Prediction of simulation parameters of fiber laser cleaning Range hood based on BP neural network

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Abstract. In order to study the influence of process parameters on the surface oil pollution of fiber laser cleaning Range hood, the test of laser cleaning to remove the surface oil pollution of Range hood was carried out. Based on the BP neural network, a prediction model of the process parameters such as laser scanning speed, cleaning times and cleaning line spacing is established. the training samples collected by the cleaning test were trained online, and the training model was verified by using the test samples. The results show that the neural network prediction model has high accuracy and good training effect, and the maximum relative error between the predicted value and the test sample value is 8.4%. The model can predict laser cleaning effectively oil stain quality on Range hood surface.

1. Introduction

1.1. Laser oil removal mechanism
The traditional cleaning methods of pollutants on the surface of materials include mechanical cleaning and chemical cleaning, but mechanical cleaning will lead to higher roughness, traditional cleaning with chemical reagent method, the effect is better, but the treatment time is long, the operation is complex, the cleaning waste liquid is difficult to deal with, and the environmental pollution is large[1-2]. Laser cleaning technology is a new technology developed in recent years. Compared with traditional mechanical or chemical cleaning methods, it has the advantages of no pollution, high efficiency, good quality and no damage to the substrate, people pay more and more attention to it[3]. At present, the industry has been used to clean rust, oxide film, weld black smoke, grease [4], paint and so on. This paper mainly studies the laser cleaning of oil stains on the surface of stainless steel, which is an efficient, high-quality, safe and environmentally friendly treatment method. However, due to its complexity, scholars have no unified conclusion. At the same time, the decontamination depth is affected by scanning speed, decontamination times, line spacing, laser pulse width and other factors, and its internal influence law can not be completely described accurately. After each process test, the decontamination depth needs to be measured by laser confocal microscope, so it is necessary to explore the correlation between ablation process and decontamination thickness through simulation and simulation.

1.2. Introduction of BP Neural Network
The artificial neural network has the powerful ability of pattern recognition and data fitting, which can automatically adjust the structural parameters and change the mapping relationship by training the sample data, so as to produce the corresponding expected output to the specific input, which has strong adaptability. Because the traditional mathematical method can not accurately describe the relationship
between scanning speed, decontamination times and the depth of laser decontamination, and by introducing neural network to train the original sample data, a model can be constructed to describe the relationship between process parameters and decontamination depth, which can predict the depth of laser decontamination under different process parameters.

2. Laser cleaning test

2.1. Test equipment
The cleaning equipment adopts a fiber laser with wavelength 1080 nm, the average laser power is 500 W and continuously adjustable, and the laser beam line width is 200 mm, and cleaned by using mirror scanning.

2.2. Test samples
For the surface of the range hood mainly for some grease polymer, cleaning process, the main need to study is the laser and grease polymer process. Materials of range hood is generally stainless steel, in order to ensure that no damage to the surface of the range hood, it is necessary to strictly control the damage of laser to stainless steel. That is, the laser energy must be higher than its oil pollution ablation threshold, lower than the stainless steel damage threshold. At the same time in different areas of oil fume machine oil thickness is different, so it is difficult to control the appropriate parameters in the actual cleaning, the same stainless steel material as the range hood is fixed on the range hood with a size of 110 mm×110 mm, after it accumulates to attach 10μm of oil pollution, it is taken down as the experimental material. The test samples are divided into prediction samples and validation samples. Each test sample contains various combination process parameters for laser cleaning. On 110 mm×110 mm clean stainless steel brush a layer of 10μm thick edible oil, the main chemical composition is triglyceride.

2.3. Design of test programmes
The network training samples were collected to combine the process parameters with better quality in the cleaning orthogonal test, 15 groups of process parameters were designed for laser cleaning test to collect network training samples. The process parameters and depth values were measured as shown in table 1, and the first 1-15 groups of data were used for network training.

| Serial number | Scanning speed | Number of scans | Scanning spacing | Cleaning depth |
|---------------|----------------|----------------|------------------|--------------|
| 1             | 3500mm/s       | 1              | 0.04mm           | 5.35μm       |
| 2             | 3500mm/s       | 2              | 0.05mm           | 8.52μm       |
| 3             | 3500mm/s       | 3              | 0.06mm           | 10.00μm      |
| 4             | 4000mm/s       | 1              | 0.06mm           | 4.67μm       |
| 5             | 4000mm/s       | 2              | 0.05mm           | 7.76μm       |
| 6             | 4000mm/s       | 3              | 0.05mm           | 9.56μm       |
| 7             | 4500mm/s       | 1              | 0.05mm           | 4.11μm       |
| 8             | 4500mm/s       | 2              | 0.06mm           | 7.53μm       |
| 9             | 4500mm/s       | 3              | 0.05mm           | 8.78μm       |
| 10            | 5000mm/s       | 1              | 0.04mm           | 3.69μm       |
| 11            | 5000mm/s       | 2              | 0.05mm           | 7.21μm       |
| 12            | 5000mm/s       | 3              | 0.06mm           | 8.32μm       |
13 6000mm/s 1 0.06mm 3.17μm
14 6000mm/s 2 0.05mm 6.85μm
15 6000mm/s 3 0.06mm 7.56μm
16 7000mm/s 1 0.06mm 2.67μm
17 7000mm/s 2 0.05mm 6.38μm
18 7000mm/s 3 0.06mm 6.23μm
19 7500mm/s 1 0.04mm 2.50μm
20 7500mm/s 2 0.06mm 6.17μm

