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Genetic algorithm-least squares support vector regression based predicting and optimizing model on carbon fiber composite integrated conductivity

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ABSTRACT

Support vector machine (SVM), which is a new technology solving classification and regression, has been widely used in many fields. In this study, based on the integrated conductivity(including conductivity and tensile strength) data obtained by carbon fiber/ABS resin matrix composites experiment, a predicting and optimizing model using genetic algorithm-least squares support vector regression (GA-LSSVR) was developed. In this model, genetic algorithm (GA) was used to select and optimize parameters. The predicting results agreed with the experimental data well. By comparing with principal component analysis-genetic back propagation neural network (PCA-GABPNN) predicting model, it is found that GA-LSSVR model has demonstrated superior prediction and generalization performance in view of small sample size problem. Finally, an optimized district of performance parameters was obtained and verified by experiments. It concludes that GA-LSSVR modeling method provides a new promising theoretical method for material design.

1. Introduction

With the rapid development of society and science, especially electronics and information technology, which means we will need more and more conductive composite materials. Because of their excellent mechanical properties, carbon fiber conductive polymeric composites play more and more important roles in the field of composites. In recent years, they have been widely used in such diverse areas as anti-static materials, self-restrict heating materials, pressure and temperature transmitter and electromagnetic interference shielding materials [1–3]. However, during the process of searching for relationship between the technical parameters and desired electrical conductivity of carbon fiber conductive polymeric composites, lots of experiments have to be repeated. Such traditional material design method would be bound to waste lots of manpower and resources. Due to subjectivity of researchers being excessively stressed, it is very difficult to make rational conclusions. Fortunately, theoretical modeling offers a reasonable alternative by which part or total of complex and time-consuming experiments can be replaced [4].

Nowadays, intelligent theory and method have been used to predict, estimate and optimize for material engineering [5–7]. Before this work, we had done a number of studies on conductivity and tensile strength predicting model of carbon fiber/ABS composites using neural network (NN). Previous studies had showed that NN model had obtained more satisfied results than those of the symbolic modeling methods; however, the serious disadvantage is that network training last long. Recently, support vector machines (SVM) has been introduced to solve machine 1earning tasks such as pattern recognition, regression and estimation [8]. Compared with NN, SVM provides more reliable and better performance under the same training conditions. Because of such good properties as globally optimal solution and good learning ability for small samples, SVM has received additional consideration. Furthermore, SVM has been successfully used for support vector regression (SVR), especially for nonlinear systems modeling [9–12].

In this study, we proposed a new two-stage GA-LSSVR learning system. In stage I, LSSVR model was established by experimental data regression and analysis. In stage II, GA was used to optimize model parameters and improve precision and efficiency.

2. Experimental

Carbon fiber conductive polymeric composite are reinforced with carbon fiber conductive material and dispersed by the compound. They perform both excellent conductivity and excellent performance of polymer materials. However, the processes mechanism of carbon fiber conductive polymeric composites had

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seldom been investigated till now. In this paper, carbon fiber conductive polymeric composites were prepared with acrylonitrile–butadiene–styrene (ABS) resin as base and pitch based activated carbon fibers (PACF) as reinforcement.

2.1. Experimental materials

The materials used in this work were medium-flow acrylonitrile–butadiene–styrene (ABS) resin (density = 1.05 g/cm^3) and pitch based activated carbon fibers (PACF), whose density is 1.68 g/cm^3; diameter, 10 μm; volume resistivity, 1.8×10^{-3} Ω cm; and tensile strength, ~800–1200 MPa. Carbon fibers were chopped into 3 mm.

2.2. Experimental process

The extrusion technology process was conveniently operated and a process flow diagram of extrusion process is shown as in Fig. 1.

In the extrusion process, the chopped carbon fibers were dispersed by mechanical stirring in ABS resin, which had been dissolved into paste in chloroform. The fiber filled paste then dried at room temperature. Finally, the composites were molded into filets under certain temperature and pressure.

Ten phr general pitch based activated carbon fibers and 100 phr ABS resin were mixed into the extruder when screw speed was 25 r/min and the cylinder temperature were 453 K, 463 K, 473 K, 488 K, and 503 K. Then, PACF and ABS resin were mixed when screw speed were 25, 50, and 75 r/min under certain temperature. Finally, the composites were molded by hot pressing at 40 MPa and 423 K for about 5 min.

