LASER ARC HYBRID WELDING

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ABSTRACT

Hybrid Welding means the coupling of the energy of two different energy sources in a common process zone. This paper describes prospects in laser-arc-hybrid-welding. Different kinds of lasers (CO_2 laser and Nd:YAG laser) and arc processes (TIG, Plasma and GMA) are considered.

KEYWORDS

Welding, GMA welding, hybrid welding, hydra welding, energy model, filler wire, gap width

1. Introduction

The laser beam welding process can be combined or coupled, in principle, with the arc welding process. When combined in a process, the laser beam and arc generally act separately in terms of time or zone, the two processes being used without any mutual interaction. When coupled as one process, the laser beam (CO_2 or Nd:YAG laser) and arc (TIG, plasma or GMA) interact at the same time in one zone (plasma and weld pool) and mutually influence and assist one another. Such process coupling is referred to by the term of "hybrid welding process". Various studies have revealed that a process is possible in which synergistic effects are achievable through coupling of the processes and the disadvantages of the respective processes can be compensated for, thereby opening up technically and commercially interesting possibilities for a multitude of applications.

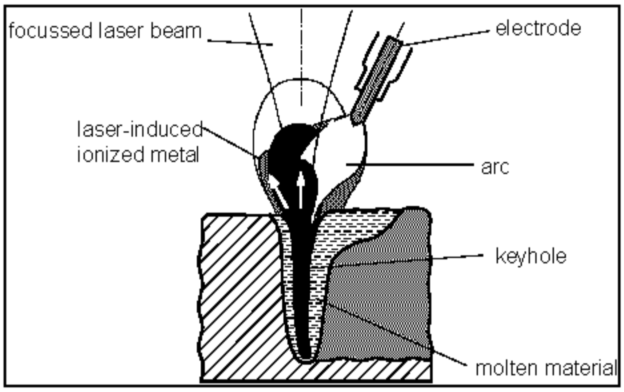


Fig. 1 Principle of the hybrid welding process

The hybrid process is sketched in detail in Figure 1. The arc, in addition to the laser beam, supplies heat to the weld metal in the upper weld region, giving the weld seam its U-shape. The mutual influences exerted by the processes can differ in intensity and form as a function of the utilised arc or laser process and the process parameters. The heat load to which the weldment is exposed as a result of the hybrid process can be kept low comparable to the laser process. The laser's or the arc's character may predominate, depending on the selected power input ratio.

Former studies have concentrated on the technical difficulties in combining these two processes. In the meantime the feasibility has been shown and different industrial applications are ready to start. By coupling of the two processes a new process with enhanced capabilities has been created, Figure 2. The bilateral influences of the processes lead to synergetic effects. The disadvantages of the single processes can be avoided.

