Vision-based detection of weld pool width in TIG welding of copper-clad aluminum cable

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Abstract *In order to realize automatic control of the width of weld pool, a visual sensor system for the width of weld pool detection is developed. By initiative arc light, the image of copper plate weld pool is taken back of the torch through the process of weakening and filtering arc light. In order to decrease the time of processing video signals, analog circuit is applied in the processing where video signals is magnified, trimmed and processed into binary on the datum of dynamic average value, therefore the waveform of video signals of weld pool is obtained. The method that is used for detecting the width of weld pool is established. Results show that the vision sensing method for real-time detecting weld pool width to copper-clad aluminum wire TIG welding is feasible. The response cycle of this system is no more than* 50 ms, *and the testing precision is less than* 0. 1 mm.

Key words visual sensor, copper-clad aluminum cable, TIG welding, weld pool, detection

0 Introduction

Copper-clad aluminum cable is bimetallic cable that aluminum pole is covered with copper plate. Instead of copper it is all right inner conductor to product coaxial radio-frequency cable, for the influence of gathering surface effect, electromagnetic wave signal of high frequency is transmitted to the conductor surface. Copper-clad aluminum cable has the same transmitting capability as pure copper cable. However, the density of copper-clad aluminum cable is only 37 percent to 40 percent of pure copper cable. In addition, the copper source is lean ore in our country. With the high-speed developing of information industry, Community Antenna Television net will be built and renewed constantly, moreover, the integrated net about Community Antenna Television and computer will be established, therefore, instead of pure copper cable, copper-clad aluminum cable would has wide foreground of application[1-2].

Copper-clad aluminum cable is produced in the welding course where aluminum pole is covered with copper plate. The welding method is TIG welding, and welding speed is more than 8 m/min. Because copper plate thickness is variable sometimes, faulty fusion and burn through usually appears in the case of constant welding current. Large quantity waste products are produced before adjusting welding current when operator find faulty fusion and burn. Therefore, it is necessary to realize width of weld pool real-time sensing and controlling in welding process.

Recently, CCD camera is applied extensively in many sensing methods. Various approaches for TIG welding such as weld pool pattern detecting and real-time controlling have been extensively explored[3-11]. However, the practicable application to TIG welding of copper-clad aluminum cable is not found.

In the course of TIG welding of copper-clad aluminum cable, continuous welding current is used, so it is impossible that distinct image of weld pool is captured during maintenance arc. In addition, welding speed is very fast, if computer image processing techniques is adopted, the system capability is reduced, therefore, vision sensing real-time detecting system for the width of weld pool is established, and the image of weld pool is obtained in the

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adjacent arc area. During continuous weld current, distinct image of weld pool is obtained through weakening and filtering arc light. Video signals is processed by analog circuit, so the delay time when is only a few nanoseconds. The width of weld pool is calculated with microcomputer. The response cycle and the testing precision of this system meet require of practice to TIG welding of copper-clad aluminum cable.

1 System structure

Visual sensor for the width of weld pool real-time detecting system was established as in Fig. 1, which included CCD camera, narrow-band filter, circuit of video signals processing, video monitor, microcomputer circuit, display circuit, current controller and arc welding power source, etc.

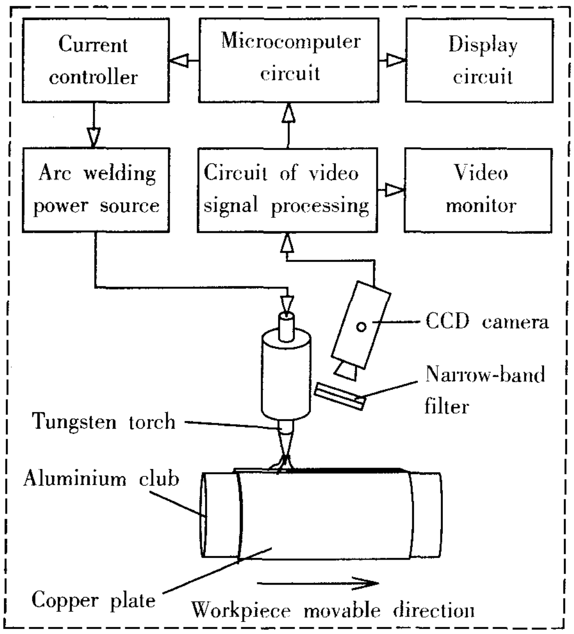


Fig. 1 The diagram of visual sensor for width of weld pool real-time detecting system

2 Flow of video signals processing

Flow diagram of video signals processed is shown in Fig. 2.

