Detection of Spot Welding Electrode Tips Using CLAHE, Bilateral Filter and Hough Transform

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1. Introduction

For spot welding, it is important to determine the optimal replacement cycle of spot welding electrodes to ensure the quality of the welds. However, the life of the electrodes is affected by environmental and operational conditions. It is often difficult to find the optimal replacement cycle of the electrodes. It was reported that the degradation of the electrodes can be estimated by observing the surface of the electrode tips during spot welding. The condition monitoring methods of welding electrodes are reported in the literature. Voltage, current, and images from sensors installed in the welding systems were analyzed to determine the conditions by nondestructive evaluation [1-3]. Based on the analysis of the image data from the electrode, the size of the electrode tips is changed as the welding process progresses. For example, Peng et al. [4] discussed the relationship between the size of electrode tips and electrode condition. It was challenging to measure size of the electrode tips accurately.

This study presents a combination of image processing methods that can detect the electrode tips. When images of the electrodes are given, electrode tips are detected and isolated from unnecessary objects. The image processing methods includes (1) contrast limited adaptive histogram equalization (CLAHE), (2) bilateral filtering, and (3) Hough transform. This paper is organized as follows. In Section 2, the image processing methods are overviewed. Then relevant techniques including CLAHE, bilateral filtering, Hough transform were described. In Section 3, the framework of the presented method is described. Section 4 concludes this paper with future works.

2. Image Enhancement for Welding Electrode Tip Monitoring

The CLAHE is a method that adjusts image intensities adaptively using the image's histogram [5]. The method computes several histograms of each kernel image and decided threshold value to redistribute the lightness values of the image. Therefore, this technique reduces the noise caused by the illumination of the image adaptively. An example of images obtained from a test bed of spot welding machines is shown in Fig. 1(a). Defect traces on the electrode tips are not clear in the original image due to illumination. However, after processing the image with CLAHE, the defect traces become clear as shown in Fig. 1(b).

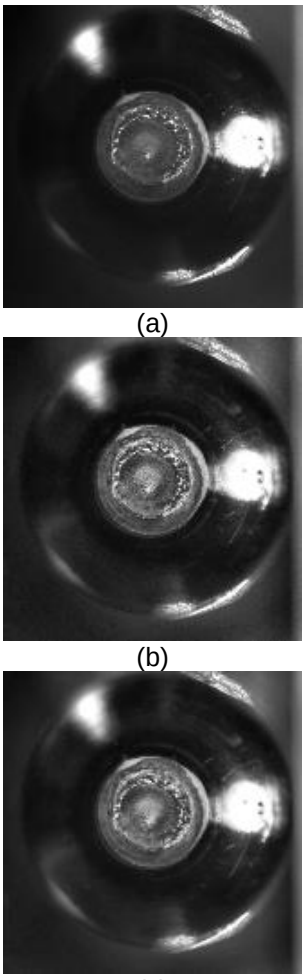


Fig.1 Spot welding electrode image: (a) original image, (b) image after CLAHE, and (c) image after CLAHE and bilateral filtering

Image blurring reduce image noise by blurring the image's pixels. However, image blurring has the disadvantage of deleting edge information of the image. To solve this problem, the bilateral filter replaces the intensity of each pixel with a weighted average of intensity values from nearby pixels [6]. Therefore, the bilateral filter removes noise on the

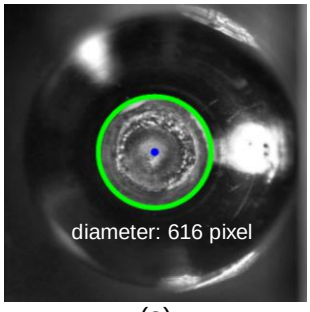
image while maintaining the edge information. The image in Fig. 1(b) was processed by the bilateral filtering as shown in Fig. 1(c).

3. Welding Electrode Tip Detection by Hough Transform

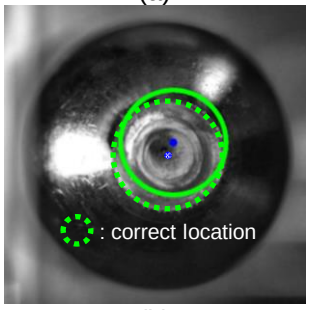
Detecting the coordinate of the electrode tip center and measuring the diameter of electrode tips is challenging since shape distortions and noise exist. One of effective methods that addressed the problem is Hough transform. Hough transform can be used to detect lines, circles or other parametric curves by isolating features of a particular shape within an image [7]. The transform can provide robust detection results under noise and partial occlusion.

Images after CLAHE and bilateral filtering as described in Section 2 were processed by Hough transform. It was assumed that the object to be detected is a circle. After preliminary study, the parameter values of Hough transform are set as follows: (1) maximum diameter of 620 pixels, (2) minimum diameter of 580 pixels and (3) distance between circles of 2400 pixels (i.e., diagonal length of the image in order not to detect other circles). When the distance between the true center of the electrode tips and the detected center by Hough transform is larger than ten percent of the electrode tip diameters (i.e., 60 pixels), it is determined that the detection failed.

The number of tested images was 500. 488 images (97.6%) showed correct detection. A representative image with correct detection is shown in Fig. 2(a). Only 12 images (2.4%) were detected beyond the detection criterion as shown in Fig. 2(b).



(a)



(b)

Fig.2 The center and diameter of the electrode tips were detected: (a) correct detection (b) wrong detection

4. Conclusion

This paper presents an image enhancement and welding electrode detection method. The image enhancement techniques including CLAHE and bilateral filtering were used. Then, Hough transform was used to determine values related to geometric shapes of the welding electrode tips. The presented method performed with the accuracy of 97.6%. However, there is a room for further improvement.

It is challenging to estimate the life of electrode with images of welding electrode tips. In future, the life of welding electrodes will be estimated by characterizing the surface condition of electrode tips and measuring voltage and current waveforms. Artificial intelligence such as convolutional neural networks (CNN) can be used.

Acknowledgment

This study was financially supported by Korea Ministry of Planning and Budget Foundation through Korea Institute of Industrial Technology (Project Number: JH190001).

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