

Difference of improving welder's skill through training progression

Nobuyoshi HASHIMOTO*

(Received Oct. 31, 2014)

Abstract

Welding training has some disadvantages such as long time required and need for a considerable quantity of training material; in addition, it is dangerous for beginners. To overcome these limitations, effective training methods are being explored. These researches target one of many welding methods. However, it is necessary to consider series training of several welding methods because almost all welders are required to acquire multiple welding skills. This paper describes the influence of different training processes for SMAW (shielded metal arc welding) and TIG (tungsten inert gas welding) on welding skill improvement. A training experiment was conducted with 6 testees, who were students of the mechanical engineering department, and had never done welding before. The testees were divided into two groups-group A with 3 testees, and group B with 3 testees-and were trained for SMAW and TIG over four days. The testees in Group A were trained for SMAW during the first and second day, whereas the testees of Group B were trained for TIG during the same time. On the third and fourth day-the testees of Group A were trained for TIG, whereas those in Group B were trained for SMAW. Each day after training, tip movement and welding bead shape were measured for skill evaluation. It was observed that welding time and welding bead shape on SMAW and TIG had improved after training for two days; however, the electrode tip movement showed no improvement. Further, it was observed that skill improvement is influenced by welding method training.

Key Words: training progression, effective training, SMAW, TIG

1. Introduction

Welding is a jointing technique by congelation of materials in which boundaries are melted by heat. It is used to join together parts of many things from atomic reactors, ships, bridges, to bicycles, and so on. Although in some mass production industries, certain welding processes have been automated by using robots, most welding processes are still performed by a human welder. Therefore, many welders are needed in industrial production processes, and thus, the welder training occupation is also flourishing.

Welding training suffers from some time-related and logistical problems: it is time-consuming and re-

quires a considerable amount of material for training; in addition, it is dangerous for beginners. To overcome these limitations, effective training methods are being explored. Asai produced an effective training system using the position sensor present on 6-Axis Robot and some cameras[1]. Asai's system displays information for effective training, e.g., difference between the torch movement of the trainee and an expert welder in the case of TIG (tungsten inert gas welding). Kadefors analyzed differences between EMG (electromyography) signals from the arm muscle of an expert welder in some of the welding positions, such as overhead and vertical-down [2]. These aforementioned researches focus on training a trainee in one of many welding methods. How-

* Department of Intelligent Mechanical Engineering, Hiroshima Institute of Technology

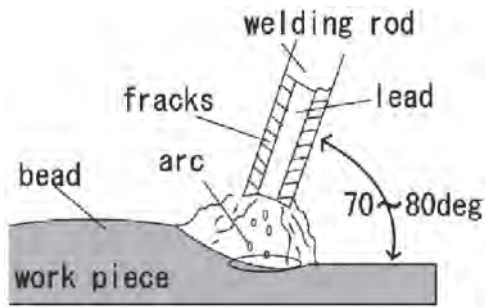


Fig. 1 Shield metal arc welding

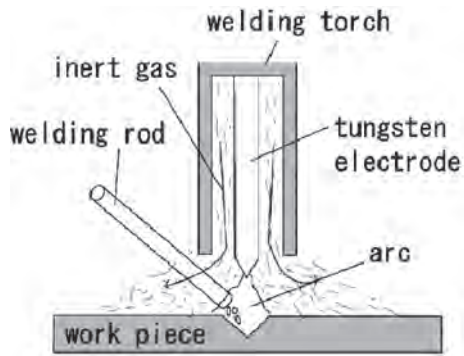


Fig. 2 Tungsten inert gas welding

ever, it is necessary to consider effective training to acquire several welding methods, because most professional welders are required to obtain skills for several welding methods.

In general, a beginner learns the SMAW (shielded metal arc welding) method first, and then the TIG method later. Based on previous experience, welding trainers know that this training format is effective. SMAW is considered a basic skill required for manual arc welding; however, this is subjective, and has not been confirmed quantitatively. This paper describes the influence of different training processes for SMAW and TIG on welding skill.