To determine whether the oil stain is clean or not, paint test (1dyn/cm=1mN/m) was carried out before and after cleaning stainless steel oil stain with preferred No.28 Dyne pen. The following figure 1 shows that there is oil pollution on the stainless steel surface before cleaning, figure 2 clear macro picture successively; figure 3 is the microscopic picture before cleaning after using the No.28 Dyne pen painting, red purple droplet dispersion, intermittent distribution, representing the surface condition measurement value less than 28 mN/m; Figure 4 shows that after cleaning, using the No.28 Dyne pen painting, red purple filling uniform uninterrupted, representing the surface condition measurement value greater than or equal to 28 mN/m.
3. Forecasting Model of Laser Cleaning BP Neural Network

3.1. Model building
BP neural network has the ability of self-learning, self-organization and self-adaptation, which is more suitable for multi-transport and multi-output multi-objective optimal structure model. As figure 5 shows the neural network model structure of the system, which includes input layer, output layer, hidden layer and error calculation.

To achieve the highest efficiency in cleaning, full power testing only studies scanning speed, scanning times, scanning spot spacing, where the input layer is mainly composed of scanning speed, scanning times, scanning spot spacing and other database parameters, each parameter is one node of one input layer. Let the total number of m; output layer be cleaning depth, each parameter is one node, let the total number of output layer is the number of n; output layer data output to the computer for comparison with the set target, feedback the results back to the input layer and hidden layer. Change the weight of each node of input layer and hidden layer or re-select the learning path, until the output is satisfactory[5]. The hidden layer represents the path selected from the input layer to the output layer and is a mapping process, and the number of nodes k determined by the input and output layers.

\[ l = \sqrt{m+n} + \alpha \]

In the above formula, \( \alpha \) is an empirical value, taking an integer between 1 and 10. according to the principle of fastest convergence speed and minimum network error, the number of hidden layer neurons is determined to be 4 in this experiment. Figure 5 shows the flow chart of BP neural network learning program. The system can continuously adjust the network parameters and learning path according to the comparison between the set goal and the learning output value, so as to obtain the optimal learning network.

3.2. Neural network training and model validation
The 15 groups of data were selected as training samples. after using matlab software for BP neural network training, after 2000 training, the network error reached the prescribed training target of 0.01. Test the accuracy of the neural network model constructed in the previous step using 16-20 experimental data. If the predicted output deviates greatly from the expected output, it returns to the previous step to rebuild the model. If the predicted output is basically consistent with the expected output change, the model construction is judged to be successful and the next step is carried out. This experiment, considering the experimental error, when the prediction error of each test sample is less than 10%, the BP neural network model to predict the depth of laser decontamination is successfully constructed. The comparison between the model prediction value and the test value is shown in Table 2, The results show that the two are very close, and the maximum relative error is only 8.40%, which
indicates that it is feasible to predict the depth of laser cleaning with BP neural network. The model can be used for parameter selection and optimization of processing process, and has a good application prospect for guiding laser cleaning range hood and ship oil pollution.

Table 2. Comparison of Model Prediction and Test Values.

| Serial number | Scanning speed | Number of scans | Scanning spacing | Cleaning depth | Forecast depth | Relative error |
|---------------|----------------|-----------------|------------------|----------------|----------------|----------------|
| 16            | 7000mm/s       | 1               | 0.06mm           | 2.67μm         | 2.51μm         | 5.99%          |
| 17            | 7000mm/s       | 2               | 0.05mm           | 6.38μm         | 6.78μm         | -6.27%         |
| 18            | 7000mm/s       | 3               | 0.06mm           | 6.23μm         | 5.91μm         | 5.13%          |
| 19            | 7500mm/s       | 1               | 0.04mm           | 2.50μm         | 2.29μm         | 8.40%          |
| 20            | 7500mm/s       | 2               | 0.06mm           | 6.17μm         | 6.56μm         | -6.39%         |

4. Conclusions

It is difficult to analyze and predict the effect of process parameters on cleaning thickness in the process of laser cleaning oil fume machine. A BP neural network model is established to predict the oil stain thickness of oil fume cleaning machine, and the laser cleaning thickness is successfully predicted. It includes the following two conclusions:

1. A BP neural network prediction model is established for the corresponding relationship between laser cleaning speed, scanning spacing, cleaning times and cleaning thickness. The maximum relative error is 8.4% and the network training effect is better.

2. Based on the analysis and verification of a large number of process tests, it is shown that the BP neural network prediction model can effectively predict the thickness of laser cleaning oil pollution. Through the detection of Dyne pen, the cleaning quality meets the practical application requirements.

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References

[1] SHAHRYARI A,KAMAL W,OMANOVIC S. The effect of surface roughness on the efficiency of the cyclic potentiodynamic passivation(CPP) method in the improvement of general and pitting corrosion resistance of 316LVM stainless steel. Materials Letters62(23),3906-3909(2008).

[2] CHEN G X,KWWEE T J, TAN K P, etal. High-power fiber laser cleaning for green shipbuilding. Journal of Laser Micro/Nanocncinccring7(3),249-253(2012).

[3] SIANO S SALIMBENI R.:Advances in laser cleaning of artwork and objects of historical interest: the optimized pulse duration approach. Accounts of chemical research 43(6),739-750(2010).

[4] A.W.Alshaer,L.Li, A.Mistry. The effects of short pulse laser surface cleaning on porosity formation and reduction in laser welding of aluminium alloy for automotive component manufacture. Optics & Laser Technology64(4), 162-171(2014).

[5] YANG D H,MA L,HUANG W D. Component,s surface quality predictions by laser rapid forming based on artificial neural networks. Chinese Journal of lasers 38(8),11-5(2011).