Materials Science and Engineering A 447 (2007) 239–243

MATERIALS SCIENCE & ENGINEERING A

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# Infrared temperature measurement and interference analysis of magnesium alloys in hybrid laser-TIG welding process

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Received 22 April 2006; received in revised form 15 September 2006; accepted 16 October 2006

**Abstract**

Infrared (IR) temperature measurement, as a convenient, non-contact method for making temperature field measurements, has been widely used in the fields of welding, but the problem of interference from radiant reflection is a complicating factor in applying IR temperature sensing to welding. The object of this research is to make a deep understand about the formation of interference, explore a new method to eliminate the interfering radiation during laser-TIG hybrid welding of magnesium alloys and to obtain the distribution of temperature field accurately. The experimental results showed that the interferences caused by radiant specular reflection of arc light, ceramic nozzle, electrode and laser nozzle were transferred out of welding seam while the IR thermography system was placed perpendicularly to welding seam. And the welding temperature distribution captured by IR termography system which had been calibrated by thermocouple was reliable by using this method in hybrid laser-TIG welding process of AZ31B magnesium alloy.



*Keywords:* Infrared temperature measurement; Temperature calibration; Interference analysis; Magnesium alloy; Laser-TIG hybrid welding

## 1. Introduction

The information of temperature field measurement in welding process has important relationship with the microstructure and mechanical properties of joints. And the data of temperature field can be used to calibrate the results of simulation. Practical temperature measurement methods can be grouped into two categories: contact and non-contact. IR thermography system, as a convenient, sensitive, non-contact method for making temperature field measurement, has large potential to apply in capturing the welding temperature field. However, the existence of radiant reflection from arc light and hot tungsten electrode decrease the accuracy of temperature measurement, especially for the materials with high reflectivity such as Al alloys and Mg alloys.

The sensor of infrared thermography system is sensitive in the spectral range of 8–12 μm, but most of the arc radiation occurs between 0.34 and 1.8 μm. And the weld radiation is greater than the arc energy for the wavelength which is greater than 2 μm [1]. Thus, filtering method now has been taken commonly. Bicknell acquired progressive improvement in image quality through high-pass and band pass filters [2]. Farson used band pass filter and shield to weaken arc and electrode interference from the infrared thermal radiation in TIG welding of AISI 1250 sheet [3]. Lukens and Morris reported a method to control weld metal cooling rate while infrared signals could be obtained without the interference from arc or electrode [4]. Ramsey et al. used radiometer to measure radiation interference from arc with alteration of observational angle and location [5]. Auburn University used infrared sensor to control the welding process [6–10]. But, these works involved how to remove the radiation interference were little.

Hybrid laser-TIG welding combining laser welding with the traditional TIG welding together results in high productivity, efficiency and welding quality. And many research results are continuously increasing [11], but there is no report about measuring and calibrating temperature field using IR thermography in hybrid laser-TIG welding process of AZ31B Mg alloy. Comparing hybrid laser-TIG welding with TIG welding, the interference factors are much more complex in hybrid welding. So, in this paper, the infrared thermography system was applied to measure the obverse temperature distribution of the weld surface during hybrid laser-TIG welding process of AZ31 magnesium alloy, a new method was introduced to decrease the radiant interference from arc light, ceramic nozzle, electrode and laser nozzle, and the

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doi:10.1016/j.msea.2006.10.069

Table 1
Welding conditions

| Welding speed ($mm\,min^{-1}$) | Ar shielding gas ($L\,min^{-1}$) | AC welding current (A) | Electrode diameter (mm) | Average laser power (W) | Observe angle, $\beta$ (°) |
|---|---|---|---|---|---|
| 400 | 5 | 70 | 3.2 | 300 | 45 |

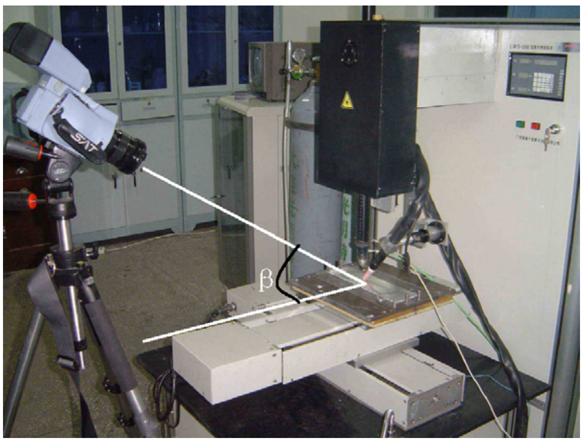



Fig. 1. Setup of hybrid laser-TIG welding.

