Recognition and classification of ultrasonic aluminum wire joint based on image morphology and C-SVM

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***Abstract*—Aiming at the quality inspection of ultrasonic aluminum wire joint, this paper proposes a method of ultrasonic aluminum wire joint quality identification based on PCA and C-SVM. Firstly, extracting the ultrasonic aluminum joint image from the ultrasonic welding element image by applying image morphological operations and image histogram equalization, and then reducing the dimension of the ultrasonic aluminum joint image data by applying PCA, finally identifying the quality of the joint by applying C-SVM with Gauss-RBF kernel function. Experimental results show that this method has a high accuracy.**

Keywords*—*Ultrasonic Aluminum wire welding; Machine Vison; SVM; PCA

I. INTRODUCTION

Ultrasonic metal welding is a special connection technology which has been widely used in the fields of electronic manufacturing, e.g. new material preparation, aerospace and nuclear power industry, etc. [1]. Although ultrasonic metal welding can obtain good welding effect, there still exists the stability problem between the ultrasonic generator and the mechanical system. The unstable situation of the ultrasonic system has a direct impact on the welding effect. To reduce this effect, this paper proposes a method which use machine vision to identify the quality of the ultrasonic metal welding spot, and based on the result to identify whether the output power of ultrasonic is up to standard.

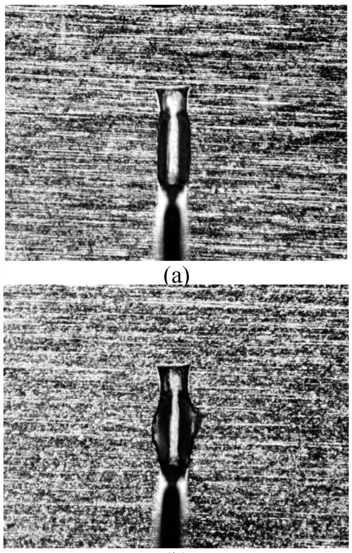
Many achievements have been obtained in joint recognition using machine vision. Mar, N.S.S., etc., put forward two kinds of solder joint classification models “front-end model” and “back-end model” [2]. Makabe, Akira, etc. proposed a method to detect solder joints using Mahalanobis distance [3]. Ma Jiquan of Harbin Institute of technology proposed a solder spot quality detection using image surface visual recovery technology [4]. Yang Xiaolong of Harbin Institute of Technology proposed a quality inspection based on the ring RGB features of solder spot [5]. Han Yueping, etc. put forward a method of welding quality inspection of micro circuit based on X ray [6].

Though many of the above methods are applied in the field of PCB welding, many of them can also be applied in the field of ultrasonic metal welding. In view of ultrasonic aluminum wire joint, this paper puts forward an ultrasonic aluminum wire joint image extraction algorithm, and then use PCA to reduce the dimensions of the solder joint image data. Finally, the quality of ultrasonic aluminum wire joint can be identified by applying C-SVM.

II. JOINT EXTRACTION AND CLASSIFICATION

A. Source of the original image

In this paper, the standard output power of the ultrasonic welding machine is 60W and the excess power is 65W (the heating platform is not used). The diameter of the aluminum wire is 60 μm, and the aluminum wire is welded on the surface of high power thyristor. Fig. 1(a) is the joint image in standard output power case. Fig. 1(b) is the joint image in exceed output power case. It can be observed clearly in Fig. 1(b) that the region of the joint is larger, the edge of joint is irregular and not smooth. Therefore, the fluctuation of output power of ultrasonic welding machine can be detected by identification of the quality of ultrasonic aluminum wire joint.



(a)

(b)

Fig. 1. (a) The joint in standard output power. (b)The joint in exceed output power.

B. Extraction of ultrasonic aluminum wire joint image

To extract the ultrasonic aluminum wire joint image, some image processing methods are used, including average filter, image morphological closed operation and equalization. The algorithm for joint image extraction is shown in TABLE Ⅰ.