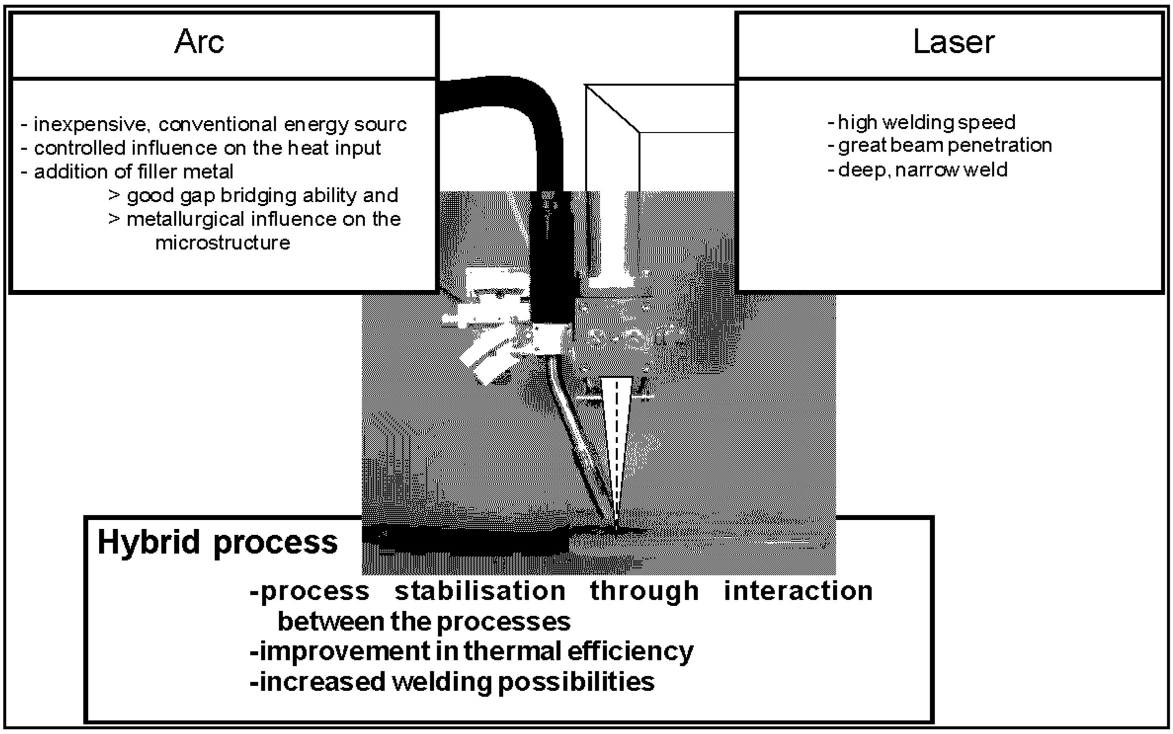


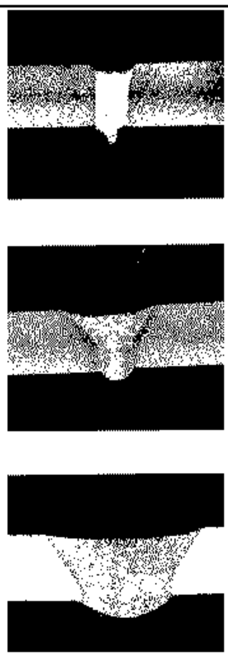
Fig. 2 Advantages through process coupling

The examples given below serve to overcome the present obstacles to using the hybrid technology for industrially realisable applications. Their purpose is to indicate the possibilities for this process technology's utilisation and thus reduce the fear of confrontation with this technology.

2. Laser TIG Hybrid Process

Combinations of Nd:YAG or CO_2 laser beam welding with tungsten inert-gas welding (TIG) find use mainly for small plate thicknesses. The laser beam stabilises the anode spot through the laser-induced plasma or the keyhole.

Use of the laser TIG hybrid process can increase the welding speed. Figure 3 shows a comparison of square butt joints on 2 mm-thick AlMg3 sheets welded by means of the Nd:YAG laser TIG hybrid process and by means of the individual processes (P_L: laser power; F: ratio focal length/aperture diameter; r_F: focus radius; v_W: welding speed; I: current; Φ: electrode diameter; t: plate thickness). In the hybrid process the welding can take place in the DCEN mode which, compared with the AC mode in the TIG process on its own, increases the energy input, energy density and electrode life. In the TIG process the electrode is dish-shaped, and in the hybrid process it is pointed with a tip angle of 40°. Worth noting is the significant increase in the welding speed which becomes possible through the hybrid process. It is virtually doubled in comparison with the pure laser process, and the notch angles are reduced. The weld area provides a yardstick for the heat exposure of the weldment. While it is relatively large for the TIG process, it is small and roughly the same for the laser beam and hybrid processes [1, 2].



