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Prediction of Mechanical Properties of Welded Joints Based on Support Vector Regression

Gao Shuangsheng^{a*}, Tang Xingwei^a, Ji Shude^a, Yang Zhitao^b,

^a *Shenyang Airspace University, Shen Yang, 110136, China*

^b *Harbin University of Science and Technology, Harbin, 150080, China*

Abstract

Support vector regression (SVR) networks were developed based on kernel functions of linear kernel, polynomial kernel, radial basis function (RBF) and Sigmoid in this paper. The input parameters of TC4 alloy plates include weld current, weld speed and argon flow while the output parameters include tensile strength, flexural strength and elongation. The SVR networks were used to build the mechanical properties model of welded joints and make predictions. A comparison was made between the predictions based on SVR and that based on adaptive-network based fuzzy inference system (ANFIS). The results indicated that the predicted precision based on SVR with radial basis kernel function was higher than that with the other three kernel functions and that based on ANFIS.

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1. Introduction

As an advanced connecting technique, welding has been widely used in many fields of industrial production for its high efficiency, energy conservation, high quality, automation and intelligentization. To better predict the mechanical properties of welded joints, it is very important to develop a model between welding parameters and the mechanical properties. In recent years, lots of studies have been done by researchers both in home and abroad, and some prediction methods have been developed which are mainly about neural network or modified neural network[1-3]. Although these methods can get better predictions, the prediction accuracy and training speed are still not enough. The contradiction between

* Corresponding author. Tel.: +86-024-89723472; fax: +86-024-89723472

E-mail address: gaoshsh@163.com.

over-fitting and generalization can not be reconciled easily with these methods. Also, the neural network may converge to a local optimum rather than a global one. Therefore, it is quite necessary to find a faster, more accurate and more efficient prediction method.

Support vector machine (SVM) is a new machine learning method developed by Vapnik based on statistical learning with succinct mathematical terms and good generalized applications[4]. Compared with other prediction methods, the rationale of SVM is more complete, and the parameters needed is relatively less, and it can better avoid getting stuck in local optimum. The author used experimental data of mechanical properties of TIG welded joints of TC4 alloys reported in reference[3], and developed the mechanical properties models of welded joints under different technological parameters based on SVR and made predictions. Compared with the prediction results with adaptive-network based fuzzy inference system (ANFIS) used in reference [3], the results showed that SVR was superior than neural network.

2. Support vector regression network

As a machine learning method, support vector machine (SVM) is based on statistical learning and can be divided into support vector classifier (SVC) and support vector regression (SVR). The aim of SVR is to obtain the mapping approximate $f(\cdot)$, i.e. SVR network $\hat{f}(\cdot)$, according to the given training data. It can be formulated in parameterized formation as:

$$\hat{f}(\cdot) = C_k k(x, x_k) \quad (1)$$

where $k(\cdot, \cdot)$ is kernel function. Radial basis function (RBF) is chosen as kernel function in this paper. According to the principle of Structural Risk Minimization, formula (1) is the solution of the regularization problem mentioned below:

$$\min_{f \in F} J_0(f) = C \sum_{k=1}^N L(y_k, f(x_k)) + \frac{1}{2} \langle f, f \rangle_F \quad (2)$$

in which, F is the reproducing Hilbert space defined by $k(\cdot, \cdot)$; $\langle \cdot, \cdot \rangle_F$ the inner product; the loss function, which can be defined as:

$$L(y, f(x)) = \begin{cases} 0, & |y - f(x)| < \varepsilon \\ |y - f(x)|, & \text{the others} \end{cases} \quad (3)$$

where $L(y, f(x))$ is the error of y obtained by measuring function $f(\cdot)$ at x . The parameter C is used to balance the accuracy of approximation and complexity of mapping.

The above mentioned regularization problem can be equally described as optimization one with certain restraints. And the optimization problem can be transformed into quadratic programming though solving the coefficients $c = [c_1, c_2, \dots, c_N]^T$ by using Lagrange multiplier.

$$\min_c J_2(c) = \frac{1}{2} \sum_{k,l=1}^N c_k c_l k(x_k, x_l) - \sum_{k=1}^N c_k y_k + \varepsilon \sum_{k=1}^N |c_k| \quad (4)$$

To meet the restraints, let

$$|c_k| < C, \quad \sum_{k=1}^N c_k = 0 \quad (5)$$

The training error is estimated by the formula (2) and the result shows the solution of the above mentioned quadratic programming question is sparse, i.e. only a few c_k are not zero. The amount of has nothing to do with the training data N . The corresponding non-zero c_k is the so-called SV. The formula (1) can be written as SV network:

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