Study on prediction model of surface roughness of SiCp / Al composites based on Neural Network

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Abstract. In order to effectively meet the actual industrial production standards and improve the prediction accuracy of composite surface roughness, a prediction model of SiCp / Al composite surface roughness based on neural network is proposed. The influence parameters of surface roughness of SiCp / Al composites are analyzed from the cutting tool parameters, and the mathematical calculation of surface roughness of SiCp / Al composites is carried out. Using neural network technology, by determining various parameters of neural network, collecting and processing various data of material surface, the surface roughness prediction model of SiCp / Al composite is constructed to realize the surface roughness prediction of SiCp / Al composite. The experimental results show that the maximum error between the actual value and the predicted value of the surface roughness of composite materials from the prediction model established in this paper is only 0.013, and the average error percentage between the actual value and the predicted value is 0.705%, which can effectively improve the prediction accuracy of the surface roughness of composite materials and meet the standards of actual industrial production.

1. Introduction
The material SiCp / Al studied in this paper is a silicon carbide reinforced aluminum matrix composite. This material has the advantages of strong heat dissipation capacity, low density, light relative weight, stable structure and strong compressive capacity, especially good fatigue fracture performance [1]. At present, the research on SiCp / Al composites mainly focuses on drilling. Machining parts need to drill a large number of micro holes of about 1 mm on the surface of the composites. The smoothness of these micro holes has an important impact on the structural stability of the whole product in the later stage. Therefore, the requirements for cutting tool parameters and cutting technology are very strict. Using the current method for drilling processing and roughness detection and reprocessing will cause great damage to the processing equipment and waste the bidirectional material resources of equipment and composite materials [2].

With its advanced computing mode, unique operation mode and multi field auxiliary performance, computer digitization technology has won the most scientific research energy in the world. The big data thinking mode can not only help the enterprise management personnel make strategic decisions, but also go deep into the technical grass-roots level to detect and repair the performance of machinery and equipment, Even before it is put into use, the simulation Standard Test of various indicators is carried out, which greatly reduces the failure rate of enterprise machines after operation, reduces the manufacturing cost, and effectively promotes the development of social economy [3]. Therefore, it is of great significance to combine the smoothness detection of silicon carbide reinforced aluminum
matrix composites with computer technology to predict the roughness of materials and reduce the material cost before they are put into use. Therefore, a prediction model of surface roughness of SiCp / Al composites based on neural network is proposed in this paper.

2. Theoretical analysis of surface roughness prediction of SiCp / Al Composites

In order to establish the surface roughness prediction model of SiCp / Al composites, it is necessary to analyze and calculate the formation mechanism and influencing factors of surface roughness, and establish the data basis of influencing factors of the prediction model. Therefore, firstly, in the theoretical analysis of the prediction model, the influencing parameters of roughness and their digital expression are studied.

2.1. Study on influencing parameters of surface roughness of SiCp / Al Composites

In the process of material cutting, the high temperature environment within the range is easy to cause the oxidation reaction of silicon carbide. After cooling, these elements will adhere to the surface of the cutting tool, which will affect the sharpness of the cutting tool. The relationship trend between cutting speed and composite surface roughness is shown in Figure 1.

![Figure 1. Relationship between speed and roughness](image1)

It can be seen from the trend in Fig. 1 that the surface roughness is affected by the cutting speed, and the overall influence shows a law that decreases first and then increases. When the speed is 20m per minute, the surface roughness is the lowest, which is the most suitable cutting speed. The relationship trend between feed rate and surface roughness is shown in Figure 2.

![Figure 2. Relationship between feed rate and roughness](image2)
According to the analysis of Figure 2, the overall trend of feed rate and surface roughness is rising. As long as the feed rate increases, the roughness will increase [4]. Therefore, it is necessary to control the feed rate at the minimum state.

The experimental samples are selected to prepare for the experiment to study the influence of variable factors such as cutting parameters on the roughness of composite materials, as shown in Table 1. The parameters of each experimental sample need to be measured and prepared in advance. A removable cleaning tool made of aluminum titanium nitride with a diameter of 15 mm is used for cutting and drilling. The hole length is 1125 mm. Use new punching equipment every time you cut or punch.

Table 1. Surface roughness measurements

| Serial number | Speed | Feed rate | Abrasion | Roughness |
|---------------|-------|-----------|----------|-----------|
| 1             | 10    | 0.05      | 0.09     | 0.71      |
| 2             | 15    | 0.05      | 0.11     | 0.41      |
| 3             | 15    | 0.20      | 0.04     | 2.01      |
| 4             | 20    | 0.15      | 0.07     | 1.68      |
| 5             | 20    | 0.20      | 0.04     | 1.78      |
| 6             | 39.7  | 0.17      | 0.26     | 2.28      |
| 7             | 31.5  | 0.21      | 0.24     | 2.28      |
| 8             | 1.3   | 0.15      | 0.001    | 0.49      |
| 9             | 36.9  | 0.25      | 0.34     | 3.29      |
| 10            | 21.9  | 0.29      | 0.235    | 2.29      |
| 11            | 32.8  | 0.23      | 0.28     | 2.65      |

Select several groups of random data in Table 1 for multi-factor and multi-level test, analyze these data, and compare the degree order relationship of influencing factors such as speed, tool walking amount and wear. According to the experimental results, we can get which factor is the main influencing factor.

