Development of Neural network based Plasma Monitoring System and simulator for Laser Welding Quality Analysis

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Abstract

Neural networks are shown to be effective in being able to distinguish incomplete penetration-like weld defects by directly analyzing the plasma which is generated on each impingement of the laser on the materials. The performance is similar to that of existing methods based on extracted feature parameters. In each case around 93% of the defects in a database derived from 100 artificially produced defects of known types can be placed into one of two classes: incomplete penetration and bubbling. Especially we present simulator for weld defects classification and data analysis. The present method based on classification using plasma is faster, and the speed is sufficient to allow on-line classification during data collection.

1. INTRODUCTION

The inspection of welded components often requires the collection of data from a few meters of weld, followed by a rigorous characterization to detect significant defects. This characterization is at present performed largely by human operators, often after the data collection from the weld has been completed. The human eye is unparalleled in its ability to recognize significant patterns after a period of suitable training and experience. However, even the best operators suffer from fatigue and loss of concentration, so human error cannot be neglected. Automated characterization offers the possibility of an impartial, standardized performance 24 hours a day.

In this paper, we will discuss how neural networks may be used to assist in the automation process, by providing a rapid and accurate classification of a number of different defect types. In Section 2, we discuss the theoretical background, defining the several intrinsic transitions that form weld nugget during laser welding. A feature vector extraction is presented in section 3. In section 4 we present a plasma detection signal processing technique for an on-line system. There we describe an optical technique applied in conjunction with a signal processor and a PC for ascertaining information from the plasma that is generated on each impingement of the laser on the materials. A CO2 laser with a velocity of 5m/min and an average power of 4KW was used for the welding. An UV sensor is used to detect the high-intensity plasma given off from the material during welding. The signal is then amplified, filtered, and quantified in terms of the spectral density distribution of the signal. The information is then used to characterize the weld quality. In section 5, we present the classification method using neural networks. The classification rates of neural networks with different numbers of hidden neurons for classifying weld defects are presented in section 6. We draw some final conclusions in section 7.

II. THEORETICAL BACKGROUND

During laser welding the formed weld nugget experiences several intrinsic transitions. These transitions are recrystallization, melting, vaporization, and solidification. Under normal welding conditions, melting and vaporization are the most viable stages that can be
related to weld integrity. The detection technique is based on measurements from the observed vaporization, it is appropriate to justify the relationship between melting, vaporization, and the observed measurements. Intuitively, it is apparent that a relationship between melting and vaporization does exist; however, the extent of this relationship is uncertain. To achieve melting at the inner surfaces of a material of some thickness, a considerable amount of vaporization is generated during the welding process. This vaporization is given off in the form high-intensity plasma. The plasma is detected by an UV sensor that converts the light energy into electrical energy, from which information pertaining to the weld quality is extracted by measuring the electrical energy.

III. FEATURE VECTOR EXTRACTION

The action of the UV sensor is to convert the spasmodic light energy into an electrical signal. The sensor's response is a continuous signal going through positive and negative peaks of varying amplitude and frequency; hence, the signal is both amplitude and frequency modulated. The rise and fall times of the UV sensor is within nanoseconds; consequently, its response to the plasma is almost instantaneous, leaving no trailing effect. Therefore, the resulting signal is a true representation of dynamic behavior of the plasma. For this study spectral density distribution is chosen as feature vector. Spectrum density distributions for classifying the types of weld defects are calculated in DSP unit. These are sent to the input layers of the MLP. Fig. 1 to Fig. 3 shows spectral distribution for each collection of data after the FFT algorithm is applied. As shown in these figures they have different spectral density distribution characteristics. The overall procedure from feature extraction to defects classification is shown in Fig. 4.

IV. PLASMA DETECTION AND SIGNAL PROCESSING

The overall system is shown in Fig. 4. The plasma from the welded parts is detected using the UV sensor.

Fig. 1. Frequency response characteristics showing a good weld

Fig. 2. Frequency response characteristics showing incomplete penetration weld

Fig. 3. Frequency response characteristics for void weld

The UV sensor is a B1961 ultra violet sensor made by HAMAMATSU with an operating wavelength range between 190 and 550 nm. The beam from the plasma to the UV sensor is focused using a lens as shown. The output of the UV sensor an electrical signal, is amplified and filtered with a 4-kHz low-pass filter. To extract the feature vector, the signal from the amplifier is passed through an analog-to-digital
V. CLASSIFICATION USING NEURAL NETWORKS

Here we briefly introduce the type of neural network used in the present application to classify defect types from the spectral density distribution calculated in DSP unit. In this application the neural net is used as a classifier of suitable features extracted by classical methods. In this study the most widely used artificial neural network, the multi layer perceptron (MLP) is chosen. For example one neuron may be allocated to turn on for an incomplete penetration defect while another is activated when an void defect is presented as an input. The Error-back-propagation learning algorithm is used to adjust each weight in a direction guaranteed to reduce the overall error. Proper structure of MLP has 65 neurons for the input layer, 50 neuron for the hidden layer and 3 neurons in the output layer.

VI. EXPERIMENTS

On line welding defects monitoring process is shown in fig. 6. Top window stands for laid materials for welding. The classified results displayed on left bottom window in text.

we prepared user also other classifiers like Fuzzy and probabilistic classifier to choose better one. The user interface mode to choose classifier is shown in Fig. 7
A clear potential advantage of neural network methods in general is their speed in carrying out classification. This is a significant advantage in on-line weld defects classification. An MLP approach must be tuned in to a number of layers and number of neurons in each layer. Trial-and-error methods were chosen to find the most accurate model for this study.

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VII. CONCLUSIONS

Neural networks classifiers have been applied to the problem of detecting, incomplete penetration and bubble defect from plasma data. Success rates of over 90% have been obtained from it. A MLP can describe the arbitrary boundaries between the clusters in feature space.

Fig. 8. Laser welding process

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