

Measurement of welder's movement for welding skill analysis

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, a welding training system using virtual reality can be used to teach appropriate tool movements. However, most trainees may not perform appropriate welding even if they understand the appropriate tool movements. Therefore, teaching appropriate movements of the arm can be more effective than teaching the appropriate movements of the tools. The goal of this study was to produce an effective welding simulator to teach appropriate arm movements. This paper discusses measurements of a welder's behavior. The angle of each joint of the welder's arm, including the shoulder, elbow, and wrist, was measured using bend sensors. Electromyography (EMG) sensors were used to perform surface electromyography on a welder's arm. Six sensor electrodes were placed on two muscles of the upper arm and four muscles of the forearm. A workpiece clasper with charge-coupled device cameras measured the three-dimensional coordinates of each electrode tip. A three-dimensional surface measuring instrument measured the shape of the welding bead. The welding tasks of three professional welders and four beginners were measured. The differences between the movements of a professional's arm and those of a beginner's were found. This showed that the beginners moved their elbow and shoulder, whereas the professionals moved all three joints. The EMG signals indicated a tendency for the frequency of variation of the beginners to be greater than that of the professionals. However, more data are needed to clarify this.

Key Words: manual arc welding, measurement of movement, skill training

1. Introduction

Although some welding processes in mass production have been automated using robots, most welding processes are performed by professional welders. Therefore, many welders are needed in production, and training programs for welders are flourishing. However, there are some inherent challenges in welding training. These include the large quantity of time and materials involved, which have a high cost, along with the danger posed for beginners. A welding simulator using virtual reality [1][2] has been proposed to overcome these challenges.

Previous simulators have provided trainees with a virtual training environment for welding at a low cost, while keeping the training safe and teaching the appropriate movements of tools. However, most trainees may not perform appropriate welding even if they understand it, because they do not know how to move their arm correctly. Therefore, teaching the appropriate movements of the arm can be more effective than teaching the appropriate movements of the tools. The goal of this study was to produce an effective welding simulator for training to teach appropriate arm movements. This paper considers arm movement measurements, electrode movements, and

* Department of Intelligent Mechanical Engineering, Hiroshima Institute of Technology

electromyography (EMG) outputs during welding.

2. Measuring instrument

2.1 Outline of the measuring instrument

The objective welding method in this study was shielded metal arc welding (SMAW). In SMAW, a welder uses a holder with a flux-shielded electrode in their right hand. It is necessary for the angle between the electrode and the weld line to be maintained between 60° and 70°, and for the tip of the electrode to be kept 2~3 mm above the weld line and moved from left to right at a constant rate. During welding, the electrode gradually shrinks as the tip melts [3].

Figure 1 shows an outline of the measuring instrument. This consists of the motion sensor, six electrodes for EMG, the workpiece clamber with charge-coupled device (CCD) cameras, and a PC. Additionally, there is a three-dimensional surface measuring instrument. The workpiece clamber with CCD cameras for measuring the three-dimensional coordinates of the electrode tip and the three-dimensional surface measuring instrument for the welding bead were explained in detail in a previous paper.

2.2 Measurement of arm joints angle

In order to analyze the behavior of a welder's arm, the angle of each joint on the arm was measured using the equipment shown in fig. 2. Shape tape (Measurand Inc. S1280-96NL) was used to measure the angles of the shoulder and elbow. A goniometer (Biometrics Ltd SG65) measured the angle of the wrist. The shape tape had thirty two bend sensors,

with a length of 960 mm. The three-dimensional coordinates of sixteen points at 60mm intervals along the shape tape were calculated based on the outputs of the bend sensors. The coordinate system was based on the communication box of the shape tape, as shown in fig. 3. The wrist position and the joint angles of the shoulder and elbow were calculated based on coordinates of the shape tape, which was fixed to the welder's back, brachium, and forearm.