2. Objective welding

This study examines the training processes for SMAW and TIG, and their impact on welding skill improvement.

Figure 1 depicts SMAW [3]. In SMAW, a welder uses a holder with an electrode shielded flux with the right hand, and hits or rubs the tip of the electrode on the workpiece to generate an arc discharge at the tip of the electrode. After the arc discharge initiates, the angle between the electrode and the weld line must be kept between 60 and 70 degrees, and the tip of the electrode should be moved 2–3 mm

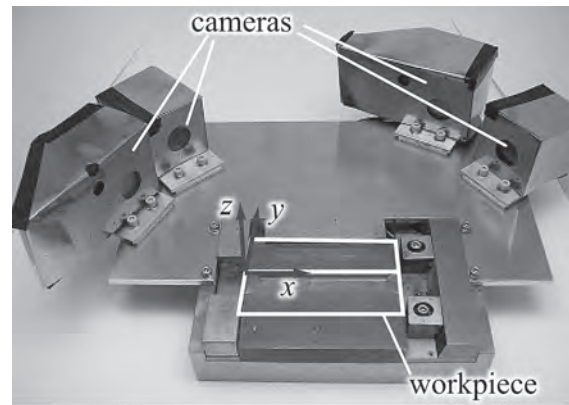
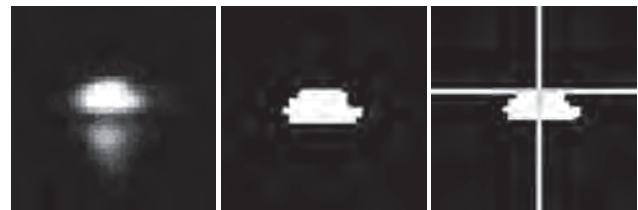


Fig. 3 Workpiece clamber with cameras



(a) Raw image

(b) Binary image

(c) Tip position

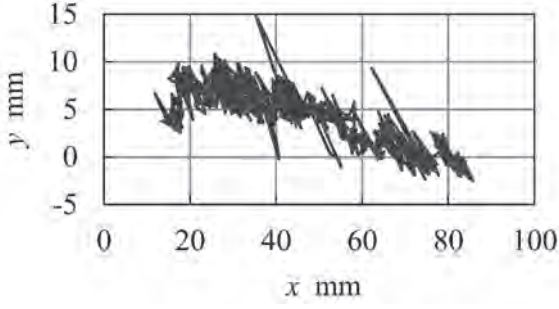
Fig. 4 Welding arc image on screen

above the weld line from the left to the right from the welder's perspective, and at a constant rate. During welding, the electrode is gradually shrinking because the tip melts.

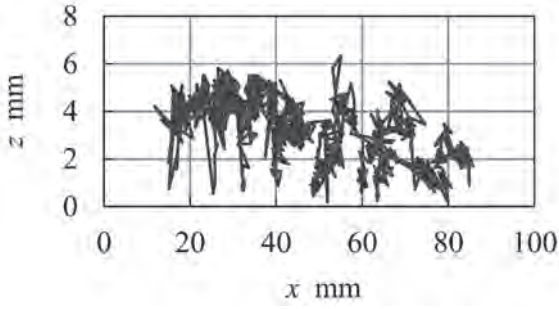
Figure 2 shows TIG process [3]. In TIG, a welder uses a welding torch with the right hand and a welding rod with the left hand, and turns on the switch present on the welding torch to generate an arc discharge at the tip of the tungsten electrode in the torch. After that the arc discharge initiates, the angle between the tungsten electrode and the weld line is kept between 60 and 70 degrees, and the tip of the electrode is moved 2–3 mm above the weld line from right to left as welder's perspective, and at a constant rate. During welding, the tip of the welding rod is subjected to the arc, because of which it melts and the drops from the welding rod form the required weld.

3. Evaluation of skill level

In this research, the welding skill level is evaluated by studying the movement of the tip of the electrode during the welding task, and by the shape of welding bead after the welding task is complete. The following subsections describe how these measurements were recorded.



