PRELIMINARY EVALUATIONS ON LASER – TANDEM GMAW

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Recently there has been considerable research and development activity in the use of lasers for welding operations, turning this process into an important tool for a variety of applications. Although it is possible to use lasers as a unique source of heat to promote union of materials, the combination of the beam provided by a laser system with an arc welding process has been studied widely and applied in the so-called hybrid welding systems. Generally, the final result of such a combination is an increase in the weld penetration depth, width and welding travel speed. Despite these advantages, there are many issues still requiring further research and development concerning the use of hybrid welding using laser and arc welding, including a more comprehensive understanding of the various welding phenomena involved and the exploitation of new combinations. This paper describes an approach for hybrid welding combining a laser with tandem GMAW, in particular placing the laser beam between the tandem GMAW wires. This hybrid process variation is described and some basic aspects regarding its performance are discussed. The laser beam was found to have a positive effect on the appearance of the weld beads produced and best results are obtained if the laser is located halfway between the leading and trailing wires. A 10 mm inter-wire distance was found to be the most appropriate of the separation distances tried. The hybrid process approach was able to increase the welding travel speed or penetration depth significantly in comparison with tandem GMAW (operating in pulsed mode).

IIW-Thesaurus keywords: Combined processes; GMA welding; Laser welding; Tandem welding.

ABSTRACT

Systems have been described for hybrid welding combining laser with Gas Tungsten Arc Welding [1], with Plasma Arc Welding [2, 3], with Gas Metal Arc Welding [4, 5] and even with Submerged Arc Welding [6]. Regardless of the arc welding process chosen, the general result is an increase in the effectiveness of the welding process. It is well-known that LBW (laser beam welding) provides high power density, deep penetration, high welding speed, low distortion and high precision. However, because the small focused laser beam spot, LBW exhibits poor gap bridging ability and increased precision in joint preparation is an essential requirement. On the other hand, arc welding processes produce wider weld beads, delivering good bridging ability of joint gaps and improved tolerance to joint preparation. The combination of LBW and arc welding tends to enhance the advantages and compensate for the limitations found in each process. Generally the result is an increase in the weld penetration depth, width and welding travel speed.

A number of studies on hybrid welding employing a laser and single wire GMAW process have been published, most of them using CO₂ or Nd:YAG lasers. Qin et al. [7], for instance, studied hybrid Nd:YAG laser – pulsed GMA welding and found that the laser energy influences the weld penetration, that the weld width depends on the arc process and that the hybrid process increases the welding speed and improves the weld appearance at low arc currents. Cho and Farson [8] showed that the use of a laser beam in front of the GMAW weld pool prevents the formation of weld bead humping. Kim et al. [4] found that the heat input delivered to the plate is dependent on the nature of the leading heat source (laser or GMAW) and also on the joint condition used in the hybrid setup. Kim et al. [4] also mention that the synergistic effects of the two heat sources are maximized when the laser beam is located between the arc centre and the impact point of the molten droplets within the weld puddle. Tusek and Suban [6] claim that the main advantage of the use of both heat sources is the more efficient use of the energy supplied. They also state that the synergic action of the laser beam and welding arc, when current intensities are low, affects ionisation, reduces arc resistance, and increases the number of carriers of electric current. The hybrid process has even become an option for use in pipeline girth welding applications, where the demand for high speed welding is always present [9]. Besides being largely used in combination with pulsed GMAW, Mulima et al. [5] undertook preliminary trials using a diode laser combined with GMAW in a controlled dip transfer mode and showed that, in this case, by adding the laser beam in front of the GMAW wire, the welding travel speed could be significantly increased and deep penetration achieved. A process using a laser and two GMAW arcs has also been developed [10]. This processes, named HyDRA (Hybrid welding with Double Rapid Arc), has been able to bridge gaps of more than 2 mm in the roots of V-prepared joints without any weld pool support and in one pass for a thickness of 5 mm. In this process all the three welding heat sources act in one zone and the geometrical arrangement of the individual
components is of vital importance. Staufer [11] mentions another hybrid approach for laser and tandem GMAW. In this version a tandem GMAW torch trails the laser beam. It has been claimed that this process is able to increase not only the welding speed, but also the ability to bridge root gaps when compared to the conventional laser hybrid – single GMAW.

In recent years tandem GMAW (especially in pulsed mode) has been widely applied in production due to developments of digital welding power sources and advances in control of this process [12-15]. In pulsed tandem GMAW the waveform control technique ideally produces one droplet per pulse of current, which results in a stable welding process and less spatter at high travel speeds. It is believed that a combination of this arc welding process with LBW should be investigated further since it may potentially improve weld quality, provide even higher welding speeds and increase penetration. The current paper describes an approach to hybrid welding combining LBW with tandem GMAW, in this case placing the laser beam between the tandem GMAW wires. Details of this hybrid process variation are described and some basic aspects regarding its performance are discussed.

2 Experimental procedure

2.1 Equipment set-up

In order to evaluate the chosen variation of hybrid welding using LBW and tandem GMAW, a test rig was designed to provide a mounting for the components of a tandem GMAW torch whilst providing accommodation for a 3 kW diode laser head between the two GMAW heads. In this approach, the laser head is placed between the wires, and its beam can be used perpendicular to the workpiece, meaning that the laser can deliver its energy with maximum efficiency. Figure 1 shows the test facility and the hybrid welding head.

As the use of a laser beam between the wires in a tandem torch is a new approach for hybrid welding, some basic evaluation of the process was needed to determine the effect of the position of the laser beam in relation to the wires, whether the laser beam allows increased inter-wire distances (IWD) to be used, and the effect on weld bead profile caused by the addition of the laser beam between the wires. In order to evaluate the first two aspects, tests were carried out varying the position of the laser beam between the wires whilst varying the inter-wire distance for two levels of laser beam power (1 and 2 kW). As illustrated in Figure 2, three relative positions for the laser beam were used for each of the inter-wire distances tested (5, 10 and 15 mm) and for each beam power level. After these tests, an evaluation of the effect of adding the laser beam to the tandem GMAW process on the weld bead profile was performed. Bead on plate welding on 2 mm plain carbon steel sheets without backing was used throughout the tests. The laser beam focus point was always placed on the upper surface of the sheets.