2.1 Image collection

Continuous welding current is used in the course of TIG welding for copper-clad aluminum cable, and it is no less than 200 A. The image of arc that is weakened by dimmer glass is shown in Fig. 3a. For the intensive arc light, the image of weld pool is fuzzy. The image of arc that is weakened by dimmer glass and filtered by light filter is shown Fig. 3b. The end of tungsten torch and the edge of weld pool is distinctive enough in the image. According to this character of the image, by initiative arc

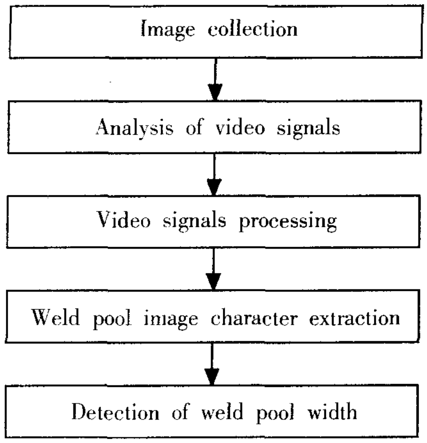
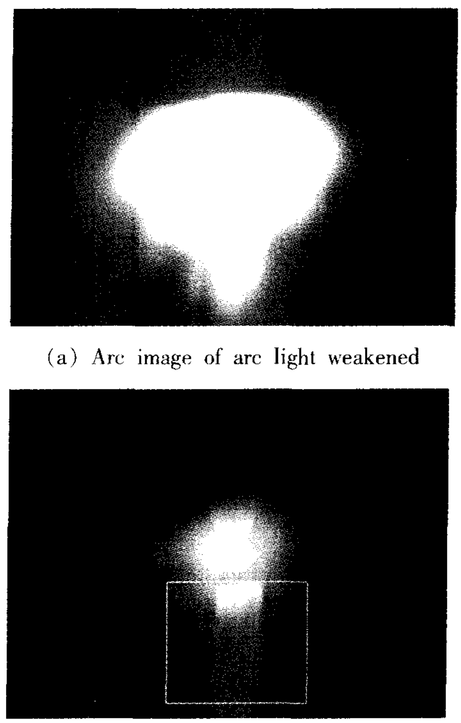


Fig. 2 Flow diagram of video signals processed



(a) Arc image of arc light weakened

(b) Arc image of arc light weakened and filtered

Fig. 3 Arc image

light, the image of weld pool (selected area is shown in Fig. 3b) is taken back of the torch with visual sensor. The actual width of weld pool is 1 mm, and its enlarged image in monitor is shown in Fig. 4. Temperature and radiation of weld pool is very intensive, so the image character of weld pool is white in the video monitor. The action of copper plate mirroring arc light is not intensive, so the image character of copper plate is dim in the video monitor. The edge of weld pool is obvious.

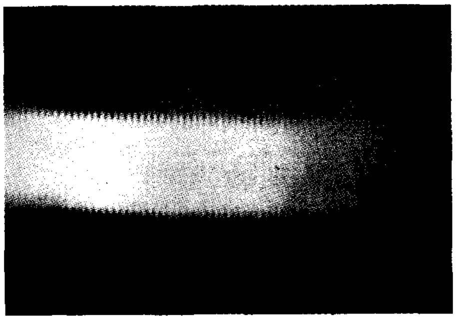


Fig. 4 Image of weld pool in monitor

2.2 Analysis of video signals

Video signals waveform in oscillograph is shown in Fig. 5. Video signals voltage of weld pool is the highest, its waveform is regular, and it occurs a sudden change in edge of weld pool. Video signals voltage of copper plate is lower than video signals voltage of weld pool. The signal of frame synchronism cycle is 20 ms. Two low lines of the waveform between two signals of frame synchronism is horizontal synchronism signal. As a result, the video signals, which have many low horizontal synchronism signals, cannot be used for identifying the edge of weld pool with microcomputer.

2.3 Video signals processing

The signal waveform is shown in Fig. 6, it is obtained after video signals are magnified, trimmed and the interval of horizontal synchronism signal is filled up. The waveform consists of video signals of weld pool, video signals of copper and the signal of frame synchronism. It can be found from Fig. 6 that noise signal and horizontal synchronism signal disappears after video signals are processed. Results show that video signals voltage of weld pool is the highest, and the peak value of voltage is different from voltage of copper plate, and it is corresponding to the center of weld pool. According to this character of the image, the edge of weld pool is possibly identified.

