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Using infrared thermography in order to compare laser and hybrid (laser+MIG) welding processes

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ABSTRACT

In order to deepen the understanding of the differences between laser and laser-arc hybrid welding, comparisons were undertaken using thermography. The experiments were carried out for a T assembly of aluminium alloy plates. Modelling, based on the finite element method approach, was realized using IR temperature measurements and seam geometry. For a value of the power supply, depicted as a surface source in the hybrid case, agreement was found between simulated and measured temperatures. The arc power supply efficiency value is similar to the usually used value.

1. Introduction

Hybrid laser-MIG welding, combining laser welding with MIG welding, results in high productivity and low deformation as well as prevention of porosity formation. Some work on the modelling of this process has been reported [1,2]; but until now a complete phenomenological description of the laser hybrid process cannot be found in literature. In the paper of Aubert et al. [1], an analytical formulation of a hybrid laser-MIG source is proposed. This source is the sum of two volumic sources. This approach does not allow the description of phenomena occurring in the weld pool. On the other hand, a mathematic model to investigate the transport phenomena in a hybrid laser-MIG welding process was proposed by Zhou and Tsai [2]. However, this study is only related to low-power laser keyhole welding with a few ms pulse duration.

Thermography is a convenient, non contact method for making temperature field measurements. The data of the temperature field can be used to calibrate the results of simulation and to obtain information on thermal phenomena which occur during the welding process [3,4]. Huang et al. [5] applied an infrared thermography system to observe the temperature distribution of the weld surface during hybrid laser-TIG welding of AZ31 magnesium alloy. For the studied setup, the problem of interference from radiant reflection was found to be a complicating factor in applying IR temperature sensing to welding. So, these authors proposed a new method to decrease radiant interference. The obtained data were not linked with simulation results.

In this paper, infrared measurements obtained during T welding of two aluminium alloy plates, the first one using a laser and the second one using the hybrid process, are compared. In the chosen configuration, the infrared thermography system recorded an IR image of the face of the piece that was not directly illuminated by the sources (the back face). So no problem of interference can occur. A relatively simple model using the finite element method is used to show how the description of the energy supply differs for the two processes.

2. Experimental procedure

2.1. Materials

The work pieces to be assembled are two AA2024 heat-treated T3 plates 4 mm thick. The filler material is an aluminium alloy 4047 with 1 mm diameter. The thermophysical properties of this alloy are summarized in Table 1.

2.2. Laser process

The used laser source was a continuous wave Nd:YAG from TRUMPF© (HL 6004D) with a maximum power of 6 kW. The used power is 4 kW. The beam is carried to the target surface through a 400 μm diameter fibre-optic cable. A 200 mm focal length collimating lens is used together with a focusing lens of 200 mm focal length. The welding seam is in the focal plane of the focusing

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lens. The angle between the laser axis and the wire axis is 43°. The angle between the laser axis and the horizontal axis is 35°. The laser spot exhibits a circular shape with a near-uniform intensity profile. The shielding gas (Ar) is emitted with a flow rate of around $20\,L\,min^{-1}$. The welding speed is $3\,m\,min^{-1}$ and the wire speed is $4\,m\,min^{-1}$ (Table 2).

2.3. Laser hybrid process

A combined welding head including the same Nd:YAG laser and a MIG torch was used (Fig. 1). The wire speed is $4\,m\,mn^{-1}$. The angle between laser axis and weld torch is 43°. The distance between laser impact and arc impact is 5 mm. The moving of welding head is carried out with a numerically controlled 6 axes robot KUKA KR 600.

Table 1
Thermal properties of 2024 T3 (MATWEB).

Specific heat capacity	$0.875\,J\,g^{-1}\,°C^{-1}$
Thermal conductivity	$193\,W\,m^{-1}\,K^{-1}$
Melting point	502–638 °C
Solidus	502 °C
Liquidus	638 °C

Table 2
Welding conditions for the laser process.

