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APPLICABILITY OF A NEW SURFACE PREPARATION METHOD FOR STEEL STRUCTURE USING LASER

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Surface preparation is very important in re-painting of steel structures so as to extend the effective term of corrosion prevention. Though grinding or blasting have been widely used to remove rust and old coating film on steel surface, both these methods have difficulty in completion of rust-removal and cause some problems such as dust scattering, noise, etc. In order to solve these problems, this paper presents the laser cleaning method which instantaneously sublimes/evaporates the rust on the surface of steel structure. The authors investigate the effects and the applicability of laser cleaning using the specimens made by accelerated corrosion method. The test results confirmed that the laser cleaning can remove the rust almost much as using sand blast, and the salt on the surface of steel can also be evaporated as good as the rust. Moreover, this method seems can be applied on wet surface condition because the moisture and water on the surface of steel can also be evaporated.

Keywords: Evaporate, Remove rust, Remove salt, Wet condition, Fiber laser.

1 INTRODUCTION

In recent years, maintenance of the steel structure is regarded as important. For the long life of steel structure, re-painting is carried out periodically. As listed in Table 1, the durability of the anti-corrosive is greatly influenced by the quality of surface preparation[1]. Therefore, blasting which can completely remove rust and old coating becomes the basic of surface preparation. However, blasting has some problems such as the need for dust scattering prevention and noise control, and the increasing in cost processing of large amount of grinding material and old coating film. As a solution to the problems above, laser cleaning method has been noticed[2,3]. This method instantaneously sublimes/evaporates rust by irradiating high energy density laser.

[1] Japan Bridge Association Inc.
[2] Laser cleaning of steel for paint removal, G.X. Chen, T.J. Tan, Y.S. Choo, M.H. Hong, Appl Phys A Materials Science & processing, 2010.
[3] Corrosion Deterioration of Painted Steels with Different Surface Preparations of Steel Substrates, Yoshihito Itoh, In-tae Kim, Shigenobu Kainuma, Yoshihisa Kadota, Japan Society of Civil Engineers No.766/I-68, 291-397, 2004.

Moreover, it can be expected that not only rust and old coating film but also salt can be simultaneously removed from the surface of material.

In this paper, primary tests were conducted for verification of the applicability of laser cleaning technology. At the same time, in consideration of the implementation in marine structures and steel structures under the rainy weather, the authors also examined whether or not can be performed immediately painting after the surface preparation to the surface which was in wet condition.

Table 1. Influence of various factors to the lifetime of coating.[1)]

Factor	Contribution ratio (%)
Surface preparation	52.7
Number of coating times	16.1
Types of coating material	7.9
Other factors	23.3

Note 1: The test environment is the actual bridge of countryside
Note 2: Test paint is lead-based anticorrosive plus ready-mixed paint

2 SPECIMENS AND METHOD OF THE TEST

The specimens were prepared by carrying out the brine bubbling accelerated corrosion test[4] as listed in Table 2.

Figure 1 illustrates the rust condition of the specimen. Laser cleaning was conducted by laser marking device to the specimens. Summary and appearance of the laser marking device are shown in Table 3 and Figure 2. Laser irradiation range is rectangular 40mm by 20mm, and the initial setting of laser at the time of cleaning is the moving speed of 1.0mm/s and the heat input of about 1.3j/mm^2. In addition, each specimen has changed the frequency for each No.1=30kHz, No.2=50kHz, No.3=100kHz. We irradiated with a laser several times at the same range of each specimen, and the test was terminated when the rust on the surface cannot be confirmed by eyes.

After the test, we performed component analysis of the steel surface using a scanning electron microscope to confirm the effect of removing the rust and salt. In addition, the surface condition at the time of laser cleaning was not the dry condition which is required by the dry blasting etc, but it was wet condition such as marine structures and steel structures under the rainy weather. If this method can remove the rust equal to blasting in wet condition, it can be expected to be greatly reduced the limitation by the environmental condition.

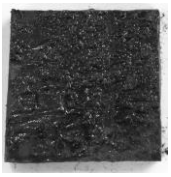

Figure 1. The rust condition of the specimen.