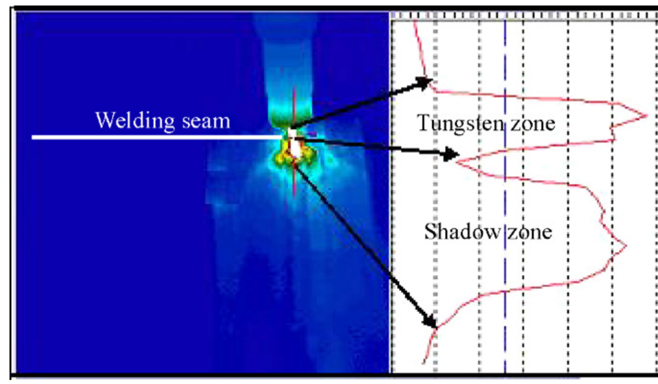



Fig. 2. Tungsten electrode interference.

data of welding temperature field captured by IR termography system was calibrated.

## 2. Experimental setup

The workpieces used in this paper is AZ31B magnesium alloy plate with 300 mm × 100 mm × 2.5 mm. The surface of the plate was cleaned by acetone and scratch brushed before welding to maintain consistent surface conditions and minimize the fluctuation of emissivity. Welding conditions are shown in Table 1, and setup of the experiment is shown in Fig. 1. The infrared thermography system measures temperature field by sampling portion of the emitted energy within a wavelength band of 8–14 μm, each infrared image is consisted by 240 × 320 discrete temperature sensors.

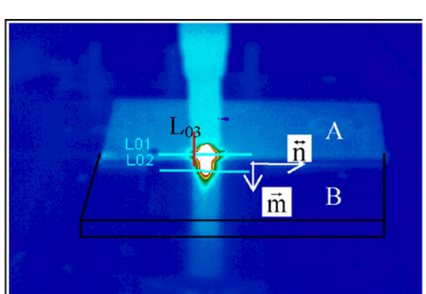
## 3. Interference analysis

### *3.1. TIG tungsten electrode interference*

An experiment was designed as follow to discuss the interference of tungsten electrode in welding temperature field measured by IR system: worktable and TIG torch were fixed and the IR image was captured after the arc burning for 3 s, as shown in Fig. 2. Fig. 2 shows that there are two high-temperature zones (highlight zone) by scan-line analysis. One is tungsten electrode zone and the other is the shadow zone of tungsten electrode caused by specular reflection, which will disturb the accuracy of welding temperature field measurement. The shadow is parallel to the observational direction and the length of shadow changes with observational angle varies. And scan-line shows that interference in low-temperature zone from tungsten electrode is little.

### *3.2. Arc light interference*

In this experiment, TIG torch located above A plate, and had the distance of 9 mm to the verge of A plate. B plate was placed parallel to A with 1 mm clearance, as shown in Fig. 3a. The infrared thermography system caught IR image while arc was burning steadily. L01 line scaned arc temperature profile, and L02 line scaned arc inverted image. The temperature in L01 is higher than L02, as shown in Fig. 3b. Area of radiant specular reflection interference is little in $\leftrightarrow n$ direction which is mostly caused by arc diffuse reflection, but that is larger in $\vec{m}$ direction

(a) 

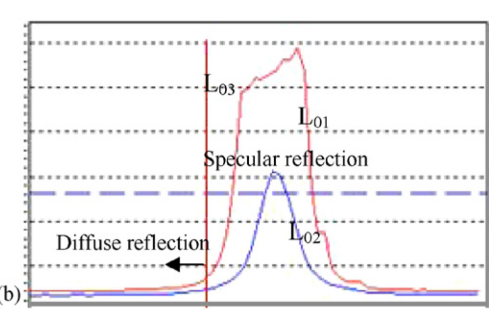

(b) 


Fig. 3. (a and b) Arc IR image and scan-line analysis.