(a) X-Y axes



(b) X-Z axes

Fig. 5 Example of electrode tip movement

3.1 Movement of the tip of the electrode

Position of the tip of the electrode during welding is calculated using images of arc discharge light. Figure 3 shows the workpiece clamber with cameras. Cameras that capture images of arc discharge light above the workpiece are fixed and do not obstruct the welding process; in addition, they are covered by the stainless steel boxes to protect them from spatters that occur in welding. In order to prevent camera halation by the intense light of the discharge arc, shutter time is fixed at 1/10000 of a second, and there are optical filters, ND1.0, ND3.0, BPM53 (Fujifilm Co.), that are inserted in front of the lenses.

Figure 4 shows an example of an arc image and how it is processed. The electrode cannot be observed in the raw image (a). This binary image (b) is created by evaluating all the pixels from the raw image (a) and transposing only those pixels that have an intensity rating 95% or higher. The position of the tip is determined from the horizontal center and upper end of arc in the image as shown in (c). The coordinate of the tip (x, y, z) is calculated by eq. (1) [4].

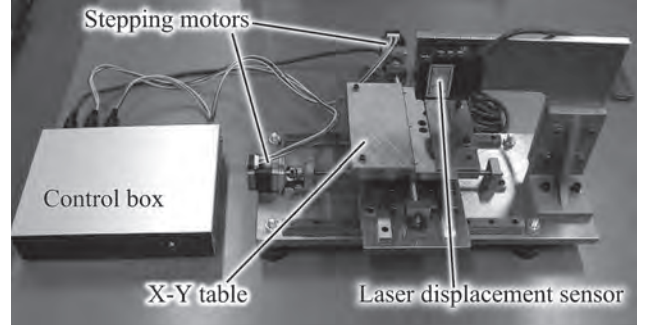


Fig. 6 Three-dimensional surface measuring instrument

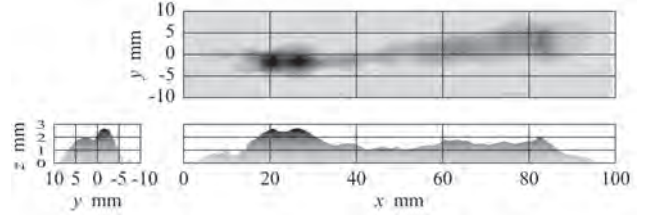


Fig. 7 Example of welding beads shape

$$\begin{bmatrix} P_{31}u - p_{11} & P_{32}u - p_{12} & P_{33}u - p_{13} \\ P_{31}v - p_{21} & P_{32}v - p_{22} & P_{33}v - p_{23} \\ P'_{31}u - p'_{11} & P'_{32}u - p'_{12} & P'_{33}u - p'_{13} \\ P'_{31}v - p'_{21} & P'_{32}v - p'_{22} & P'_{33}v - p'_{23} \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} P_{14} - p_{34}u \\ P_{24} - p_{34}v \\ P'_{14} - p'_{34}u \\ P'_{24} - p'_{34}v \end{bmatrix} \quad (1)$$

$$\mathbf{M} = \begin{bmatrix} p_{11} & p_{12} & p_{13} & p_{14} \\ p_{21} & p_{22} & p_{23} & p_{24} \\ p_{31} & p_{32} & p_{33} & p_{34} \\ p_{41} & p_{42} & p_{43} & p_{44} \end{bmatrix} \quad \mathbf{M}' = \begin{bmatrix} p'_{11} & p'_{12} & p'_{13} & p'_{14} \\ p'_{21} & p'_{22} & p'_{23} & p'_{24} \\ p'_{31} & p'_{32} & p'_{33} & p'_{34} \\ p'_{41} & p'_{42} & p'_{43} & p'_{44} \end{bmatrix}$$

where, (u, v) is the coordinate of tip as observed from one camera, (u', v') is the coordinate of the tip observed from another camera, and \mathbf{M}, \mathbf{M}' , are the matrices of extrinsic parameters of each camera, respectively. Accordingly, the three-dimensional coordinate of the tip, or the movement of the tip, is measured.