[4] Guidelines for Evaluation of Durability and Load-carrying Capacity for Steel Structures under Marine Environment, Japan Society of Civil Engineers, March 2009.

Table 2. The test conditions.

Item	Details
Steel grade	SS400
Surface condition	Nothing is coated
Salinity	About 5%
Temperature	50℃
Air quantity	2.5 l/mm
Test period	About 2 month

Table 3. Summary of the laser marking device.

Oscillation method	Yb-fiber laser
Output	30 W (Processing end 26.6W)
Wavelength	1060-1080 nm
Focus diameter	About 40 μm
Power density at the focal point	7.1×10^8 W/cm^2 note:30kHz oscillation mode

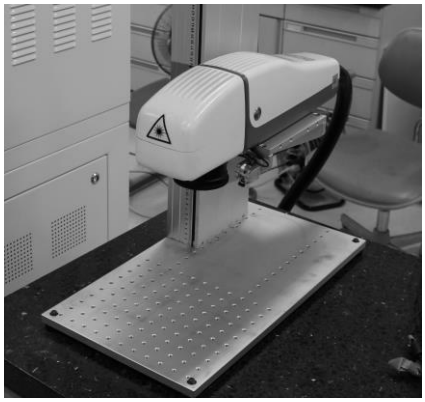

Figure 2. Appearance of the laser marking device.

3 RESULT

3.1 Consideration about Appearance of Test Specimens

Figure 3 shows the analysis results of steel surface by the scanning electron microscope. In this test, each laser irradiation number of times is No.1 = 7 times, No.2 = 5 times and No.3 = 6 times. It can be seen that the rust is roughly removed in all specimens (Figure 3). The surface appearance of No.1 was different from the other ones; it has light yellow color because of the impact of the oxidation reaction at the time of laser irradiation. On the other hand, the surface of No.3 came to burn a little. Consequently, the surface of No.2 has become the best-looking by Laser cleaning in this test.