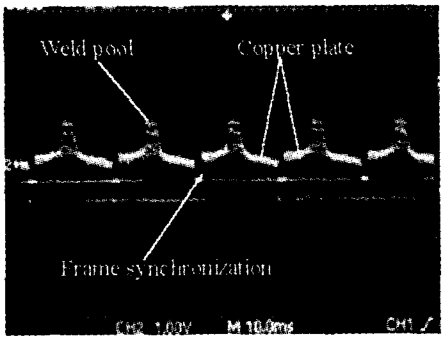


Fig. 5 Waveform of video signals

2.4 Weld pool image character extraction

The analog signal that is shown in Fig. 6 is difficult to be processed by microcomputer. Moreover, for the influence of arc light and copper mirroring action during the course of manufacturing, visual signal voltage of copper plate changes frequently. A video signal that is processed into binary on the datum of dynamic average value is shown in Fig. 7. Video signal that is shown in the video signals processed curve is magnified, trimmed and the interval of horizontal synchronism signal is filled up. The dynamic average value curve represents dynamic average value that can reflect whole mirroring status of the copper plate surface. The square waveform signal that is obtained through binary processing is shown in Fig. 8. The analog circuit is applied in the course of video signals processed,

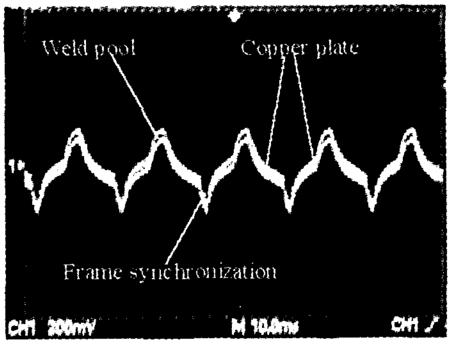


Fig. 6 Waveform of processed video signals

so delay of this course is only a few nanosecond, however, this kind of the rapidly responding velocity is not reached by computer image processing techniques.

The brim of rise and fall in the waveform that showed in Fig. 8 corresponds to two edges of weld pool. Time sequence both video signals processed and square waveform of weld pool is shown in Fig. 9. The video signals curve represents video signal that is magnified and trimmed. The square waveform curve represents square waveform of weld pool.

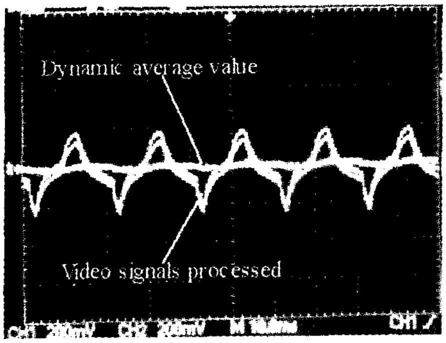


Fig. 7 Waveform of binary processing

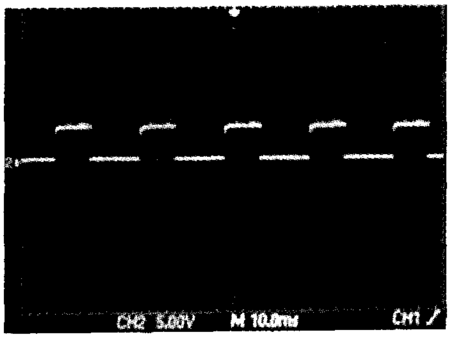


Fig. 8 Square waveform of weld pool

2.5 Detection of weld pool width

Microcomputer is used to calculate width of pulse signal of weld pool. Motion of work piece is smooth in the course of production to TIG welding of copper-clad aluminum cable, so the distance between visual sensor and surface of work piece does not vary. Results show that the width of square waveform in video signals of weld pool is 3 ms while the practical width of weld pool is 1 mm. Therefore, the change of 0.3 ms about square waveform in video signals of weld pool is corresponding to the change of 0.1 mm in the practical width of weld pool. However, the accuracy of 0.3 ms pulse width that measured with microcomputer is realized easily. So the testing precision of this system is less than 0.1 mm.

The frame cycle of video signals is 20 ms, and the time of two frames video signals processed in microcomputer is no more than 40 ms, in addition, the time of procedure processing is less than 10 ms, so the response cycle of this system is no more than 50 ms.

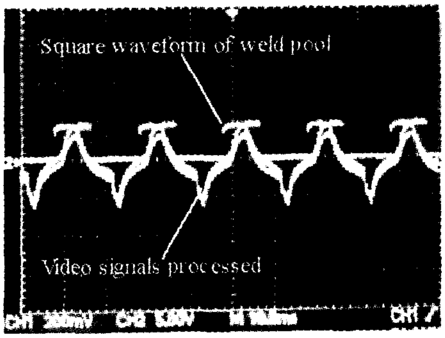


Fig. 9 Time sequence diagram of two signals

3 Conclusions

(1) By initiative arc light, through the process of weakening and filtering arc light, the vision sensing method for real-time detecting weld pool width to copper-clad aluminum wire TIG welding is feasible.

(2) Video signals is magnified, trimmed and processed into binary on the datum of dynamic average value. The video signals waveform of weld pool is obtained. In addition, real-time detection the width of weld pool is realized.

(3) The analog circuit is applied in the processing where video signals is magnified, trimmed and processed into binary on the datum of dynamic average value, therefore the time of video signals processed is reduced extremely. The response cycle of this system is no more than 50 ms, and the testing precision is less than 0.1 mm.

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