Figure 5 shows an example of movement of the electrode tip. Based on such data, skill evaluation indices Y_a, Y_s, Z_a , and Z_s are calculated by follow equations.

$$Y_a = \frac{1}{n} \sum_{i=1}^n Y_i$$

$$Y_s = \sqrt{\frac{1}{n} \sum_{i=1}^n Y_i^2}$$

$$Z_a = \frac{1}{n} \sum_{i=1}^n (Z_i - Z_o)$$

$$Z_s = \sqrt{\frac{1}{n} \sum_{i=1}^n (Z_i - Z_o)^2}$$

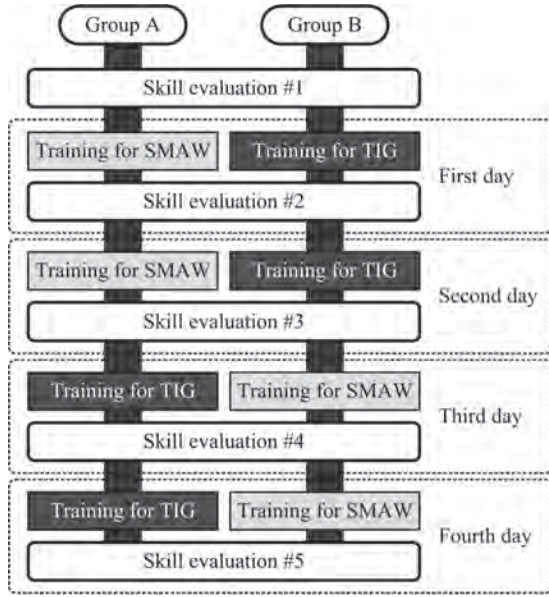


Fig. 8 Experiment flow

where, n is the number of calculated coordinates, and Zo is the ideal z-coordinate of the electrode.

3.2 Shape of the welding bead

Figure 6 shows the device used for measuring the shape of the welding bead. The laser displacement sensor measures the height of workpiece surface on the X-Y table by moving the table using the stepping motors.

Figure 7 shows an example of the shape of a welding bead. In our experiments, the welding bead is more than 0.5 mm higher than the surface of the workpiece. Figure 3.5 shows the projection of the bead shape. Based on this data, skill evaluation indices W_a , W_s , H_a , and H_s are calculated using the following equations [5].

$$W_a = \frac{1}{n_w} \sum_{i=1}^n (W_i - W_o)^2$$

$$W_s = \sqrt{\frac{1}{n_w} \sum_{i=1}^n (W_i - W_o)^2}$$

$$H_a = \frac{1}{n_w} \sum_{i=1}^n (H_i - H_o)$$

$$H_s = \sqrt{\frac{1}{n_w} \sum_{i=1}^n (H_i - H_o)^2}$$

where, n_w is the divided number of the welding bead on x-axis, W_o is the ideal welding bead width, and H_o is the ideal welding bead height

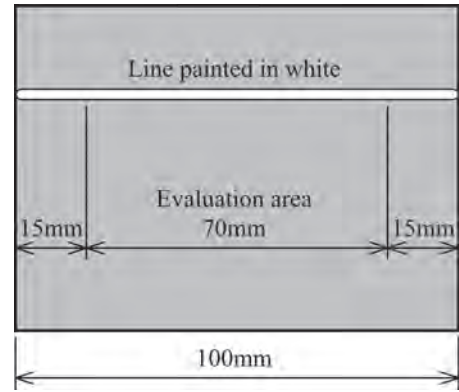


Fig. 9 Workpiece for evaluation

Table 1 Appropriate value of welding

	SMAW	TIG
Welding time	30 s	80 s
Width of welding bead	9 ± 1 mm	7 ± 1 mm
Height of welding bead	1.5 ± 0.5 mm	
Y coordinate of electrode tip	0 ± 1 mm	
Z coordinate of electrode tip	1.5 ± 0.5 mm	

