Stereo Measurement of Cross-Sectional Shape of Weld Beads by Marking

Mitsuaki Yoshimura*, Yonghoon Ji** and Kazunori Umeda***

Abstract: This paper proposes a system to inspect weld beads using a stereo camera. In general, a special scale or a welding inspection tool using laser light is used for welding bead inspection. However, the inspection tool has a problem that the size of the equipment is large and the measurement accuracy decreases when the surface of the welded material is close to the mirror surface. In the proposed system, marking is performed at an arbitrary welding point. Then, the system inspects the weld bead using a small stereo camera, which works even if the surface of the material is close to the mirror surface. The stereo camera detects the marked part. The three-dimensional (3D) information of the marking part is obtained using the principle of triangulation, and the validity of joining is evaluated using the 3D shape of the marked part. In the experiment, the accuracy is evaluated by measuring the distance between the camera and the object from 100 mm to 300 mm. The experimental results show the effectiveness of the proposed method.

Key words: arc welding , stereo camera , weld bead , 3D reconstruction , marking

1. Introduction

Arc welding is one of the popular welding methods. A raised weld bead is produced at the arc welded location. Weld bead inspection is carried out by using a special scale or a welding inspection tool based on a laser beam. However, when using a special scale, it is difficult to perform a whole-count inspection. In addition, the size of the inspection tool is large, and the measurement accuracy is reduced when the surface of the welded material is close to a mirror surface.

Takano et al. performed the measurement of the bead shape by a spot light laser sensor[1]. However, measurement using a laser beam is prone to be affected by the surrounding illumination conditions, in addition to the issue of mirror surface mentioned above.

To overcome the limitation of the laser-based measurement system, we propose a novel stereo camera-based measurement system. Firstly, marking is made at arbitrary welding points along the cross section. In particular, there is no specified line width. Then, a small stereo camera is used to inspect the weld bead at the points. The measurement with the marking is expected to work even if the surface of the material is close to a mirror surface.

2. Methods

2.1 Detection of Marking Points

Firstly, Marking, as shown in Fig.1, is done along the cross section of the weld bead. In particular, there is no specified line width. The marking parts are extracted by setting thresholds for RGB values of color image. Here, we use a fluorescent pink color for the marking as a stable color. The threshold values in this case are as follows

$$R \geq 135, \quad G/R \leq 0.91, \quad B/R \leq 0.92 \tag{1}$$

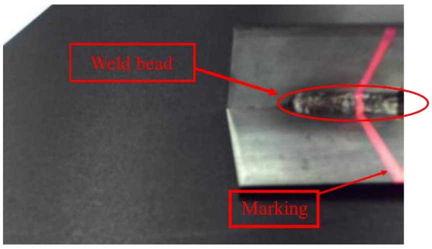

Fig. 1. Weld bead with marking.

2.2 Cross-Sectional Shape Estimation at Marking Locations

The disparity of stereo images is obtained using stereo matching. As shown in Fig. 2, the center coordinates on the horizontal axis of the extracted marking image are used in calculation of disparity. Then, using the principle of triangulation, the 3D information of the marking part is acquired.

Fig. 2. Extracted marking part.

2.3 Evaluation of welded points

In order to evaluate the state of the welded joint, the leg lengths S of the weld bead part and the extra height $\Delta a + a$ shown in Fig. 3should be obtained. To this end, the acquired 3D points are compressed into 2D by principal component analysis (PCA) and are projected in the cross-sectional direction using projective transformation. In order to detect the plane of the measurement object, a straight line is detected from the converted 2D information using RANSAC[2]. The point group deviating from the detected straight line is regarded as the welding bead. The leg lengths and extra height are calculated from the results.

* Course of Precision Engineering, School of Science and Engineering, Chuo University, 1-13-27 Kasuga, Bunkyo-ku, Tokyo 112-8551, Japan (yoshimura@sensor.mech.chuo-u.ac.jp)
** School of Materials Science, JAIST, 1-1 Asahidai, Nomi, Ishikawa 923-1292, Japan(ji-y@jaist.ac.jp)
*** Chuo University, 1-13-27 Kasuga, Bunkyo-ku, Tokyo 112-8551, Japan (umeda@mech.chuo-u.ac.jp)

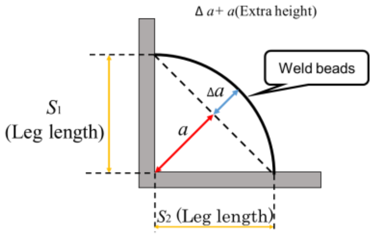

Fig.3. Weld bead part and leg lengths.