A goniometer is a two-axis angle sensor. One end was fixed on the forearm, and the other end was

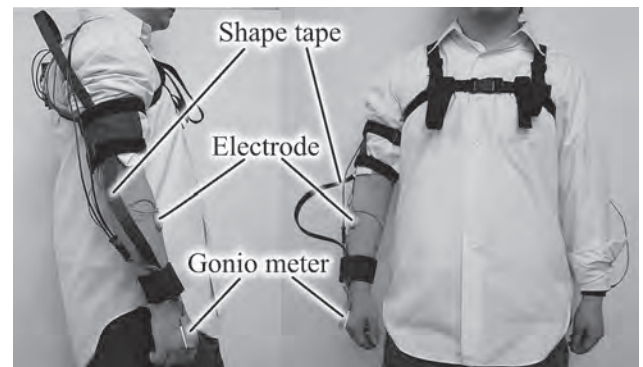


Fig. 2 Equipment for measurement of movement

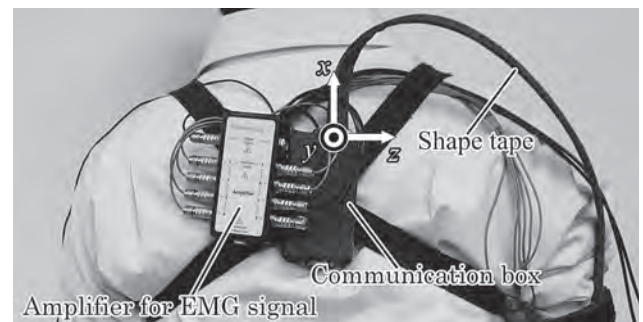


Fig. 3 Coordinate system of shape tape

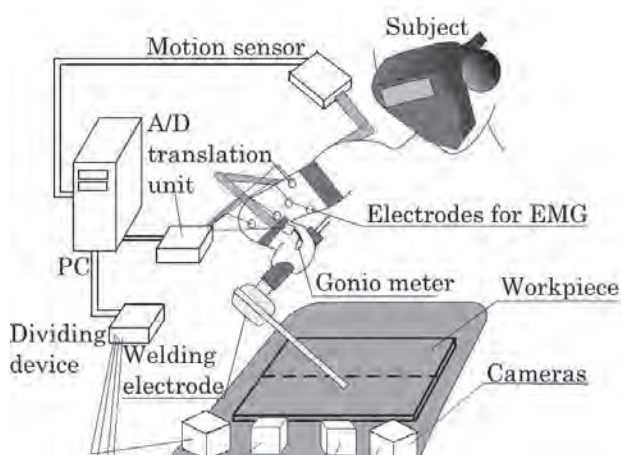


Fig. 1 Outline of measurement system

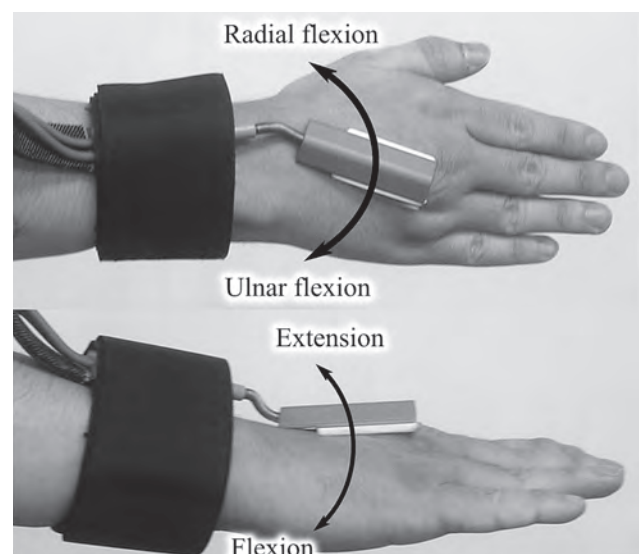


Fig. 4 Flexible goniometer

fixed on the metacarpal of the middle finger. The ulnar flexion and radial flexion were measured using the goniometer, as shown in fig. 4.

2.3 Measurement of surface electromyography on the arm

EMG sensors (Biometrics Ltd SX230) were used for surface electromyography measurements on the arm muscle. The surface electromyography signals supplied information about whether the muscle was tensed or relaxed. Because the signal was very faint, it was influenced by electrical noise from the arc discharge during welding. To reduce this influence, an active electrode was used (fig. 5), which was an electrode with a small amplifier. The EMG electrodes were placed on six muscles expected to vary frequently during welding: the biceps brachii, triceps brachii, extensor carpi radialis longus, extensor carpi ulnaris, flexor carpi radialis, and flexor carpi ulnaris.