TABLE Ⅰ.Algorithm of joint image extraction

Input: Ultrasonic welding images of high power thyristor taken by industrial camera

Process:

a) Applying 5×5 mean filter to the original image.

b) After mean filtering, applying Canny edge detection.

c) Applying 35×35 mean filter to the result image of step b).

d) To improve the contrast of image of step c), histogram equalization is applied to the image of step c).

e) Applying image morphological closed operation on the image of step d) and the kernel size is 80×80.

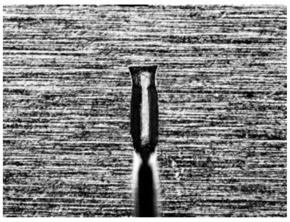
f) Applying inverse two value operation on the image of step e). The threshold is 90, the equation is,

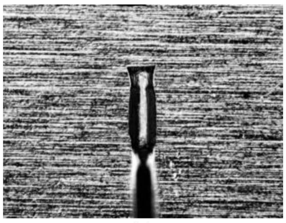
$$dst(x,y)=\begin{cases}0, src(x,y) > threshold \\ max\,value, otherwise\end{cases}$$

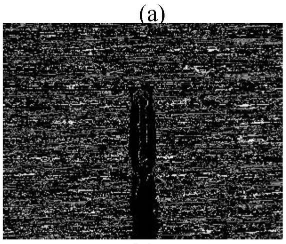
g) Extracting contour of the image of step f) and the regions of quadrilateral fitting of contours are the potential joint area. Applying algorithm shown in TABLE Ⅱ to screen and merge the regions.

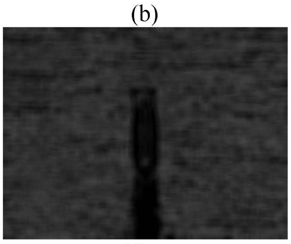
Output: Image of ultrasonic aluminum wire joint

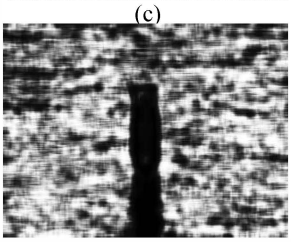
The output of each steps is shown in Fig. 2 (a)~(h),

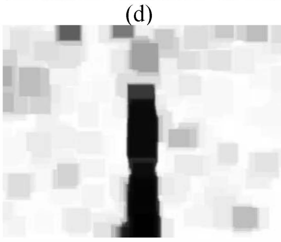

(a)


(b)


(c)


(d)


(e)


(f)


(g)


(h)

Fig. 2. (a)Source image. (b)Average filter image. (c)Canny edge image. (d)Average filter image after canny edge extraction. (e)Histogram equalization image. (f)Image morphology closed operation image. (g)Inverse binarization image. (h)The solder joint image.

TABLE Ⅱ. Contours screening and merging algorithm

Input: The contours of step f) of algorithm shown in TABLE Ⅰ.

Process:

a) Calculating the number of contours.

b) Eliminating the contour with less than 400 points.

c) Eliminating the contours at the top of the ultrasonic welding image of high power thyristor.

d) Applying quadrilateral fitting on contours with greater than 1200 points.

e) Eliminating the contour at the top of the ultrasonic image of high power thyristor.

f) Merging the contours with less than 1200 points.

Output: The region of ultrasonic metal joint

The algorithm shown in TABLE Ⅱ. is designed to process the excessive segmented joints which are shown in Fig. 3(a)~(b).


(a)

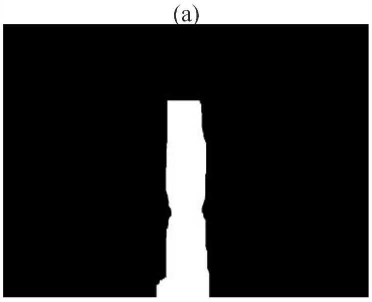

(b)

Fig. 3. (a)The joint which is segmented excessively. (b)The joint which is segmented perfectly.

The algorithms shown in TABLE Ⅰ. and TABLE Ⅱ. can still be applied on multi joint images and the result is shown in Fig. 4(a)~(b).