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Experimental Study on Parts of Laser Cleaning Device

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Abstract

The purpose of this study was to investigate the cleaning effect under different laser output power, pulse frequency and scanning speed. Taking the pulse fiber laser with 50W power and 1064nm wavelength as the control object, a test-bed of laser cleaning device is built in the laboratory. An experimental study was performed on the rust removal of parts made of 45 steel in different process parameters conditions. The results show that process parameters such as laser output power, pulse frequency and scanning speed have varying degrees of influence on the effect of laser cleaning and work efficiency. Changing these process parameters can lead to the best laser cleaning effect.

Keywords

Laser cleaning; automatic control; modulation frequency; scanning speed; cleaning efficiency.

1. Introduction

Laser cleaning technology is an effective way to remove surface adhesion or surface coating. Using high frequency and high energy laser pulse to irradiate the surface of the work piece, the coating layer can instantly absorb the focused laser energy and make the oil, rust or coating on the surface evaporate or peel off [1]. Compared with traditional rust removal methods, laser rust removal technology has the advantages of non-contact, no damage, high cleaning efficiency, good cleaning quality and pollution-free. It has gradually replaced traditional cleaning processes in many fields [2].

At present, the development of laser cleaning technology at home and abroad is rapid. The National University of Singapore and other overseas related institutions have systematically studied the dry laser cleaning mechanism, proposed the thermal desorption model, and carried out the research on the precision removal control technology of various surfaces according to the model, which is in the leading position in the world [3]. Laser fusion research center of China Institute of Engineering Physics, Huazhong University of science and technology, Jiangsu University and other laser cleaning research institutions have carried out a lot of researches and explorations in the direction of device development, processing research and experimental technology [4-7]. In the existing research, process parameter research has always been the focus of laser cleaning technology research. Wu Yonghua et al. used Nd:YAG quasi-continuous laser to carry out laser rust removal cleaning test on Q235 steel plate sample, studied the effect of laser energy density, scan rate, scan width, off-focus volume and repeat frequency on cleaning quality, and obtained the best laser process parameter of Q235 steel [8]. Wan Zhuang et al. used solid-state fiber laser, controlled the single factor parameters of cleaning frequency, and took Q235 low-carbon structural steel surface oxide layer as an example to carry out cleaning experiment, and explored the cleaning effect, cleaning mechanism and surface performance under different frequencies [9]. Li Xinyan et al. used 1064nm fiber laser to clean the rust layer on Q345 steel surface, and studied the effect of scanning speed on cleaning quality

[10]. Chen Shuixuan et al. used orthogonal experiments to study the influence of laser cleaning adjustable process parameters on the cleaning effect of coating, and the relationship between the three to the cleaning effect was studied by changing the laser energy density, laser cleaning speed and laser spot overlap rate [11].

Although Chinese and foreign scholars have made some research achievements in the cleaning effect and cleaning quality of metal rust surface, there is still a lack of systematic laser cleaning process research, and the degree of influence of different process parameters of various substrates on laser cleaning effect has not been fully explored. Based on the pulse laser cleaning test device and the automatic control system, this paper obtains the key factors affecting the laser cleaning effect through the experimental research of the laser cleaning process on the highly rusty 45 steel, so as to enrich and improve the research of laser cleaning process parameters, and provide the basis for further optimization of process parameters.

2. Laser Cleaning Experimental Scheme

2.1. Laser Cleaning Test Device

Taking a 50W pulsed fiber laser as the control object, the effect of different process parameters on laser rust removal effect is studied under laboratory conditions. The test device consists of pulsed fiber laser output system, mobile platform system, master computer and other equipment, see Figure 1.