3. Measurement of welding behavior by welders and beginners

Welding tasks performed by professionals and beginners were measured. The subjects were three welders who had passed the examination for manual arc welding skill by The Japan Welding Engineering Society (JWES) [4][5], and four beginners who were students at the mechanical engineering department and had no welding experience. The subjects were equipped with the shape tape and electrodes, and performed welding three times using the workpiece clumper with CCD cameras in the posture shown in fig. 6. The objective welding was bead-on-plate, which is an operation that places a welding bead on a white line painted on a workpiece, as shown in fig. 7. The workpiece material was steel (SS400 JIS G

3101), and the size was 150×100×4.5 mm. The welding of each subject was evaluated in the welding area shown in the figure.

4. Result and discussion

4.1 Movement of arm

Figure 8 shows the movement of the right wrist, with a welding holder, in comparison with the body during the welding. In this figure, the track of the three-dimensional position in the coordinate system shown in fig. 3 is projected onto the z-x and y-z planes, and the arrows indicate the direction of the wrist movement. To compare the tracks, three beginners' wrists move from left to right, and all professionals' move from right to left. It is expected that the movement of a beginner's wrist is the same as the movement of the electrode. The movement of

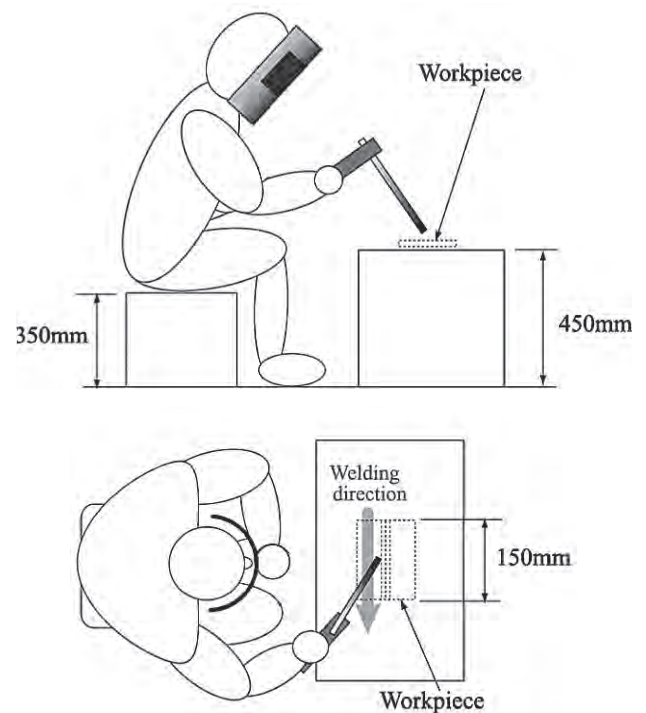


Fig. 6 Posture in welding



Fig. 5 Active Electrodes for EMG

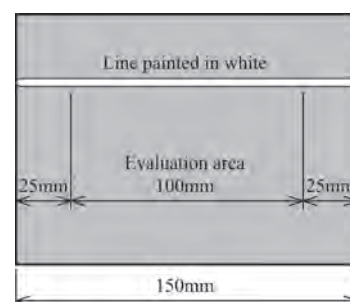
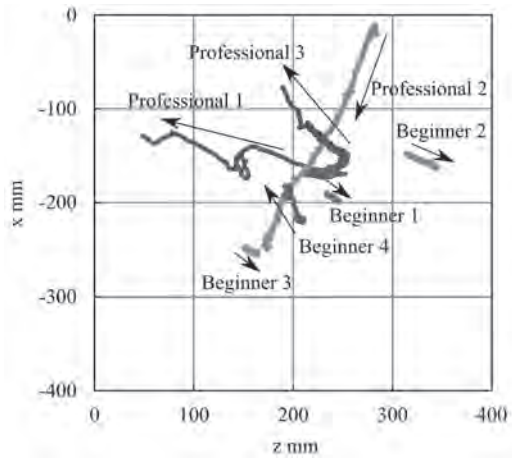
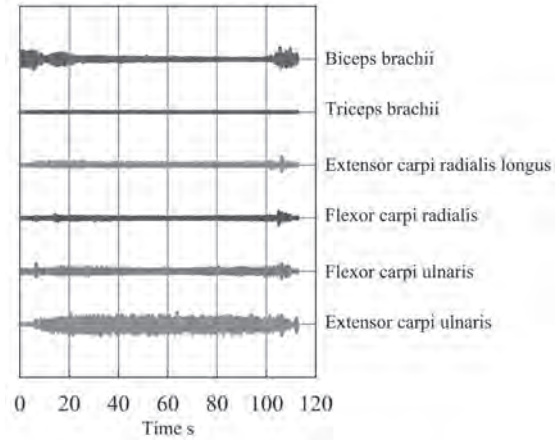


