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EMD-based pulsed TIG welding process porosity defect detection and defect diagnosis using GA-SVM

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ABSTRACT

A portable spectrometer based on a linear CCD is designed with real-time acquisition and processing of spectral data in the welding process of aluminum alloys. An innovative method is introduced to diagnose and detect porosity defects. The method extracts several characteristic spectral lines and calculates the intensity ratio between H I and Ar I. The intensity ratio is used to diagnose extraordinary cases of hydrogen content. Empirical mode decomposition (EMD) is used to acquire adaptive decomposition of the ratio signal, which has been proved to have better performance in eliminating the influence of pulse current on the ratio signal than wavelet packet transform. Experiments based on X-ray inspection are designed to verify the proposed method. Monitoring of the arc atmosphere and detection of porosity under different welding processes is achieved by extracting the feature parameters. An improved support vector machine (SVM) classification model based on a genetic algorithm (GA) is built in order to guarantee accurate estimation of different types of porosity defects.

1. Introduction

One of the defects of the aluminum alloy welding process is porosity, which is prone to happen and causes huge damage to weld performance (Ascari et al., 2012). To ensure weld quality, nondestructive testing is always needed after welding. Nondestructive testing methods that can be used for detection of weld porosity include X-ray testing (Zou et al., 2015), ultrasonic testing (Yamamoto et al., 2014) and spectroscopy testing (Harooni et al., 2014).

Valavanis and Kosmopoulos (2010) extracted 43 descriptors corresponding to texture measurements and geometrical features based on weld radiographs. The descriptors were used to identify the worm holes, porosity and other defects after training by SVM. A morphological image processing approach was proposed by Anand and Kumar (2006) to detect flaws, which were further categorized according to their properties from radiographic weld images. Sun et al. (2005) designed a set of real-time image acquisition systems based on X-ray to automatically detect defects such as slag inclusion, porosity and lack of penetration using a fuzzy pattern recognition method. Using an acoustic emission technique, welding porosity was detected in the structural component of a track crane with characteristic parameters such as amplitude and centroid frequency (Tao et al., 2014). Ultrasonic testing was employed by Kadumberi et al. (2012) to acquire data from a range of electrofused welding joints, and good corroboration between the observed weld quality and the ultrasonic data was achieved.

However, both X-ray testing and ultrasonic testing have a higher requirement to the instruments and environmental conditions. In addition, it is difficult to distinguish porosity and slag inclusion using these test methods. Therefore, it is necessary to identify a novel method to detect porosity. An arc spectrum contains information about metal vapors, shielding gases and arc gases. Therefore, it is intrinsically linked to internal weld defects, which makes it the most promising new method for real-time detection of weld defects. Węglowski (2007) preliminarily studied the influence of welding parameters on the spectral intensity. A method was proposed to measure hydrogen content in the electric arc based on spectroscopy technology (Shea and Gardner, 1983). Sibillano et al. (2012) conducted welding experiments with three different types of laser source and found that there was a corresponding relationship between plasma electron temperature and penetration. Thus they put forward a method for on-line monitoring of the welding joint penetration. According to Kong et al. (2012), a correlation between the electron temperature and defects within the weld bead was identified. Mirapeix et al. (2007) used artificial neural

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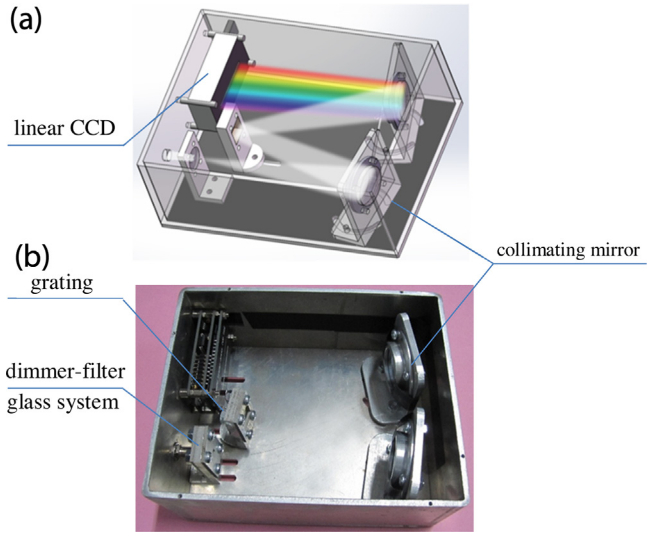

Fig. 1. Internal structure of the spectrometer: (a) Schematic diagram of the light path, (b) Spectrum sensor.

