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An investigation into an intelligent system for predicting bead geometry in GMA welding process

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Abstract

Gas metal arc (GMA) welding process has been chosen as a metal joining technique due to the wide range of usable applications, cheap consumables and easy handling. The welding quality is generally controlled by the welding parameters. To achieve a high level of welding performance and quality, a suitable algorithm is required to fully understand the influence of welding parameters on bead geometry in the GMA welding process.

In this paper, we develop an intelligent system in GMA welding processes using MATLAB/SIMULINK software. Based on multiple regressions and a neural network, the mathematical models are derived from extensive experiments with different welding parameters and complex geometrical features. Graphic displays represent the resulting solution on the bead geometry that can be employed to further probe the model. The developed system enables to input the desired weld dimensions and select the optimal welding parameters. The experimental results were proved the capability of the developed system to select the welding parameters in GMA welding process according to complex external and internal geometrical features of the substrate.

Keywords: GMA welding; Welding parameters; Bead geometry; Intelligent system; Multiple regression; Neural network

1. Introduction

In the early days, arc welding was carried out manually so that the weld quality can be totally controlled by the welder ability. The welder, when welding, can directly monitor the flow pattern in puddle and make immediate adjustments in welding parameters to obtain a good weldability. To consistently produce high quality of weldability, arc welding requires welding personnel with significant experience. One reason for this is the need to properly select welding parameters for a given task in order to get a good weld quality which identified by its micro-structure and the amount of spatter, and relied on the correct bead geometry size. Therefore, the use of the control system in arc welding can eliminate much of the “guess work” often employed by welders to specify welding parameters for a given task [1]. In addition, of specific importance is the development of mathematical models that can be employed to predict welding parameters about arc welding process with respect to the workpiece and bead geometry to develop a robotic welding system.

Many efforts have been carried out development of various algorithms in the modeling of arc welding process using various technologies [2–5]. Multiple regression techniques were used to establish the empirical models for various arc welding processes [2,3]. However, the regression techniques cannot describe adequately the arc welding process as a whole. One of 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 [4,5]. While numerical techniques such as finite element method (FEM) also have several limitations. The potentially viable processing routes are numerous and, therefore, various intelligent systems are necessary to identify optimal processing parameters [6].

Now, it is possible to make this selection with the help of a computer, and complex simulations become an effective memory for choosing the welding parameters. Also, arc welding requires a steady hand to keep the electrode at a constant distance from the parts being welded. At the same time that the hand has to move at constant speed, it has to adjust for the distance, as the electrode shortens. This operation

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requires hundreds of hours of practice, burning expensive electrodes. There are many systems that simulate a welding machine and permit significant saving in consumables. The selection of welding parameters for a given welding process is based on experimental methods and human qualifications according to fabrication standards and empirical rules [7].

Recently, a European Social Funded Project (ESFP) has established a real-time computer package "Robotic Teaching System" for using virtual reality (VR) technique to teach pendant programming of the robot and learn the skills required to move the robot to safe position and re-starting safely and efficiently when clearing a welding problems [8]. Ozcelink developed and demonstrated the simulation and animation package for a GMA welding process using the numerical software due to easily use software that effectively control techniques applied to it [9]. However, this software could be applied to control welding process, not to predict bead geometry depending on welding parameters.

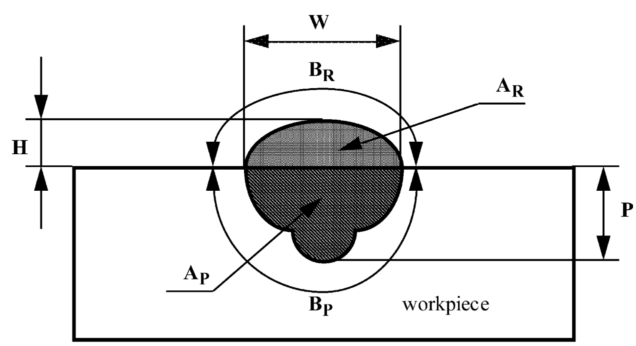
This paper represents the development of an intelligent system to obtain detailed information about the bead geometry in relation to the welding conditions, and to provide the welding engineer with sufficient information to design the most economic and reliable welded component for a given set of the fabrication conditions. Using factorial experimental design, two multiple regression models and a neural network model were developed. Commercial software, called MATLAB/SIMULINK was chosen due to take care of the technicalities involved in numeric simulation, window and menu creation, and graphing. It also describes how the system is modeled and how it is employed to improve the skill-based components of welder proficiency in the welding environment.

2. Experimental procedure

The factorial design method was employed to provide the optimum number of treatment combination where factors can be studied in a complete factorial classification, and the main effect of each factor as well as the interactions between them should be defined. The experimental materials were AS 1204 mild steel plates with chemical composition of C 0.25%, S 0.4% and P 0.04%. The selection of the welding electrode wire was based principally upon matching the mechanical properties and physical characteristics of the base metal, weld size, and existing electrode inventory. The welding parameters included in this study were three levels of arc current (180, 260, 360 A), three levels of welding speed (250, 330 and 410 mm/min) and three levels of welding voltage (20, 25 and 30 V). All other parameters except these parameters under consideration were fixed. Experimental test plates were located in the fixture jig by the robot controller, and the required weld conditions were fed for the particular weld steps in the robot path. With welder and argon shield gas turned on, the robot was initialized, and welding was executed. This continued until the predetermined experimental runs were completed.

Fig. 1. Micro-photograph of a sectioned bead geometry.

They were sectioned metallographically to permit bead shape and size measurements as shown in Fig. 1. Several critical parameters such as bead width, bead height, penetration depth, bead penetration area, bead reinforcement area, length of bead penetration boundary and length of bead reinforcement boundary were taken from bead geometry as shown in Fig. 2. The size of bead geometry also calculated and documented in terms of penetration shape factor, reinforcement shape factor, bead total area and bead dilution, respectively. The experimental results were analyzed on the



W : Bead width

H : Bead height

P : Bead penetration depth

WPSP : Penetration shape factor, W / P

WRFF : Reinforcement shape factor, W / H

A_T : Bead total area, $A_P + A_R$

A_P : Bead penetration area

A_R : Bead reinforcement area

DI : Bead dilution, $A_P / A_R \times 100$

B_P : Length of bead penetration boundary

B_R : Length of bead reinforcement boundary

Fig. 2. Relationship between input and output parameters of the GMA welding process.