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LSSVM Model for Penetration Depth Detection in Underwater Arc Welding Process

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Abstract. For underwater arc welding, it is much more complexity and difficulty to detect penetration depth than land arc welding. Based on least squares support vector machines (LSSVM), welding current, arc voltage, travel speed, contact-tube-to-work distance, and weld pool width are extracted as input units. Penetration depth is predicted in underwater flux-cored arc welding (FCAW). For improvement prediction performance, the LSSVM parameters are adaptively optimized. The experimental results show that this model can achieve higher identification precision and is more suitable to detect the depth of underwater FCAW penetration than back propagation neural networks (BPNN).

Keywords: underwater arc welding, penetration depth, least squares support vector machines

1. Introduction

The weld penetration depth can mainly represent the weld quality in weld bead geometry (penetration depth, bead height, and weld pool width) [1]. If the defective weld penetration occurrences can be recognized in time, the weld quality can be monitored on-line. For land arc welding, some reports can be found on monitoring welding quality through penetration depth detecting. For underwater arc welding, it is very hard to detect the depth of penetration real-time, ascribed to the invisibility of welding process. Up to now, there is no research report on this technique in underwater arc welding, due to its more complexity and difficulty than land arc welding. Nevertheless, the underwater arc welding technique plays a critical role in construction and maintenance of ships, dockyards, port facilities, and ocean terrace etc [2]. As one of gas metal arc welding, flux-cored arc welding (FCAW) is suitable for underwater arc welding. In this paper, penetration depth detecting in underwater FCAW is investigated in detail. In order to set up a guideline for penetration depth detection from the multi-sensor data fusion model, the welding process variables are systematically and quantitatively analyzed on their influence on depth of penetration and weld pool width through underwater FCAW experiment. Because of hard environment in underwater FCAW, it is difficulties to get enough training sample sets for penetration depth prediction. Suggested by Suykens [3-4], the least squares support vector machines (LSSVM) is more suitable for non-linearity function prediction with a reasonably small size of training sample sets. With higher performance of predication than back propagation neural networks (BPNN), LSSVM has been very successfully applied in pattern recognition, non-linear function estimation, and machine learning domains, etc [3-6]. Hence, the LSSVM is introduced into penetration depth prediction modeling in underwater FCAW. In this model, the radial basis function (RBF) is selected as kernel function and the LSSVM parameters are adaptively optimized to improve prediction performance.

2. Methodology

Underwater FCAW is a complex heat transfer process. The formation of underwater welding pool is interacted by electric field, magnetic field, and flow field. The study showed that the depth of penetration was mainly affected by heat-transfer energy of workpiece [7]. Moreover, the workpiece thermal energy is mainly affected by some underwater welding process variables, such as welding current, travel speed, arc

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voltage, and contact-tube-to-work distance (CTWD). Suppose the penetration depth is P, welding current is I, arc voltage is U, travel speed is S, and CTWD is H. Based on multi-sensor data fusion model, P can be represented as

$$P = f(I,U,S,H) \tag{1}$$

In addition, there is a relationship between the penetration depth and the weld pool width at certain time and welding condition. Combined with the information of weld pool width, the detected result of penetration depth will be more reliable. Thus, the depth of penetration at certain time can be predicted as

$$P = f(I,U,S,H,W) \tag{2}$$

where W is the weld pool width. In this study, welding current I, arc voltage U, and weld pool width W will be acquired and analyzed from welding current sensor system, arc voltage sensor system, and laser structured vision sensor system. Meanwhile, travel speed S and CTWD H can be confirmed and inputted. With the higher performance of predication than BPNN, LSSVM is selected as multi-sensor data fusion model [3-6].

3. Experiment and analysis

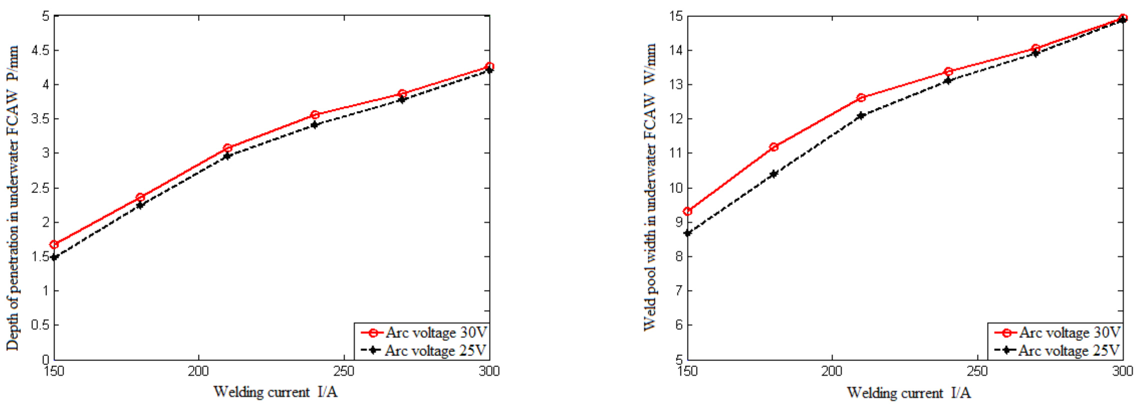
3.1. Experiment

The LSSVM prediction model of relationships between penetration depth and welding process variables must need to be established accurately. Thus, the sufficient experimental data must be provided for prediction model training and verifying [8].

Conducted the bead-on-plate welding, the experimental materials were 140mm× 40mm × (6～10)mm A3 low-carbon steel plates. In this study, the chosen welding process variables were welding current, arc voltage, travel speed, and CTWD. The SQJ501 is used as the flux-cored wire with a diameter of 1.6 mm. And the Dimension of water tank is 15000 mm× 600mm × 500mm. Positioned in a plane 100mm deep water, the workpiece welding procedure is performed. Under the bounds of welding process variables, the optimum weld geometry could be formed.

Travel speed and CTWD are confirmed for the same workpiece during underwater FCAW process. Meanwhile, welding current, arc voltage, and weld pool width are detected and recorded in time. For different workpiece, at least one of these parameters is variable. At one time of underwater FCAW process, welding current, travel speed, CTWD, arc voltage and weld pool width are obtained as input data of trial model. To measure the penetration depth, the bead section was cut transversely from the middle position using the wire cutting machine. To assure the precision of the specimen dimension, it was etched by HNO_3 3% and H_2O 97%. Hence, the actual penetration depth at corresponding time is measured after welding and selected as output data of trial model.

3.2. Effects of the welding current and arc voltage on penetration depth and weld pool width



(a) Penetration depth curves (b) Weld pool width curves

Fig. 1: Penetration depth and weld pool width with welding current and arc voltage variable.