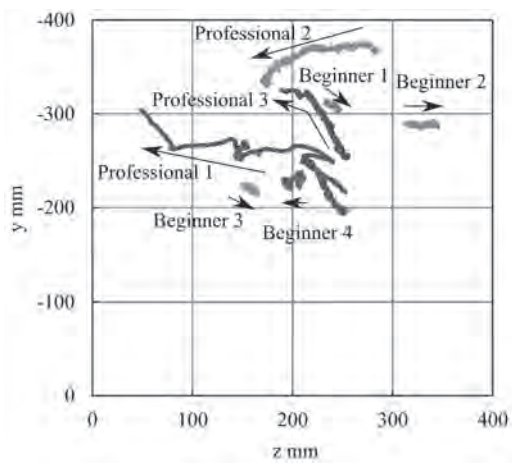
Fig. 7 Workpiece



(a) z-x plane

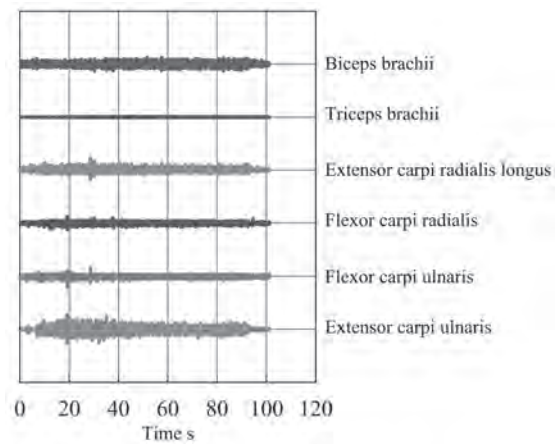


(a) Professional 1



(b) z-y plane

Fig. 8 Movement of wrist



(b) Beginner 1

Fig. 9 Signal of EMG

a professional's wrist is evidently different with the movement of the electrode. Therefore, it was concluded that the beginners moved their elbow and shoulder, whereas the professional welders moved these as well as the wrist.

4.2 EMG of arm

Figure 9 shows examples of the EMG signals for a professional and beginner. The EMG signals show a tendency for the frequency of variation of the beginner to be greater than that of the professional. However, more data are needed to clarify this.

4.3 Movement of electrode

Figures 10 and 11 show the error from the welding line (y coordinate) and height from the work-piece (z coordinate) of the electrode during welding, respectively. The bars and error bars in these figures respectively show the averages and standard devia-

tions calculated based on the electrode tracks of the subjects. Although the professionals' average errors were positive, over the welding line, and the beginners' averages were negative, before the welding line, no large difference in skill level was found. In relation to the height, the professionals' averages were lower than those of the beginners because of the difference in their skill level. In both figures, the beginners' standard deviations were greater than those of the professionals. This indicated that the electrode tip of a beginner was somewhat shaky.

4.4 Shape of welding bead

Figures 12 and 13 show the average width and height of the welding bead, respectively. The error bars in these figures show the standard deviation. A professional's welding bead was higher than that of a beginner.

In both figures, the beginners' standard deviations

were greater than those of the professionals. This indicated that a beginner's welding bead shape was uneven because of the difference in their skill level.

5. Conclusion

In order to produce an effective welding simulator to teach appropriate arm movements, measurements were performed to determine the arm joint angles, surface electromyography (EMG) of the arm, and electrode movement during welding. Welding tasks performed by three professional welders and four beginners were measured. A difference was found between the movement of a professional welder's arm and that of a beginner. It was determined that a beginner moved their elbow and shoulder, whereas a professional welder moved these as well as their wrist. A tendency was found for the frequency of variation of the EMG signal of a beginner to be greater than that of a professional welder. However, more data are needed to clarify this.