4. Improving welder's skill through training progression

4.1 Method for experiment

We conducted a training experiment with 6 testees, who were students from the mechanical engineering department at a university and had never done welding earlier. Figure 8 shows the flow of this experiment. The testees are divided into two groups, and were trained for SMAW and TIG over 4 days. The three testees that were part of Group A were trained for SMAW during first and second day, and then TIG during third and fourth day, whereas the three testees in Group B were trained for TIG during first and second day, and then SMAW during third and fourth day. Before the training each day, the testees trained in the art of welding and learnt about the appropriate shape of welding bead as shown in table 1. After the training, they were evaluated on their skill. During the training and evaluation, the testees undertook the bead-on-plate welding operation, which involves depositing the welding bead on the painted white line on the workpiece surface, as shown in fig. 9. The workpieces are made of steel (SS400 JISG3101), and have dimensions of 100 mm × 100 mm × 4.5 mm. In the training stages, the test-

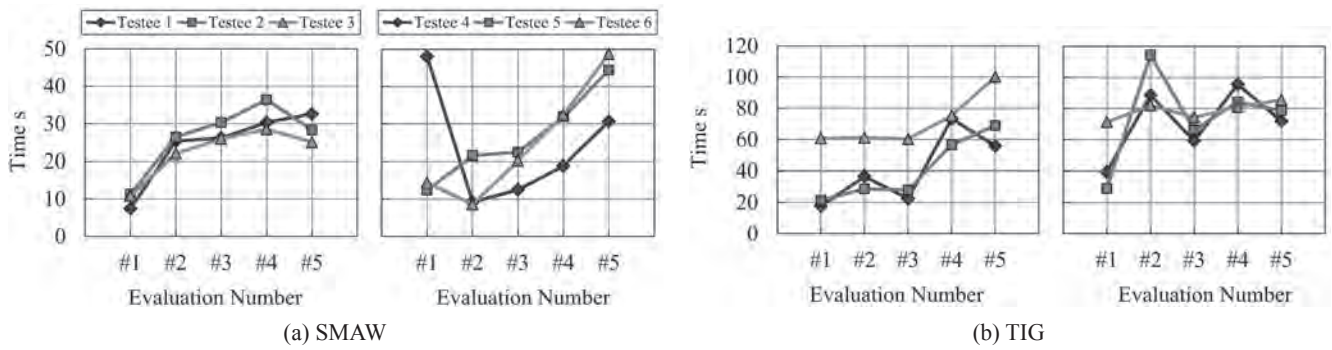


Fig. 10 Welding time

ees were trained by repeatedly performing the bead-on-plate operation for a 15-min period during arc discharge. During the evaluation stages, the tip movement and welding bead shape were measured when testees operated the SMAW and TIG equipment. Testees' skills were evaluated in their welding area as shown in fig. 9.

4.2 Result and discussion

Figure 10 shows the variation of welding time. Both groups showed an improvement in the welding time in both the cases—SMAW and TIG—because #5 data is closer from ideal time than #1 data. The testees in Group A showed an improvement in the welding time for SMAW, but not in TIG until the third evaluation of SMAW training on the first and second day, after which, their TIG welding time improved because of TIG training on the third and fourth day. Similarly, the testees of Group B showed an improved welding time for TIG, but did not show any improvement in that of SMAW until the third evaluation of TIG training on the first and second day, after which, their SMAW welding time improved because of SMAW training on third and fourth day. This indicates that the electrode tip rate remained ideal because of training. In the fifth evaluation, the SMAW welding time of group A was closer to the ideal time than that of group B, whereas the TIG welding time of group B was closer to the ideal time than that of group A. This shows that skill improvement is influenced by performing the welding method training.

Figure 11 shows the variation of electrode movement in welding. Although there is improvement in a few indices such as Y_a of SMAW by group A, no characteristic tendency was found. Testees

could concentrate only on accurate rate of the electrode tip in welding. Probably, if testees take training for an extra 1 or 2 days, the characteristic tendency would appear.