3. Results

3.1 Experimental conditions

Experiments were performed to estimate the cross-sectional shape of the marking part on the weld bead. In the experiments, the measurement object shown in Fig. 4 was used, in which two metal plates were vertically welded. Stereo Labs ZED was used as the stereo camera. The reason for using a stereo camera is to omit camera calibration. Its baseline length is 120 mm. The distance between the stereo camera and the metal plate was 100, 200, and 300 mm. We captured five images for each distance. The true values of the leg lengths and the extra height were obtained from Shape Grabber, which is a measurement instrument that uses the light sectioning method.

3.2 Experimental result

The experimental results are shown in Tables 1, 2 and Figs 4-7. Figures 4 -7 show the results of weld bead detection for 100 mm: color images of the stereo camera (Fig.4), extraction results of the marking part image (Fig.5), and the extracted 3D points projected on the 2D plane (Fig.6), and detected straight lines and extracted weld bead part (Fig.7), respectively. As shown in Fig. 7, the shape of the weld bead was acquired well. Table 1 shows the calculation results of leg lengths and extra height. Table 2 shows the results compared with the true values. When capturing at 200 mm and 300 mm distance, the 3D information could not be acquired correctly.

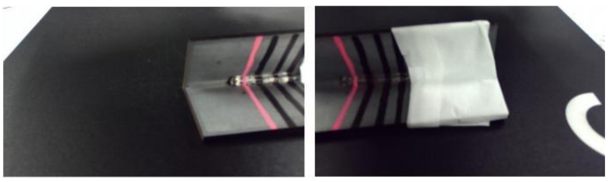

Fig. 4. Color image (left: left camera, right: right camera).

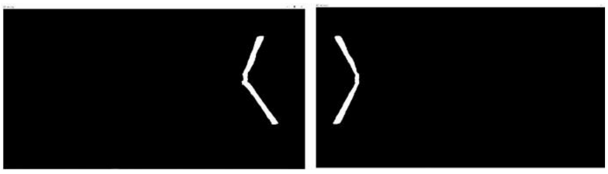

Fig. 5. Marker extraction image (left: left camera, right: right camera).

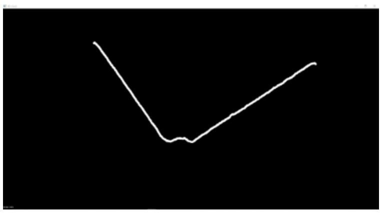

Fig. 6. Extracted 3D points on 2D plane.

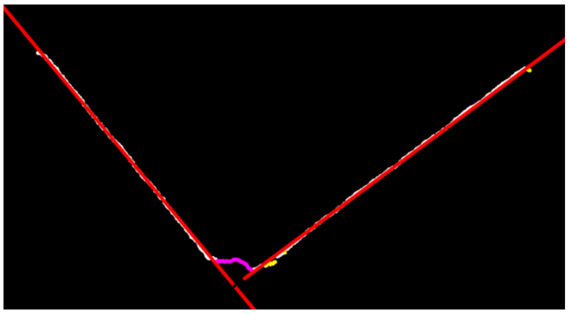

Fig. 7. Detected straight lines and extracted weld bead part.

Table 1. Measurement result of weld bead

	Extra height [mm]	Leg length1 [mm]	Leg length2 [mm]
No.1	2.75	2.05	2.73
No.2	2.94	2.92	2.34
No.3	2.89	2.20	2.88
No.4	3.03	3.01	2.45
No.5	2.88	2.86	2.09
Average	2.90	2.61	2.50
Standard deviation	0.08	0.37	0.26

Table 2. Comparison with true value

	Ture value	Measurement (Average)	Error
Extra height [mm]	3.20	2.90	0.30
Leg length1 [mm]	2.51	2.61	-0.10
Leg length2 [mm]	2.42	2.50	-0.08

4. Discussion

The 3D information of weld bead was acquired successfully with small errors at the distance of 100 mm. However, the measurement failed when the distance was 200 mm and 300mm. The reason of the failure is that the total number of points was not enough because of the long distance.

5. Conclusions

In this paper, we constructed a stereo camera-based inspection system for weld bead by marking at an arbitrary welding point. Our system facilitates the measurement even if the surface of the measured object is close to a mirror surface.

References

1) Yutaka Takano, Hikaru Yamamoto, Toru Takatani, and Yasuo Hayakawa, Measurement of groove and weld bead shape by spot laser sensor, Welding International, 14 (1), pp.706-713, 2000.

2) Kai Zhou, Guoliang Ye, Xiangdong Gao, Kaihong Zhong, Jianwen Guo, and Bing Zhang, Weld Bead Width and Height Measurement Using RANSAC, International Conference on Control and Robotics Engineering, (ICCRE), pp.35-39, 2019.