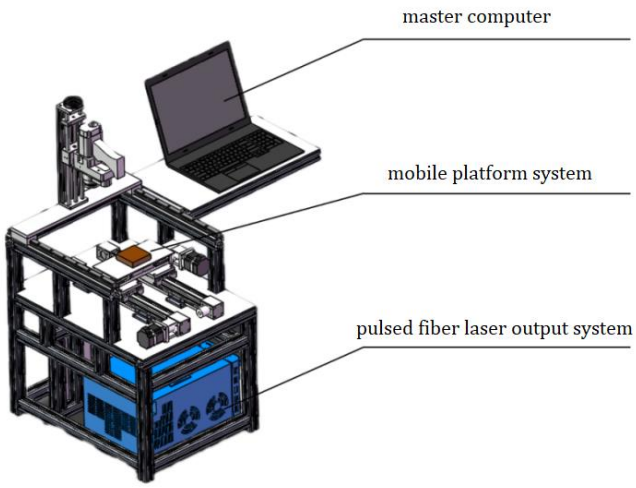

Figure 1: Laser cleaning test device

The main technical parameters of fiber lasers are set out, see Table 1.

Table 1: Laser parameter index

Numble	Parameter	Value	Unit
1	Average output power	50	W
2	Maximum pulse energy	1	mJ
3	Frequency adjustable range	20-100	KHz
4	Pulse width	90-150	ns
5	Beam diameter	6-8	mm
6	Power adjustment range	0-100	%

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2.2. Automatic Control System of Laser Cleaning Device

The automatic control system of the experimental cleaning device is designed. The power input of the laser is controlled by the program-controlled DC power supply. The power on and preheating of the laser are controlled by the DB25 serial port. The laser power, pulse frequency, spot size and other parameters are set and transmitted to the laser gun head through the beam adjustment transmission system. The workpiece is fixed on the mobile platform system, and the distance between the workpiece and the laser gun head, cleaning position and scanning speed are set by the control system. At the same time, the temperature, current and other alarm information of the laser are also transmitted to the automatic control system in real time to realize the parameter monitoring of the whole cleaning process, see Figure 2.

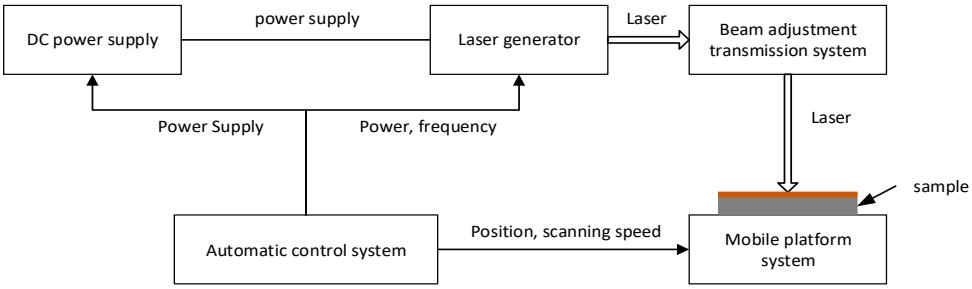

Figure 2: Automatic control diagram of laser cleaning test device

2.3. Test Process Control

In order to achieve the best cleaning effect and efficiency, a set of experimental laser cleaning control system is designed to control the laser and coordinate other parts of the system to complete the whole process of laser output power setting, pulse frequency adjustment, scanning speed control. The system uses NI LabVIEW virtual instrument development platform and Ni pci-6503 board to send control signals and receive laser feedback information. The system control flow is shown in Figure 3.

