Sensing and Control of Weld Pool by Fuzzy-Neural Network in Robotic Welding System

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When metal plates (base metal) are joined each other by welding, the penetration depth in the joining part is one of factors to determine the mechanical strength, as shown in Fig.1. It is important to keep the penetration depth constant regardless of the variation of the gap between the metal plates. In order to directly observe it by using a TV camera, sensing of the backside of the metal plate needs. In general structures, pipes, steel frame buildings and so on, it is difficult to prepare the place to set up those in the backside. Moreover, since the welding phenomena are described by partial differential equations, it is difficult to construct the depth's mathematical model described by state equations. Authors propose a new method for modelling the penetration depth. In the method, the penetration depth is estimated by using the information obtained from the welding side, i.e. the penetration depth of the weld pool is estimated from the surface shapes of the weld pool, the state of the heat input, which corresponds to the changes of the welding current, the voltage, the electrode wire feed rate and the state of the gap.

If the numerical data describing the relationship between the input and the output in the unknown plant are given, the state of the unknown plant can be described by using neural networks trained by back propagation method. The dynamical state of the penetration depth is described by using the neural network. Namely, the penetration depth is obtained without solving the mathematical model described by partial differential equations, i.e., the neural network model is made.

The system for controlling and sensing the weld pool is shown in Fig.2. CCD cameras are attached to the welding torch. CCD camera 1 takes the weld pool behind the torch. CCD camera 2 takes the gap. The typical image of weld pool and gap are shown in Fig.3.

The surface shape of the weld pool and the gap can be measured during the welding. The penetration depth of the weld pool can be also measured after the welding. The training data are constructed from these numerical data. The neural network is trained by using the experimental data.

One of the advantages of the fuzzy controller is easy to describe the expert knowledge. The fuzzy controller is valid for the plant, of which the construction of the mathematical model may be difficult. Therefore, the welding current is controlled with the fuzzy controller so as to keep the output of the neural network constant. The performance of the controller depends on the fuzzy variables and the control rules. The fuzzy variables are tuned up by using the neural network model for the penetration depth. The neural network and the fuzzy controller are verified by the welding experiments.