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Prediction of gas metal arc welding parameters based on artificial neural networks

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Abstract

This paper presents a novel technique based on artificial neural networks (ANNs) for prediction of gas metal arc welding parameters. Input parameters of the model consist of gas mixtures, whereas, outputs of the ANN model include mechanical properties such as tensile strength, impact strength, elongation and weld metal hardness, respectively. ANN controller was trained with the extended delta-bar-delta learning algorithm. The measured and calculated data were simulated by a computer program. The results showed that the outcomes of the calculation were in good agreement with the measured data, indicating that the novel technique presented in this work shows the good performance of the ANN model.

Keywords: Gas metal arc welding; Mechanical properties; Artificial neural networks

1. Introduction

The gas metal arc welding (GMA) process is a welding method that yields coalescence of metals by heating with a welding arc between continuous filler metal (consumable) electrode and the workpiece. The continuous wire electrode, which is drawn from a reel by an automatic wire feeder, and then fed through the contact tip inside the welding torch, is melted by the internal resistive power and heat transferred from the welding arc. Heat is concentrated by the welding arc from the end of the melting electrode to molten weld pools and by the molten metal that is being transferred to weld pools. Molten weld pools and electrode wire were protected from contaminants in the atmosphere by a shielding gas obtained from various combinations [1]. In the gas metal arc welding (GMAW), the common variations of shielding gases, power supplies and electrodes have significant effect resulting in several different and important process variables [2]. All commercially important metals such as carbon steel, stainless steel, aluminum and copper can be welded with this process in all positions by choosing the appropriate shielding gas, electrode and welding condition [3]. The composition of a shielding mixture in arc welding depends mostly on the kind of material to be welded. The selection of the shielding gas should, by all means, take into account chemical–metallurgical processes between the gases and the molten pool that occur during welding [4]. To reduce the defects and to have good weldability, argon and helium which are the most common purging gases are used as shield gases and they play an important role in reduction of generation of defects and protection of weld pool. There is an ever-increasing range of shielding gases available for arc welding. The gases vary from the pure gases to complex quaternary mixtures based on argon, helium, oxygen, and carbon dioxide. The shielding gas for arc welding must be easily ionized to ensure that the arc can be sustained at a reasonably low voltage [5]. Additional requirements of the shielding gas are a stable arc root mechanism, efficient shielding of the weld pool and adjacent area, and good weld penetration with a smooth weld bead profile. But they have very different characters. Helium is one of the lightest gases, approximately ten times lighter than argon. The higher ionization

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potential of helium, approximately 25 eV compared to 16 eV for argon, produces a significantly higher arc voltage. The arc formed in helium is considerably hotter than with an argon-based gas. It can often promote higher welding speeds and improve the weld bead penetration profile. But disadvantages of using pure helium are: difficulty in initiating the arc and the poor tolerance to cross-draughts, and the high price of helium, which is significantly higher than that of argon also. For these reasons, argon/helium, argon/carbondioxide, argon/oxygen and argon/carbondioxide/oxygen gas mixtures are more commonly used than pure gases [6,7].

Artificial neural networks (ANNs) have been very popular in many engineering fields because of their fascinating features such as learning, generalization, faster computation and ease of implementation [8,9]. Recently, artificial intelligence (AI) such as expert systems, artificial neural networks (ANNs) and fuzzy logic is a key technique for controlling and monitoring the robotic arc welding process. The technique of neural network offers potential as an alternative to standard computer techniques in control technology, and has attracted a widening interest in their development and application. Development of the intelligent system for prediction of process parameters in robotic arc welding has been described in the literature [1]. ANN is a complicated system composed of numerous nerve cells. It is also a new type of computer system which is based on the primary understanding of the organization, structure, function and mechanism of the human brain. With the help of rapid progress in computers and material science, material design can now be carried out based on the knowledge and experience of the fabricated materials [10]. Many efforts have been carried out in the development of various algorithms in the modeling of arc welding process using various technologies. Multiple regression techniques were used to establish the empirical models for various arc welding processes. However, the regression techniques cannot describe adequately the arc welding process as a whole. One of the artificial intelligence (AI) techniques, a neural network as a tool for incorporating knowledge in the manufacturing system is massively interconnected networks of simple elements and their hierarchical organizations. These processes are characterized by welding parameters due to the lack of adequate mathematical models to relate these parameters with bead geometry [11].

This paper introduces a novel technique based on ANNs for the prediction of gas metal arc welding parameters. Different gas mixtures used in gas mixture studies and different starting and end structures were studied using ANN in the literature. The parameters of measured and calculated data were simulated by a computer program. The results have shown that the calculated results were in good agreement with the measured data. The proposed novel technique developed in this work shows that good performance of the ANN model was achieved. The experimental data used to design, train and test the neural controller were achieved from the test rig.

2. Artificial neural networks

Artificial neural networks (ANNs) are biologically inspired by intelligent techniques. ANNs are generally made up of a number of simple and highly interconnected processing elements organized in layers as shown in Fig. 1. These processing elements or neurons process information by their dynamic state response to external inputs. ANNs are capable of learning patterns by training a with a number of known patterns. The learning process automatically adjusts the weights and thresholds of the processing elements. Once adjusted with minimal difference between ANN output and targeted output, the neural network is said to be trained.

Artificial neural networks have many structures and architectures [12,13]. Multilayered perceptrons (MLPs) are the simplest and therefore most commonly used neural network architectures [13]. Fig. 1 shows an MLP with three layers: an input layer, an output layer and a hidden layer. Neurons are represented with circles. Neurons in the input layer only act as buffers for distributing the input signals x_i to neurons in the hidden layer. Each neuron j in the hidden layer sums up its input signals x_i after weighting them with the strengths of the respective connections w_{ji} from the input layer and computes its output as a function f of the sum

$$y_j = f\left(\sum w_{ji} x_i\right) \quad (1)$$

f can be a sigmoidal or a hyperbolic tangent function. The output of neurons in the output layer is also computed similarly. A number of learning algorithms were used to adjust the weight of ANNs. The extended delta-bar-delta (EDBD) learning algorithm used to train the neural architecture is introduced below.

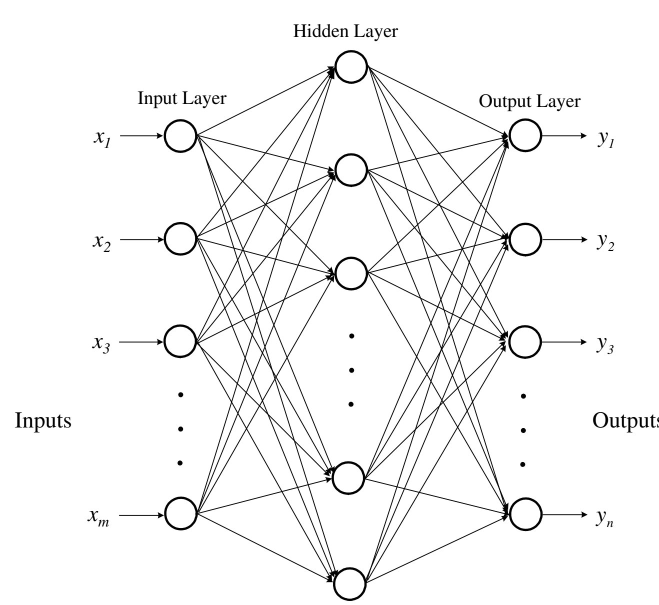

Fig. 1. A multilayered perceptron.