No. of trial	Welding speed ($m\,min^{-1}$)	Wire speed ($m\,min^{-1}$)	Laser power (kW)
1	3	4	4

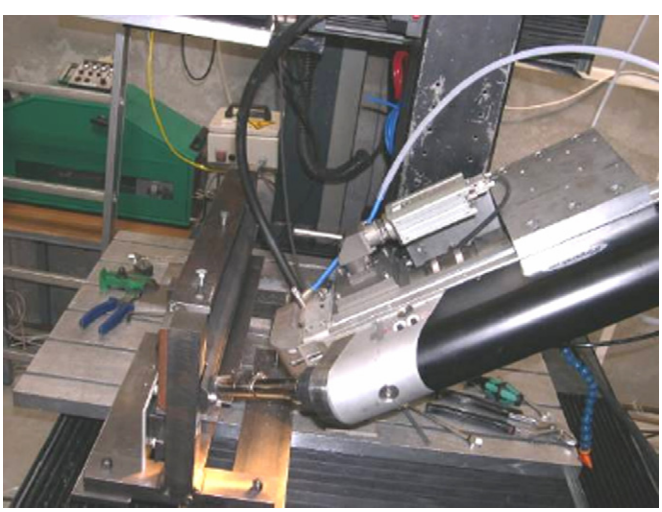

Fig. 1. Set-up of hybrid-laser-MIG welding.

Table 3
Welding conditions for the hybrid process.

No. of trial	Welding speed ($m\,min^{-1}$)	Wire speed ($m\,min^{-1}$)	Laser power (kW)	Welding current (A)	Welding voltage (V)
2	3	4	4	90	19.3

The welding conditions are summarized in Table 3. The transfer metal mode is the pulsed mode and the welding configuration is a “T” (Fig. 2).

2.4. Thermographic measurements

The camera used was a FLIR ThermaCAM S40 imaging system. It has a 240 × 320 pixels focal-plane-array uncooled microbolometer detector, with a sensitive range of 7.5–13 μm. Imaging and storage was made at a frequency rate of 50 Hz. A 100 mm close-up lens was used, which allowed a spatial resolution of 100 μm.

The infrared thermography system recorded IR image of the face of the piece not directly illuminated by the sources (the back face). The viewed plate is coated with a graphite coating whose emissivity was measured. The back face temperature does not reach the degradation temperature of the coating. In order to measure the coating emissivity, a partially coated aluminium plate, positioned on a heating table whose temperature was controlled, was observed with the thermographic system. The temperature was varied between 100 and 400 °C. The measured emissivity was 0.72 ± 0.05.

In order to locate the vertical ordinates of the measured temperature, two features were created on the viewed surface, the first one located at 2 mm from the bottom of the vertical plate, and the second being 2 mm from the first (Fig. 3).

The ordinates of the calculated temperatures and the position of the IR camera are shown in Fig. 4.

Using the features and the LI01 line (Fig. 5) superposed on the IR image, and the calculated ordinates (Fig. 4) it is then possible to access to the vertical profile of the temperature.

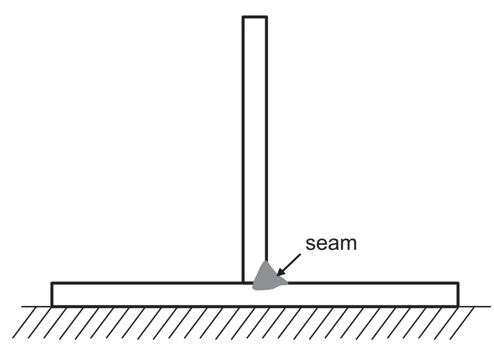

Fig. 2. Assembly configuration.

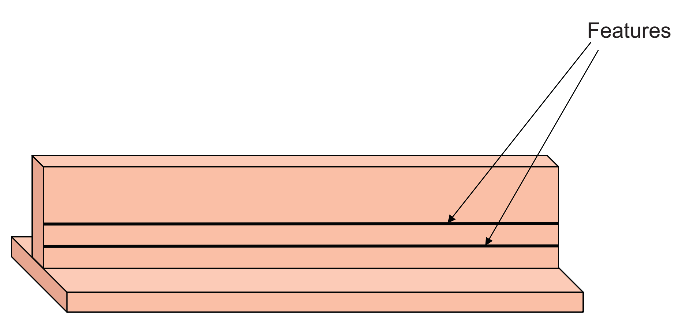

Fig. 3. Working piece with both features to locate the measured temperatures ordinates.