Nd:YAG laser

$P_L = 1.9$ kW

F = 3.9

$r_F = 170$ µm

$v_W = 5.0$ m/min

Nd:YAG/TIG (DCEN)

$v_W = 8$ m/min

TIG

I = 259 A; $v_W = 2.0$ m/min

Φ = 3.2 mm; 45° forward

Gas: Ar 20 l/min

Electrode: W20

AlMg3; t = 2 mm; cut edges

Fig. 3 Welding of aluminium by means of different processes [1, 2]

A further example of the efficient use of this hybrid technology is the joining-together of dissimilar material thicknesses, e.g. in the fabrication of tailored blanks. Shown in Figure 4 is the transverse microsection of a tailored blank. An example for the application of hybrid welded tailored blanks may be the automotive floor panel with thicker sheet in the tunnel zone. The low deposition volume of laser beam welds often leads to metal transfers with small radii. Apart from the notch effect problem, such edges prevent the adhesion of applied coatings or paint films. Use of the hybrid technology resolves such problems thanks to low-notch transitions produced by additionally fused material. Higher process speeds can also improve the productivity.

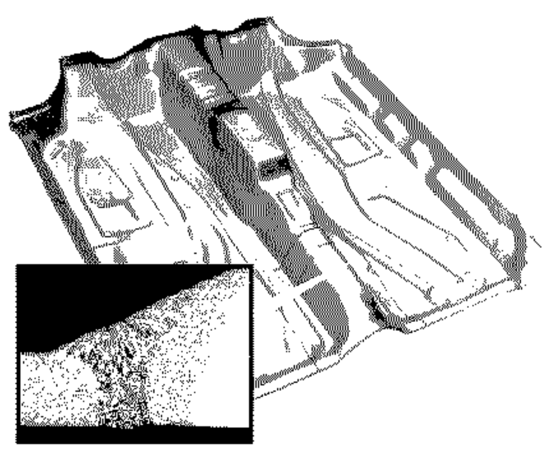


Fig. 4 Hybrid welded blanks

3. Laser Plasma Hybrid Process

Through suitable combination of the two heat sources of an electric arc and laser beam, a controlled influence is exerted on the heat input in the weld region.

Figure 5 shows the basic principle of such a process. As with previous laser beam processes, the laser beam is diverted on its way from the beam source in a mirror-optics system and focussed on the workpiece. In contrast to pure laser beam welding, however, the laser beam is here surrounded by a concentric plasma arc which transfers plasma from an annular plasma electrode to the workpiece. The plasma arc brings about an additional heat input which can be independently proportioned by the laser beam. The electric arc essentially has two functions in this respect:

- It supports the beam welding process through the additional energy input and thus increases the operative capability and, as appropriate, the efficiency of the overall process.
- The concentric arrangement of an annular plasma arc around a laser beam brings about a defined heat treatment, in which respect the arc acts during the forward and backward run. The heat treatment provides the ability to reduce the cooling rate and thereby decrease the susceptibility to hardening and development of residual stress states. It is consequently possible to tailor the microstructural condition to the application in hand.

The design-related benefits of this coaxial process variant – on the one hand, the small space requirement and, on the other hand, the non-directionality of the process – are offset by the use of welding filler metal.

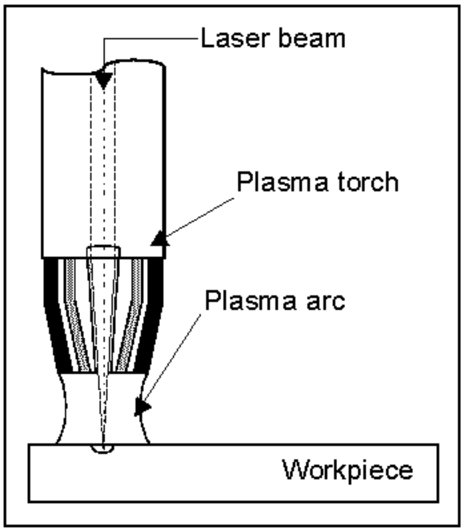


Fig. 5 Basic principle of the laser plasma hybrid process

4. Laser GMA Hybrid Process

Very recent research has proven the basic viability of the laser GMA (MIG or MAG) hybrid welding process and brought to light the productivity gains achievable in this respect as well as the mutual influences exerted by the two welding heat sources.