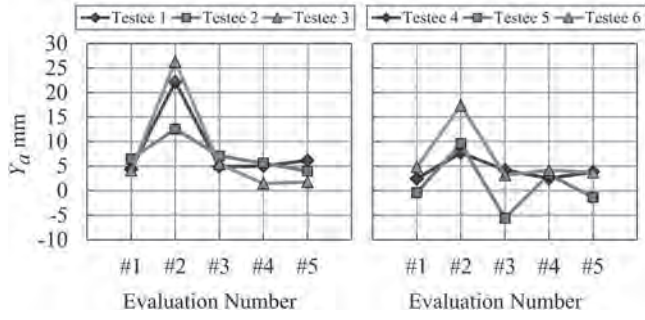
Figure 12 shows the variation of the welding bead shape. Similar result trends as those in welding time is found in the cases of W_a , W_s , H_a , and H_s .

5. Conclusion

We evaluated the difference in welding time improvements, welding bead shape, and electrode tip movement through training progression of SMAW and TIG by examining bead-on-plate operations performed by 6 testees, who were trained for 4 days. We observed that the welding time and welding bead shape on SMAW and TIG improved after training in SMAW and TIG for two days; however, the electrode tip movement showed no improvement. Therefore, we conclude that skill improvement is influenced by undergoing welding method training.

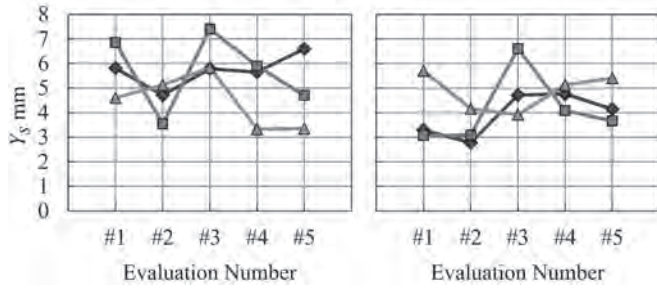
References

- 1) ASAI Satoru, SAKUMA Masatake, Digitization of welder's skill and development of welding support system, quarterly journal of the Japan Welding Society, 2002, 20, 185–190 (in Japanese).
- 2) R. Kadefors, I. Peterson and P. Herberts, Muscular reaction to welding work: An electromyographic investigation, *Ergonomics*, 19, 5, 543–558, 1976.
- 3) Klas Weman, *Welding Processes Handbook*, CRC Press LLC, 2003.
- 4) Jun SATO, *Computer Vision*, CORONA publishing co., 2003 (in Japanese).
- 5) Welding Technique Editorial Members, Establishment of "Guideline for Evaluation by Visual Inspection", *Welding Technique*, 1998, 46, 4, 109–112(in Japanese).



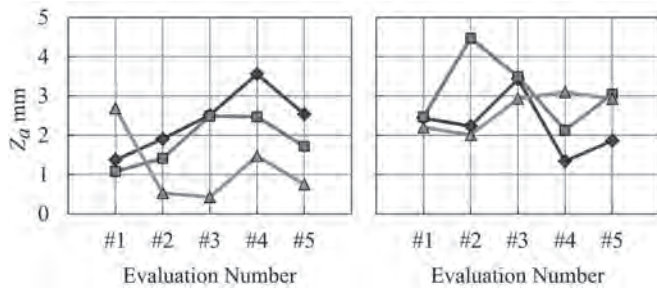
(a) Y_a (SMAW)

(b) Y_a (TIG)



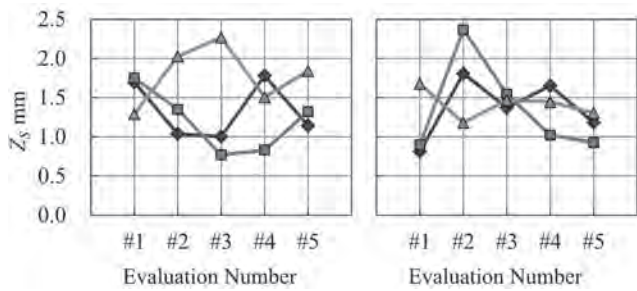
(c) Y_s (SMAW)

(d) Y_s (TIG)



(e) Z_a (SMAW)

(f) Z_a (TIG)



(g) Z_s (SMAW)