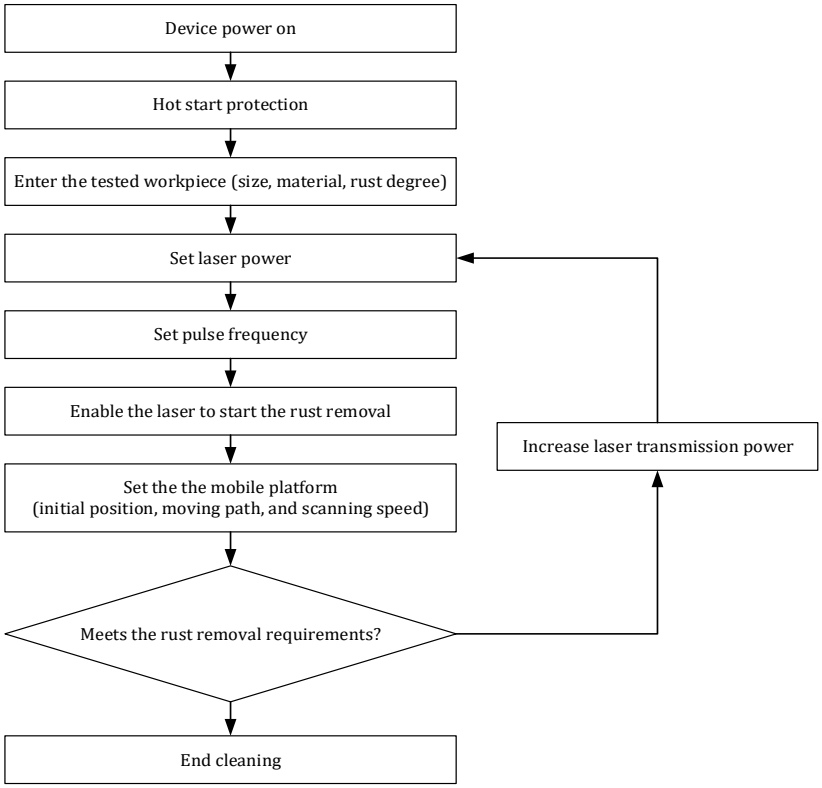

Figure 3: The system control flow

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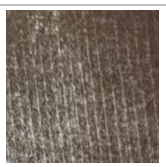
2.4. Laser Cleaning Results

Taking the highly corroded 45 steel as the cleaning object, the process parameters were optimized by using the above experimental device and control system. Considering that the adjustable parameters of the cleaning equipment are relatively fixed, which mainly focus on the adjustment of output power, pulse frequency and scanning speed, this experiment mainly studies the influence of different scanning speed, pulse frequency and laser output power on the cleaning effect based on the actual operation needs. Typical cleaning results are shown in Table 2.

Table 2: Typical cleaning results

Numble	scanning speed	pulse frequency	laser output power	results
1	10	100	100	
2	5	100	100	
3	4	100	100	
4	3	100	100	
5	3	100	90	
6	3	100	80	
7	3	100	55	
8	2	100	100	

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9	1	100	100	
10	3	80	100	
11	3	50	100	
12	3	100	60	

It can be seen that the interaction of the three factors affects the cleaning effect of surface rust, and the influence of each factor on the cleaning effect is not constant. Relatively speaking, the effect of laser scanning speed on surface rust cleaning is the most significant, followed by laser output power and pulse frequency. When the pulse frequency is above 50 kHz and the laser output power is above 80%, with the decrease of scanning speed, the more energy absorbed per unit time, the cleaning effect is gradually improved. When the scanning speed is reduced to 3r/min, the cleaning effect is the best. Subsequently, as the scanning speed is reduced below 3r/min, the cleaning efficiency is significantly reduced, and the substrate ablation oxidation is caused by the laser energy density exceeding the substrate damage threshold. When the laser output power is less than 80%, the energy density is slightly higher than the ablation threshold, the laser output power plays a leading role in the cleaning effect, and the influence of scanning speed and second pulse frequency is reduced. When the laser output power is kept between 50% and 80%, the cleaning effect is positively correlated with the laser output power.

3. Conclusion

Laser cleaning device is a high-precision, highly integrated equipment control system. In the process of operation, multiple parameters need to be set. Setting appropriate process parameters is very important to the cleaning efficiency and cleaning effect. Based on LabVIEW virtual instrument, a set of experimental laser cleaning control system is designed, which is used to control the laser and coordinate other parts of the system to complete the whole process of power setting, pulse frequency and scanning speed control. The test results show that the system runs stably and reliably with high laser output precision, which can meet the requirements of laser cleaning equipment. At the same time, the system has strong expansibility, which can provide reference for laser automatic control application in other fields.

Using 50W laser device to carry out cleaning experiments on 45 steel, the results are as follows:

(1) Due to the interaction of laser output power, scanning speed and pulse frequency, the influence of various factors on the cleaning effect changes regularly.

(2) When the pulse frequency is above 50 kHz and the laser output power is above 80%, the scanning speed plays a leading role in the cleaning effect. The scanning speed of the best cleaning effect is 3r/min; when the scanning speed is 1r/min, obvious peroxide phenomenon appears.

(3) When the laser output power is less than 80%, the laser output power plays a leading role in the cleaning effect. When the laser output power is between 50% and 80%, there is a strong positive correlation between the cleaning effect and the laser output power.

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