Conjoined with the geometrical arrangement of the individual components the arc welding process can increase the gap bridging ability, i. e. it appreciably broadens the range of tolerances with regard to edge preparation quality. The arc's energy input in the hybrid welding process also permits e.g. control of the cooling conditions. Via the keyhole the laser beam brings about easier ignition of the arc, stabilisation of the arc welding process, and penetration of the energy deep into the material. The improvement of the energy input leads to a greater welding depth and speed being achieved with the hybrid process compared with the individual processes on their own, as shown in Figure 6 (v_W: welding speed; v_{FW}: filler wire feed rate; E_W: energy per unit length).

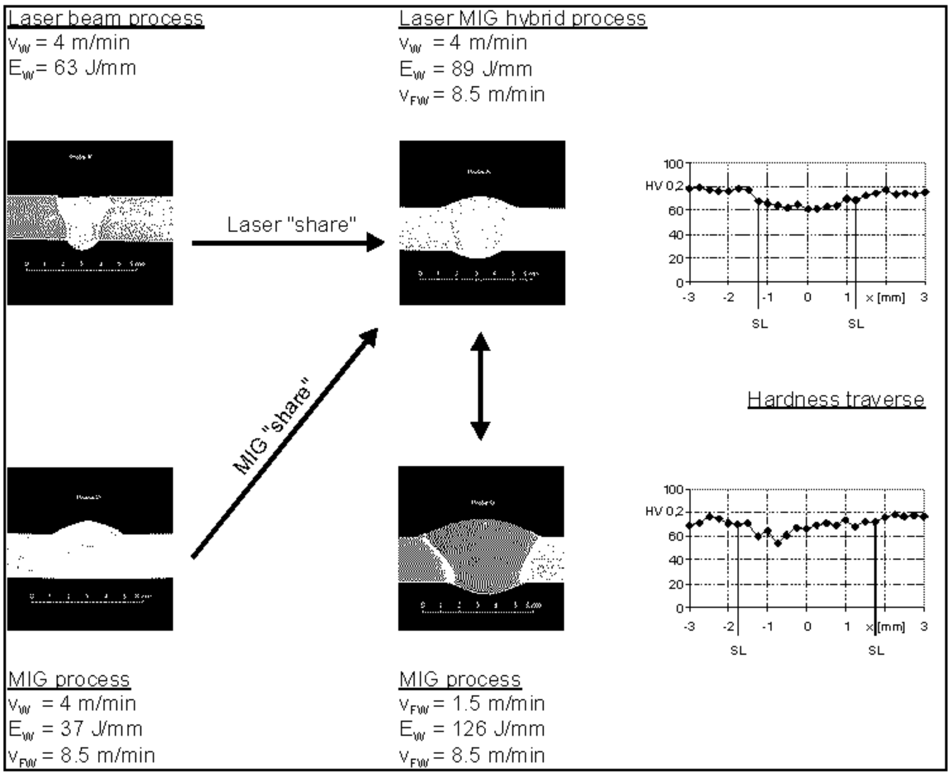
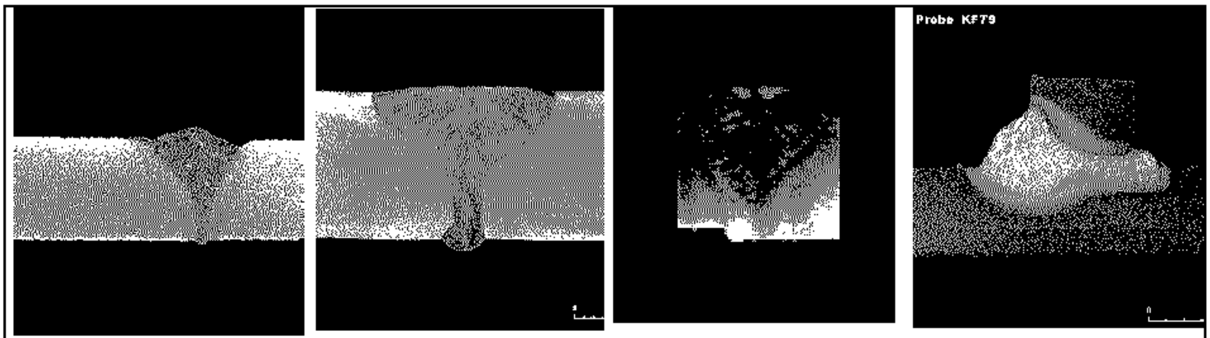