(h) Z_s (TIG)

Fig. 11 Electrode movement

Difference of improving welder's skill through training progression

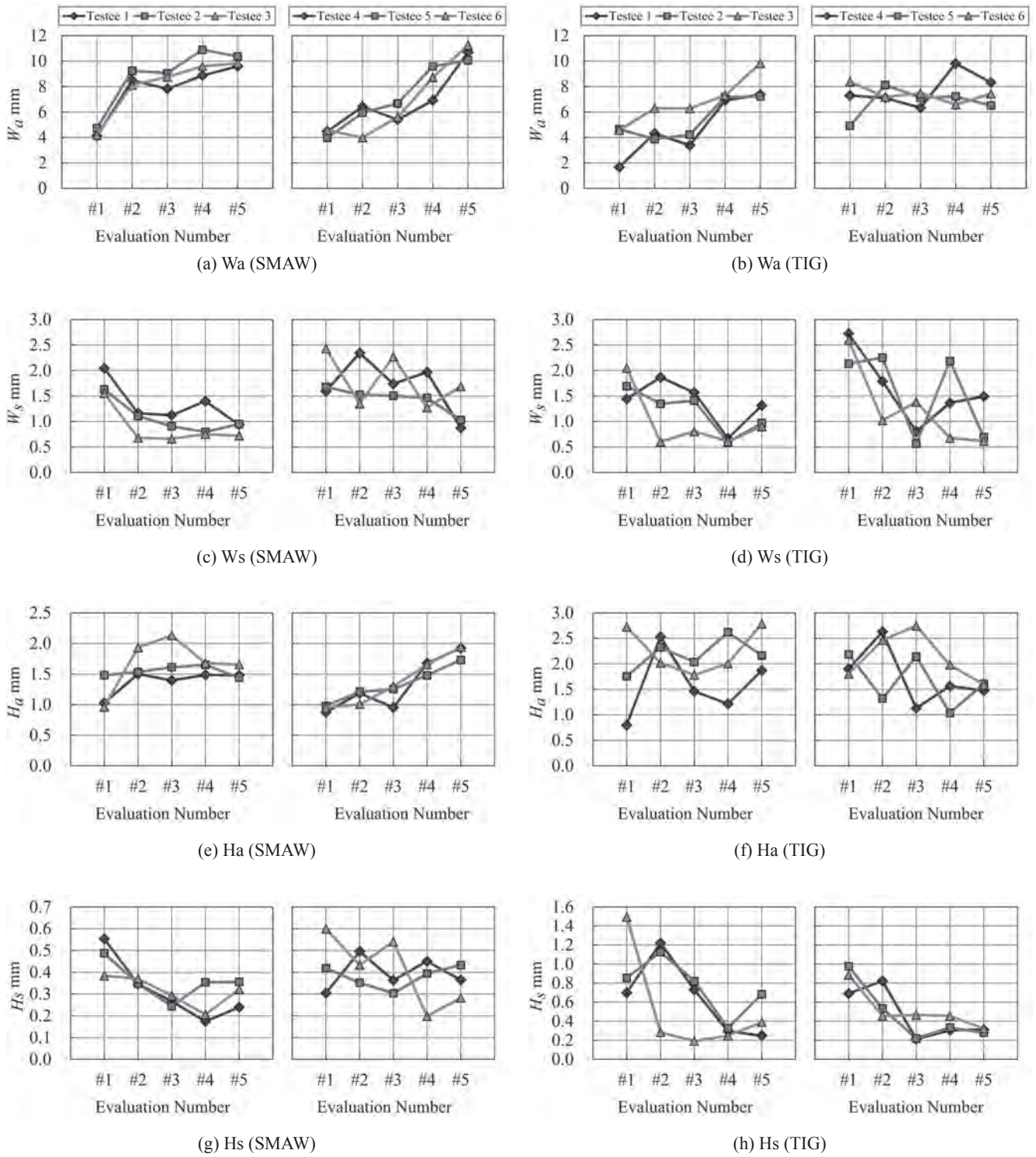


Fig. 12 Welding bead shape

