to carry out the experimental tests is based on an EL.EN. C3000 FAF 3 kW CO_2 laser source and on a CEBORA Sound MIG 3840/T Pulse 380 synergic pulsed GMAW generator. In order to couple the two sources a Binzel ABIMIG automatic torch has been exploited and assembled on the laser head of the CNC cell.

The experimental activity was carried out using AISI 304 stainless steel. The test specimens are couples of 15 mm × 10 mm × 120 mm sticks tack welded on each end in a zero-gap butt joint configuration. Every stick has been obtained by sawing from an 8 and 10 mm thick plate in order to simulate a poor

* Corresponding author. Tel.: +39 0512093456; fax: +39 0512093412.
E-mail address: giampaolo.campana@unibo.it (G. Campana).

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quality edge preparation. Every specimen has been then welded without any restraint or jigs in order to maximize the effect of weld distortion.

Several parameters have been kept constant during the whole testing:

- GMAW torch inclination: 65°.
- Welding speed: 1 m/min.
- Welding direction: MIG trailing.
- GMAW source setting: synergic pulsed.
- Laser power: 3 kW.
- AISI 308L 1.0 mm filler metal wire.

The shielding gas parameters have been varied:

- Three gas flow rates: 10, 30, 45 l/min.
- Three different gas compositions:
  - 30% He–67% Ar–3% O_2;
  - 40% He–57% Ar–3% O_2;
  - 60% He–37% Ar–3% O_2.

Previous experiments, carried out by the authors, allowed to evaluate the following setup parameters which permit to achieve good bead penetrations and geometry [9]:

- Arc voltage: 20 V.
- Distance between sources: 3 mm.
- Laser beam focal position: 7 mm below the upper base metal surface.

3. Experimental

The experiments were split into two different phases: a preliminary and a main one.

The first preliminary stage was aimed to investigate the minimum helium percentage necessary to achieve a stable process. Several tests have been carried out exploiting 10% and 20% He mixtures at different flow rates. In these cases a consistent plasma plume above the molten pool caused the absorption of a large portion of the laser energy with a negative effect on bead penetration depths and on process efficiency.

Starting from 30% He gas mixtures the working condition changed radically. The high ionisation energy of helium together with the higher percentage of the gas in the mixture allows to limit the plasma plume formation and consequently the absorption of the laser beam. According to this outcome, in the following part of the experiment 30%, 40% and 60% He gas mixtures were exploited.

During the main experimental stage every seam was produced exploiting a shielding gas environment characterized by a specific flow rate/composition match. Every single trial has been repeated twice in order to evaluate the repeatability of the process and to free the results from external disturbance factors as much as possible.

The average length of the obtained seams is 100 mm and every bead has been cross-sectioned in correspondence of its normal symmetrical plane in order to investigate the shape of

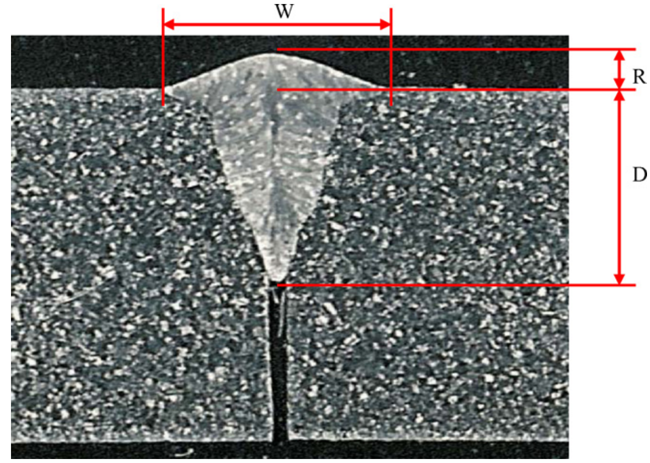

Fig. 1. Characteristic dimensions of a weld bead obtained exploiting a 40% He mixture and a 30 l/min flow rate.

the melted zone. Every cross-section has been polished and etched for observation with optical microscope and the bead geometry has been characterized by measuring the following parameters: penetration depths (*D*), widths (*W*) and reinforcements (*R*), as shown in Fig. 1.

A two-way analysis of variance has been carried out on the measured dimensions in order to get information regarding the influence of the controlled process parameters and of the external disturbance factors.

4. Results and discussion

Figs. 2 and 3 concern bead penetration depths and widths, respectively. The plotted lines show the mean values between the two repetitions for each helium percentage analyzed. These graphs show that bead depth increases if helium percentage and gas flow increase, as well as bead width.

Figs. 4–6 show the values related to bead depths for both repetitions together with the respective mean value. By comparing these graphs the evidence is that at higher helium percentages, 60%, the dispersion of results becomes more important. This is, probably, due to the destabilizing effect of helium on the GMAW arc especially in a pulsed mode.

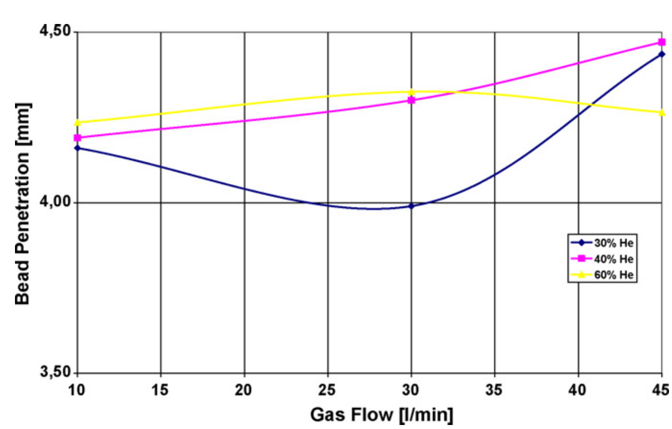

Fig. 2. Comparison between mean bead penetration depths as a function of gas flow rate and composition.