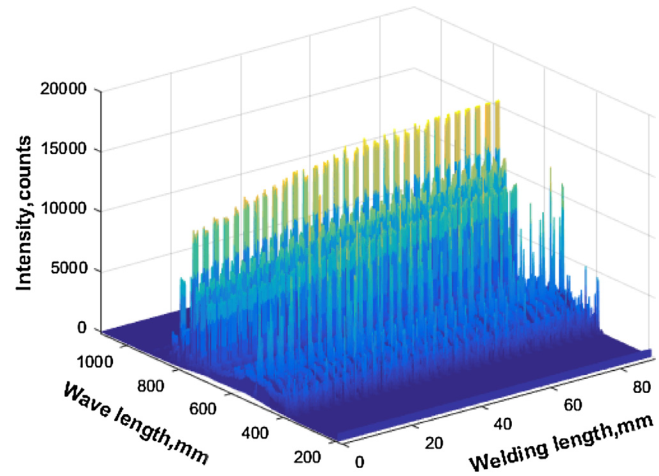

Fig. 2. Arc spectrum of aluminum alloy GTAW (peak current 240 A, base current 40 A).

networks to classify several types of surface defects by calculating the plasma electron temperature.

In this paper, a defect detection system is developed based on spectroscopy technology that is aimed at solving the existing problems in the conventional detection method of porosity defects. The system achieves real-time processing of spectral data and warns of excessive hydrogen in the arc. Furthermore, a new method based on EMD is proposed for detecting weld porosity. The method is proven to be feasible and reliable through X-ray testing of welding beads. Finally, an SVM model based on GA was built to classify different types of porosity defined by ourselves and according to the international standard of classification of porosity.

2. Experimental equipment and monitoring principle

2.1. Experimental equipment

Presently, commercial spectrometers on the market are used for general equipment, which means they are not designed for welding. Meanwhile, the secondary development of software for monitoring welding processes is costly. For these reasons, a portable spectrometer designed and manufactured for the welding process is discussed in this paper. The spectrometer achieves real-time collection of wavelengths ranging from 200 nm to 1100 nm in the aluminum alloy welding process. Moreover, a dimmer-filter glass system can be added to the internal structure to collect specific wavelength data as needed.

The internal structure of the spectrometer is shown in Fig. 1. By acquiring arc radiation measurements in the welding process, a

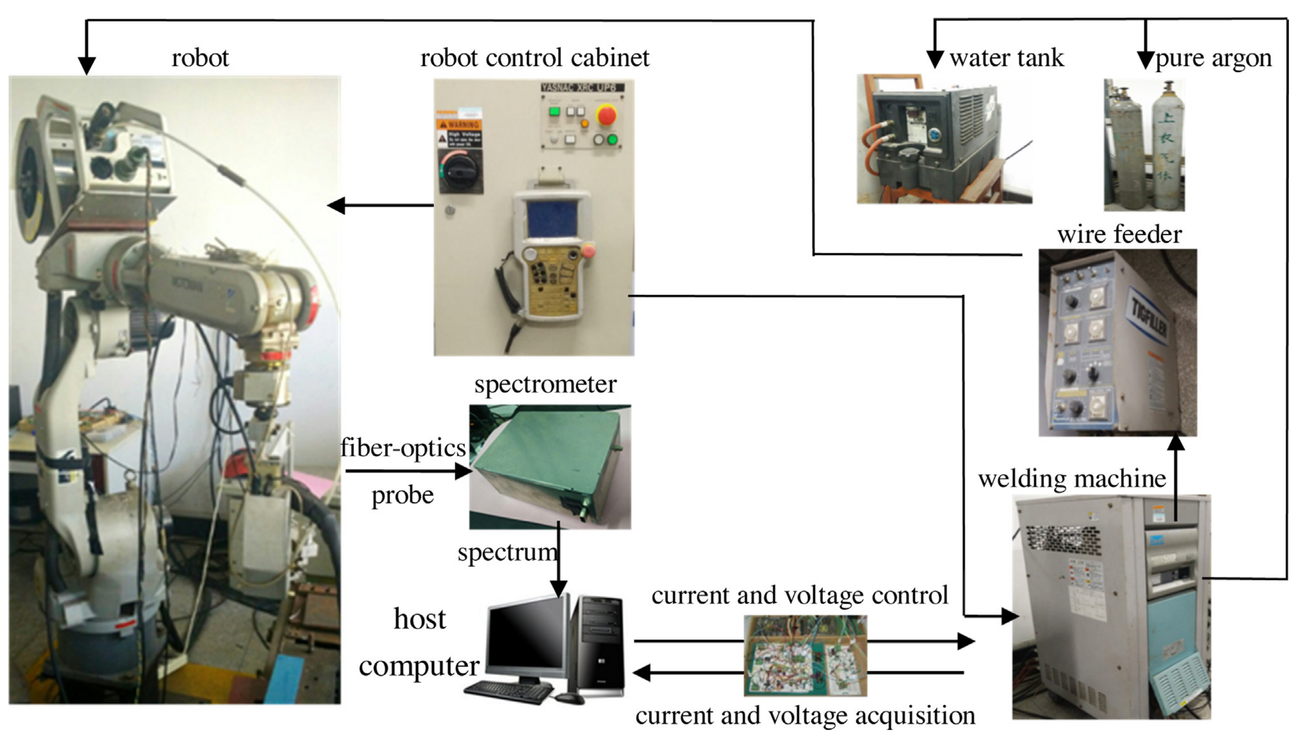

Fig. 3. Diagram of the experimental system.