Fig. 6 Advantages of the laser MIG hybrid process (AlMgSi0,5)

It is consequently possible to enhance the operative capability and energy efficiency without having to forego the advantages of using welding filler metal, e.g. metallurgical influence on the microstructure. Figure 7 shows examples of different steel types and joint types. The advantages offered by laser GMA hybrid welding caused a German shipyard to introduce this welding technique into their production line, Figure 8. Welding the complete range of plate thicknesses between 4 mm and 15 mm as butt joints as well as T-joints was approved by a classification society (DNV) [5]. Further increase of welding speed and reduction of heat load can be achieved by coupling the laser beam with two GMA processes, the HyDRA process (Hybrid Welding with Double Rapid Arc), Figure 9 [3, 6].



Shipbuilding steel AH36	high alloy steel 1.4571	Duplex steel 1.4462	shipbuilding steel AH36
t = 5 mm	t = 8 mm	t = 6 mm	t_{Web} = 7 mm
P_L = 6 kW	P_L = 6 kW	P_L = 6 kW	t_{Flange} = 6 mm
v_W = 4.1 m/min	v_W = 0.9 m/min	v_W = 2.0 m/min	P_L = 6 kW
v_{FW} = 14 m/min	v_{FW} = 6.8 m/min	v_{FW} = 14.0 m/min	v_W = 1.25 m/min
E_W = 274 kJ/m	E_W = 736 kJ/m	E_W = 500 kJ/m	v_{FW} = 12.5 m/min

Fig. 7 Examples of laser GMA hybrid welded steels [3, 4]

