Measurement 69 (2015) 64–71

Contents lists available at ScienceDirect

Measurement

journal homepage: www.elsevier.com/locate/measurement

Online welding quality monitoring for large-size electrical contact high frequency induction brazing

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ARTICLE INFO

Article history:
Received 17 February 2014
Received in revised form 8 March 2015
Accepted 18 March 2015
Available online 26 March 2015

Keywords:
Electrical contact
High frequency induction brazing
Online monitoring
Electrical parameters

ABSTRACT

In the low voltage apparatus manufacturing industry, the welding quality of electrical contact directly determines the switching capacity, lifespan and reliability of electrical equipment. Currently, only a little research on online monitoring of large-size electrical contact high frequency induction brazing has been carried out. In this research, CJ400 electrical contact was used as samples to be welded in the way of pulse induction brazing. And the electrical parameters during the whole welding process were collected and integrated with the dual 32-bit ARM (Advanced RISC Machines) controller. The relationship between welding quality and integral value of electrical parameter was analyzed. The results showed that the deviation between the ideal integral value of electrical parameters and the actual integral value of electrical parameters could be identified an indication for welding quality.

1. Introduction

As core component of low voltage equipment, electrical contact is responsible for turning on and off the circuit. For the requirement of high conductivity and good heat dissipation, electrical contact composed of contacter and tip is usually made of Ag, Cu and their alloys [1–7]. High frequency induction brazing is widely used in the welding of large-size (welding area more than 100 mm^2) electrical contact due to the advantages such as high efficiency, easy to realize mechanization and automation. To keep a high welding efficiency, the frequency of heating power is usually set in a range from 30 kHz to 50 kHz. However, the welding quality is unstable due to the fluctuation of electrical parameters such as current and voltage. Poor qualified welding would lead to a high contact resistance between electrical contacts, which could not undertake high current and high frequency turning on and off in the circuit. That would eventually result in the separation between contacter and tip.

Currently brazing rate and shear strength are adopted to estimate the welding quality of electrical contact. Brazing rate (the ratio of the actual welding area and the area of joint) is measured by ultrasonic C scanning. It costs about one hour to get the brazing rate for each large-size electrical contact. And sheer strength method has destructive consequences. So the present methods for quality testing cost too much time and manpower. Therefore, the welding quality is usually assessed by sampling inspection after welding. In the industry of high frequency induction heating, the heating temperature was used to realize the closed loop quality control [8]. However, this technique cannot be applied in production industry of electrical contact because of the restrictions of special structure. And the temperature gradient is extremely steep due to the high frequency. So how to realize the fast non-destructive quality inspection becomes a burning problem needed to be resolved.

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http://dx.doi.org/10.1016/j.measurement.2015.03.016
0263-2241/

In the previous studies about other welding industries, establishing quality control model based on electrical parameters has been carried out. In the resistance spot welding (RSW) industry, the process electrical parameters such as voltage, current are directly related to the energy output of power and the welding quality. So the technology of online quality monitoring based on electrical parameters has been widely studied [9–12]. The welding current and voltage in the primary circuit of resistance spot welding machine were detected, characteristic parameters extracted from the dynamic resistance curve were used to estimate the welding quality [13–14]. And the electrode invalidation could be also estimated by the dynamic resistance between electrodes [15]. Electrical signals of arc were used to monitor welding quality and analyze the defects in the industry of plasma arc welding (PAW) and gas tungsten arc welding (GTAW) [16,17].

In this research, a new high frequency induction heating system based on the dual 32-bit ARM controller was designed. And the integral values of electrical parameters in different process parameters of high frequency induction brazing were analyzed. The quality monitoring scheme based on electrical parameters was tested.

2. Experiment

2.1. Materials and equipment

In this study, high frequency induction brazing of CJ400 electrical contact which is composed of tip and contactor was performed. The tip measuring $20 \times 14 \times 2$ mm is made of AgCdO15. The contactor is made of T3. The Schematic diagram of high frequency induction brazing is simply presented in Fig. 1.

The high frequency induction heating system designed was digitalized and flexible with a power 45 kW and frequency 45 kHz. The system is composed of process parameter input screen, dual 32-bit ARM controller and heating power body. The framework diagram of heating system is shown in Fig. 2. As the core component of the system, the dual 32-bit ARM controller is mainly used for the collection and uploading of data, controlling of the output of high frequency induction heating power. By this controller, heating time could accurate to millisecond and voltage could accurate to millivolt from 0 to 10 V which directly determines the energy output of heating equipment. That would make the heating process flexibly and precisely controlled for different heating modes by programming the dual 32-bit ARM controller.

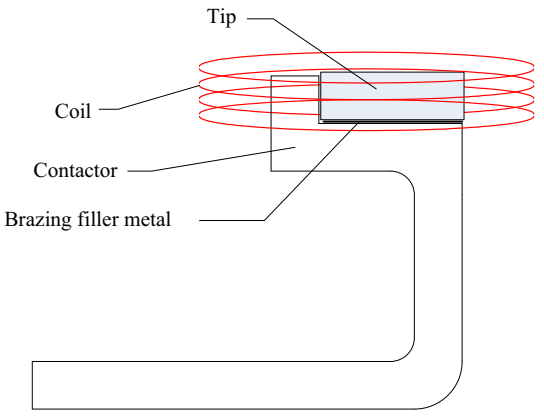

Fig. 1. The Schematic diagram of high frequency induction brazing.

In this experiment, the technology of high-frequency carrier and low-frequency modulation is adopted. Based on high frequency induction heating, output of the power is modulated by low-frequency pulse instead of traditional continuous heating mode. The process curve is shown in Fig. 3. The peak and basic value of energy output and heating time could be regulated with process parameter input screen.

The quality of the contact welding was estimated by brazing rate calculated with ultrasonic C scanning (provided by Xi'an Jiaotong University). The electrical contact which has a brazing rate between 80% and 100% is defined as good welding quality, less than 80% is defined as unqualified.

2.2. Date processing method

The current and voltage (digital value) parameter curve collected in the primary circuit of welding transformer are shown in Figs. 4 and 5. The current, voltage and power of each electrical contact are integrated by the Eqs. (1)–(3) because the acquisition time interval is equal. Where u_m and i_m are respectively instantaneous voltage and current, n is the number of collected data for each electrical contact. U, I and P are the integral value of current, voltage and power respectively. From Eqs. (1)–(3), it could be known that the integral value of electrical parameter is proportional to the output of heating power. And the integral value of each contact can reflect the fluctuations of energy output.

$$U = \sum_{m=0}^{m=n} u_m dt \tag{1}$$

$$I = \sum_{m=0}^{m=n} i_m dt \tag{2}$$

$$P = \sum_{m=0}^{m=n} u_m i_m dt \tag{3}$$

3. Results and discussion

3.1. Relationship between integral value of electrical parameter and brazing rate

It is known that fluctuation of process parameters is inevitable during the high frequency induction brazing. And only a little fluctuation of current and voltage could cause a large disturbance of energy output. Consequently, the brazing rate and welding quality of electrical contact would be unsteady. Currently brazing rate is regarded as welding quality inspection standards of electrical contact.