References

- [1] Xin Liang, Hideo Kato, Nobuyoshi Hashimoto, Kazuya Okawa, Simple Virtual Reality Skill Training System for Manual Arc Welding, *Journal of Robotics and Mechatronics*, 26(1), 2014, 78-84.
- [2] Nobuyoshi Hashimoto, Hideo Kato, Ryo Ikehara, Training System for Manual Arc Welding by Using Mixed Reality: Reduction of Position-Perception Error of Electrode Tip, *The Japan Society for Precision Engineering*, 72(2), 2006, 249-253 (in Japanese).
- [3] Klas Weman, *Welding Processes Handbook*, CRC Press LLC, 2003.
- [4] JIS Z 3801:1997, Standard qualification procedure for manual welding technique.
- [5] WES 8201:2013, Standard for certification of manual welders.
- [6] Nobuyoshi Hashimoto, Difference of Improving Welder's Skill through Training Progression, *Bulletin of Hiroshima Institute of Technology Research Volume*, 49.

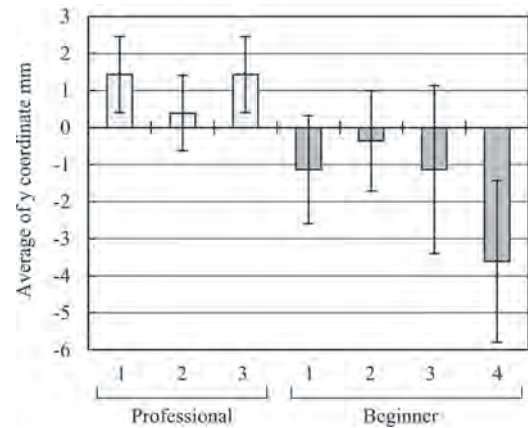


Fig. 10 Error from the welding line

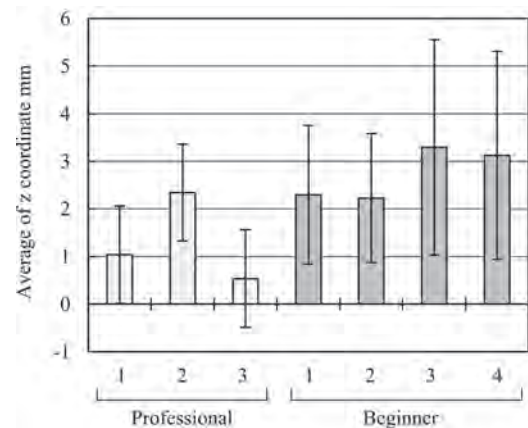


Fig. 11 Height of the electrode tip

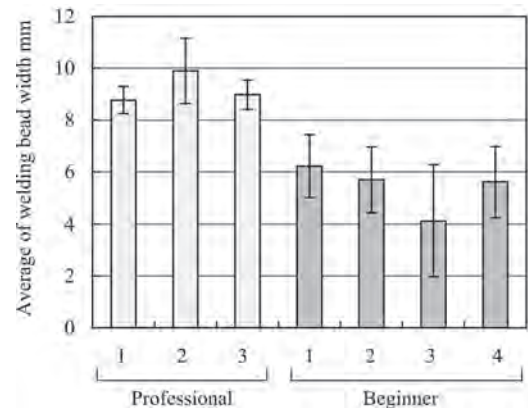


Fig. 12 Welding bead height

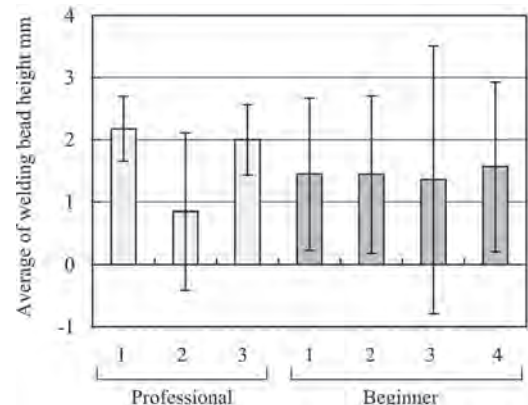


Fig. 13 Welding bead Width