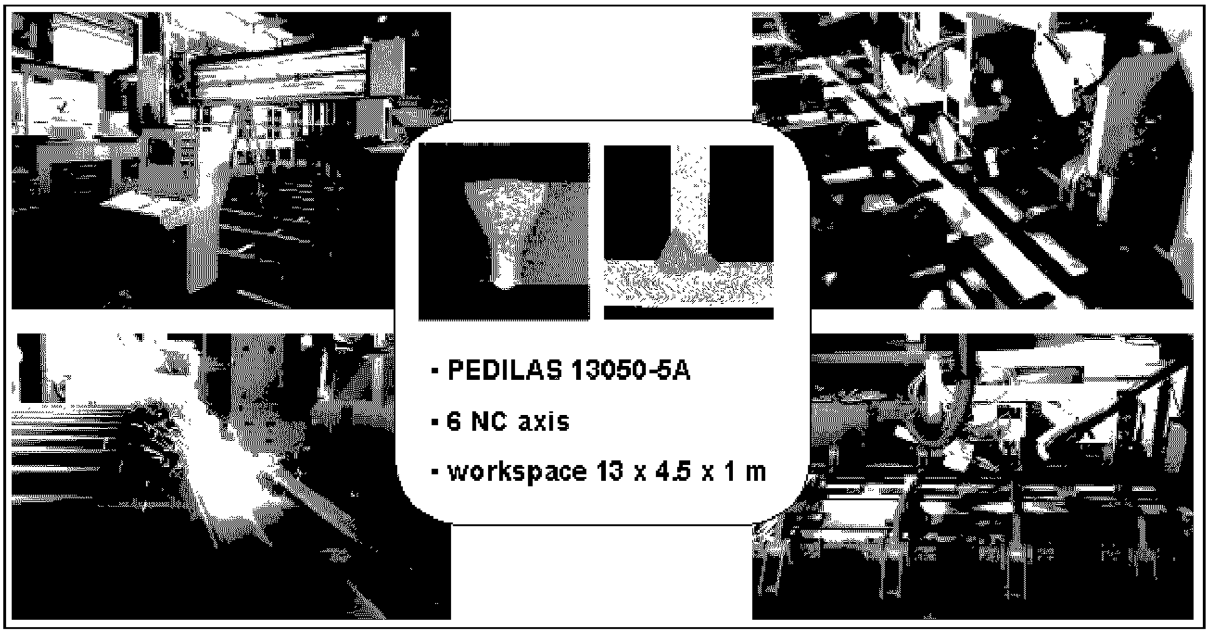


Fig. 8 Test and production installation of laser GMA hybrid process for shipbuilding [5]

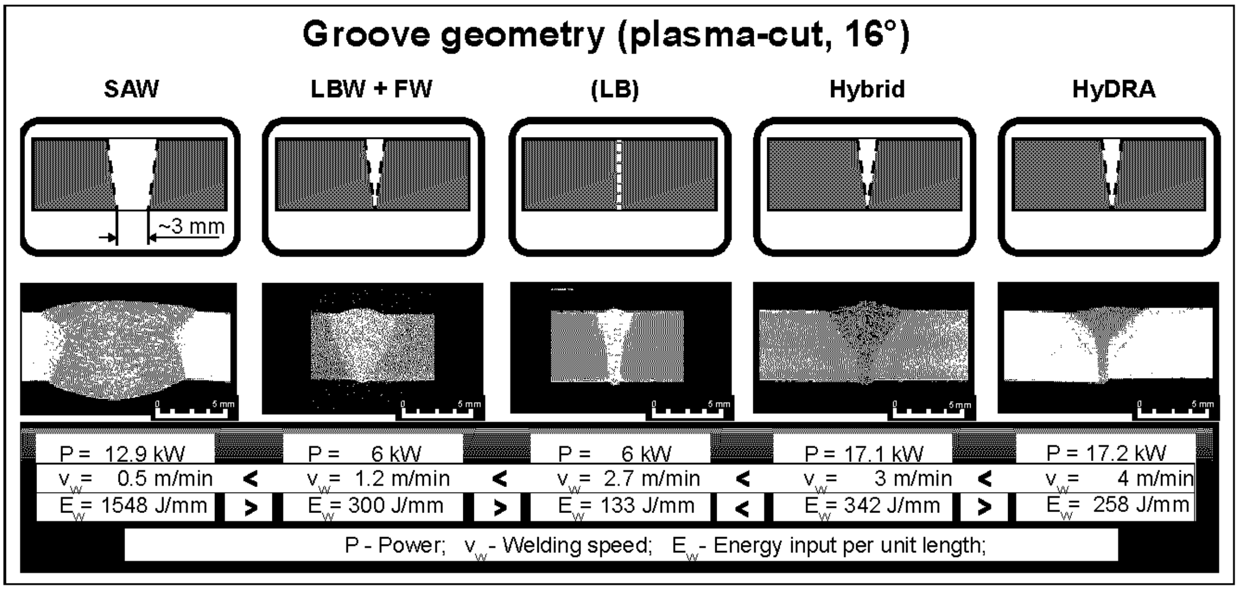


Fig. 9 Comparison of different welding methods [6]

5. Conclusions

Bringing the laser beam and arc together yields synergistic effects for broad parts of the steel- and aluminium-processing industries, e.g. for those applications where the joining-member tolerances required for laser beam welding can be guaranteed either not at all or only at high financial expense. Expansion of the possible uses and operative capability of the laser-arc welding processes will increase the productivity, flexibility and, consequently, competitiveness of those enterprises diversely active in these fields, among other reasons due to the reduced investment costs.

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