2.3. Test samples

2.3.1. Fiber length test

One gram material was placed in Soxhlet extraction by chloroform extracting the material to certain weight and observated the length of carbon fiber under microscope.

2.3.2. Composite tensile strength test

The tensile strengths of samples were tested by Shimadzu universal tensile strength instrument.

2.3.3. Composite resistivity test

When resistance of samples exceeded 200 K Ω the high resistance meter was used. The electrodes were connected with samples by conductive silver paste. The resistivity of composite with dimension of $40 \times 9 \times 1$ mm was measured in the direction of perpendicular to the pressure by four-probe method. Fig. 2 shows the sketch map of measuring resistivity of composites with four probes method.

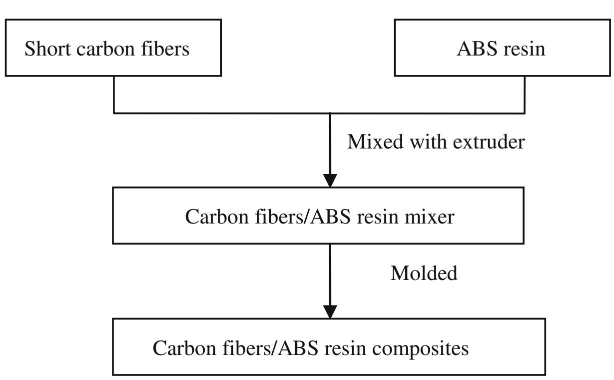

Fig. 1. Flowcharzt of extrusion process for carbon fiber/ABS resin matrix composites.

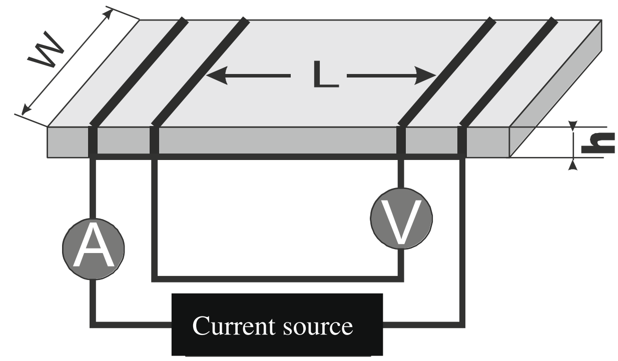

Fig. 2. Sketch map of measuring resistivity of composites with four probes method.

Resistivity of samples were calculated by as follows:

$$\rho = R \times (W \times h/L) \quad (1)$$

where ρ is the resistively of composites, R is the resistance of ρ, W, h, L are the width, height, length of composites, respectively.

2.4. Experimental data and results

Carbon fiber reinforced ABS resin based composite is a class of nonlinear multivariable objects. There are many influence factors for conductivity and tensile strength of carbon fiber/ABS resin composites. However, suitable process conditions are helpful to improve integrated conductivity which includes conductivity and tensile strength. Moreover, there are lots of process parameters such as the extruder screw speed, material barrel temperature, applied voltage, average fiber length and fiber content. Table 1 shows the different experimental data when different above parameters were selected.

From experiments the following main results can be produced:

(1) Decreasing extruder screw speed and increasing temperatures will help to maintain the length of carbon fiber.
(2) The longer length of carbon fiber and the lower resistivity of composite can get the higher tensile strength.
(3) With the increase of filling quantity of carbon fiber and the decrease of resistivity of composite, the tensile strength can be improved.
(4) It shows positive temperature effect that resistivity of composite increases with increasing temperature because thickness of the resin increases and the gap between fibers increases with increasing temperature.
(5) When carbon fiber content exceeding critical volume fraction, the resistivity of composite tends to decrease more and more slowly with increasing fiber fraction.

Occasionally, when temperatures exceeded 488 K, the conductivity decreases with the increasing fiber content. This phenomenon is mainly due to: (1) it is not conducive to maintain the electrical conductivity structure with the excessively speed growth; and (2) the resistivity of composite rapidly diseases when the average fiber length reduces more.

3. Least squares support vector regression

SVM was developed by Vapnik and his colleagues at AT&T Bell Laboratories in 1995 [8]. Unlike most traditional neural network