2.2. Mathematical calculation and analysis of surface roughness of SiCp / Al Composites

The range value can reflect the obvious trend of various influencing factors. The larger the range of the experiment, the greater the influence of this factor on the roughness. The calculation formula of range is as follows:

$$k_{jm} = \sum_{i=1}^{n} y_j$$  \hspace{1cm} (1)

$$K_{jm} = \frac{k_{jm}}{n}$$ \hspace{1cm} (2)

$$R_j = (k_{jm})_{max} - (k_{jm})_{min}$$ \hspace{1cm} (3)

Where, \( y \) is the measured depth in the experiment; \( k_{jm} \) is the test standard and of the occurrence of the variable \( m \) level in column \( j \); \( n \) is the number of tests under the same variable; \( K_{jm} \) is the average value of the test standard occurring at the \( m \) level of the variable in column \( j \); \( R_j \) is the range of the variable in column \( j \).

In combination with the above, in order to obtain high-quality composites, when drilling, the product can be processed with higher cutting speed and lower feed rate [5]. In the actual working environment, due to the limitations of machinery and equipment, medium cutting speed and relatively
small feed rate can be selected. This can not only ensure the quality of products, but also improve work efficiency.

3. Construction of roughness prediction model based on Neural Network

Based on the above analysis, the surface roughness of SiCp / Al composites is affected by processing environment and process methods, and there is a causal transmission relationship. Therefore, as long as the main influencing factors are monitored, the surface roughness of formed parts can be predicted. Because there are many parameters to be detected, neural network can be used to build roughness prediction model. Neural network is a very complex structure. It can adapt to the rapid changes of data in different environments, and carry out a wide range of operations in the rapidly changing information environment.

One of the most important characteristics of neural networks is that they can learn independently. Before using neural network to complete any command and task, it is necessary to train its rules. The learning process is basically to adjust the weight of neural network connection.

3.1. Determine the parameters of neural network

The structure of BP neural network is basically fixed, but the number of levels is constantly changing. According to the actual production needs, the number of hidden layers is analyzed. The number of input layers and output layers is basically the same and stable [6]. If you want to obtain higher accuracy, you can continuously increase the number of hidden layers. But this will make the network more complex and the time of training the network will be greatly increased. Let the number of marker points in the output layer of the neural network be n, the number of marker points in the input layer be m, and the number of hidden layer nodes be h. The following is the relationship formula between the three:

\[
    h = \begin{cases} 
    m + 0.168(m - n), & m > n \\
    n - 0.168(n - m), & m < n 
    \end{cases} \tag{4}
\]

When the neural network structure is not complex and \( m > n \):

\[
    h_{\text{best}} = \sqrt{mn} \tag{5}
\]

The basic standard for obtaining the best value is to build the model and input relevant values. On the premise of obtaining the output value, it is necessary to simplify the model scheme with fewer hidden layers as much as possible, so as to obtain a structure and facilitate future troubleshooting.

3.2. Data processing

Some samples obtained through the experiment must be processed before they can be used to train and verify the network, that is, the prior processing and analysis of the data. In general, the normalization method is used [7-8]. It should be noted that these extreme data are likely not to have a unified movement trend. The function expression is as follows:

\[
    x_i = \frac{\ln X_i - \ln X_0}{\ln X_{\text{max}} - \ln X_0} \tag{6}
\]

To sum up, determine the parameters of each part of the network, and obtain the number of marker points in the input layer and the number of marker points in the output layer, which are 3 and 1 respectively. When the number of hidden layer nodes is less than 10, the network does not converge within the specified learning times. When the number of learning times is 10000, the curve of approximation error is shown in Fig. 3.
As can be seen from Fig. 4, after the value of the hidden layer is 9, the overall error converges very slowly or even stagnates, so the value less than 9 can be excluded. Based on this, the surface roughness prediction model of SiCp / Al composites is constructed in this paper.

4. Experimental analysis
In order to verify the prediction accuracy of the established network model and whether its coverage can meet the standards of actual industrial production, performance experimental analysis is carried out. Four samples are randomly selected from the measurement samples in Table 1 and renumbered, their original data are recorded, and the surface roughness of the four samples is predicted by using the prediction model established in this paper. The comparison results between the actual value and the predicted value of composite surface roughness are shown in Table 2.

| Number | Prediction roughness | Actual roughness | Error | Error percentage (%) |
|--------|----------------------|------------------|-------|----------------------|
| 1      | 2.295                | 2.281            | 0.014 | 0.63                 |
| 2      | 2.286                | 2.274            | 0.012 | 0.56                 |
| 3      | 2.249                | 2.236            | 0.013 | 1.28                 |
| 4      | 3.118                | 3.107            | 0.011 | 0.35                 |

According to the data in Table 2, the maximum error between the actual value and the predicted value of composite surface roughness is only 0.013, and the average error percentage between the actual value and the predicted value is 0.705%. Therefore, the prediction model established in this paper can effectively improve the prediction accuracy of composite surface roughness and meet the standards of actual industrial production.

5. Conclusion
Silicon carbide is one of the typical hard and brittle materials. Its surface is easy to be damaged during precision machining. The structure of SiC reinforced aluminum matrix composites is more complex, and there are more unstable factors in the processing process. The applicability detection of this material after ultra precision machining is also very important. In this paper, the neural network technology is used to advance the detection steps to the process of product R & D and processing, and the prediction research on the surface roughness of composite materials is carried out. It is
concluded that the speed, feed rate and processing mode of processing equipment are the influencing factors affecting the surface roughness of composite materials, and the roughness prediction model is established. The model can effectively improve the prediction accuracy of composite surface roughness and meet the standards of practical industrial production.

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