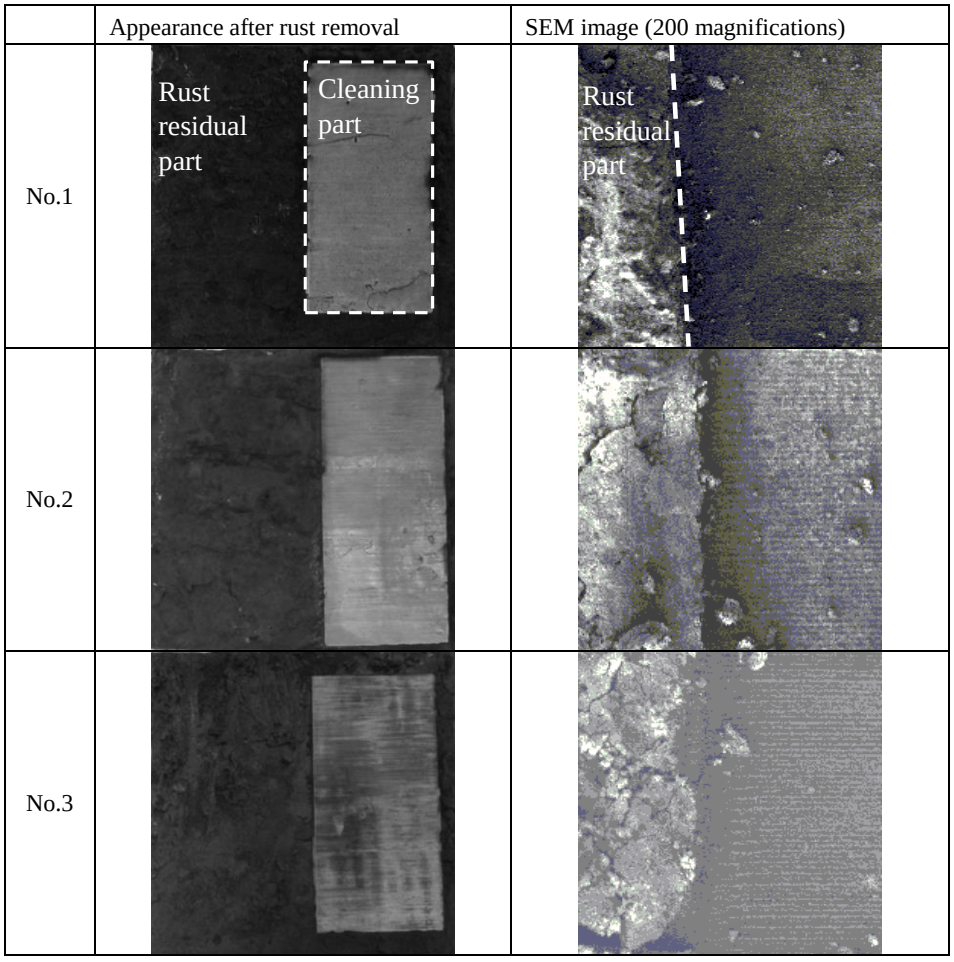

Figure 3. The analysis results of steel surface.

Thus, it is found that there are differences in appearance of the steel surface by the initial setting of the laser. However, it was revealed that regardless of the initial setting of the laser, the surface preparation with laser was approximately equal to the blasting in visual confirmation. In previous study, it has been said that there exist initial thresholds during laser cleaning[5]. Therefore, we need to investigate a more appropriate initial setting by performing the laser cleaning with many more parameters from now on. As a result, the water on steel surface was thoroughly evaporated.

3.2 The Effect of Salt Removal by Laser Cleaning

Figure 4 shows the results of the energy dispersive x-ray analysis using the scanning electron microscope. As shown in the Figure 4, chlorine molecular (Cl) is represented by gray color. Compared to the rust residual part, it can be seen that the chlorine molecular (Cl) i.e. the salt is

[5] Parameters and surface performance of laser removal of rust layer on A3 steel, Zemin Wang, Xiaoyan Zeng, Weiling Huang, Surface and Coatings Technology 166, 2003

removed in cleaning part. This also suggests from Table 4 that shows the comparison of the weight percent of sodium molecular (Na) and chlorine molecule (Cl) in specimens No.2. Table 4 indicates that both molecules can be eliminated by this method more than 98% in the measurement range. And also it can be realized that the rust is eliminated at the same time from Table 5 that shows the weight percent of Oxygen molecule (O) and iron atom (Fe) in specimens No.2.

According to the above, it is thought that the simultaneous removal the rust and salt of steel structure is possible by laser cleaning. In addition, it can be expected to apply the laser cleaning in marine structures and the steel structures under the rainy weather.

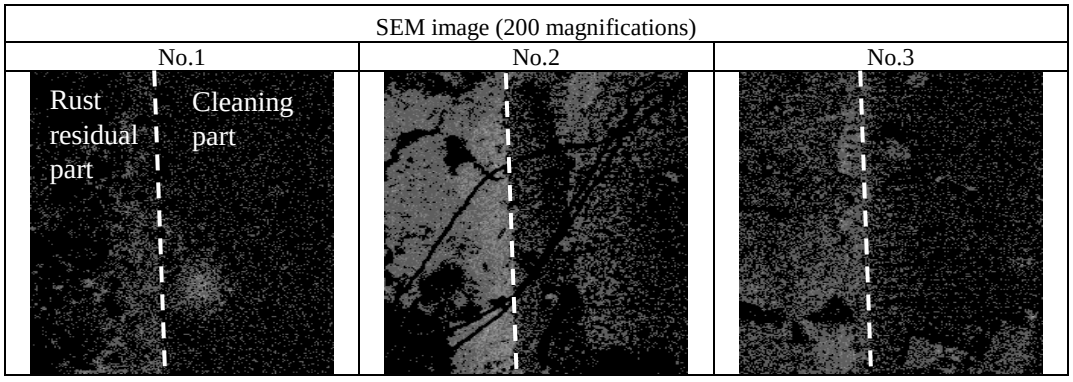

Figure 4. The result of steel surface analysis (chlorine molecular Cl).

Table 4. The weight percent ratio of Na and Cl in the specimen No.2.

	Rust part (%)	Cleaning part 1 (%)	Cleaning part 2 (%)
Na	15.95	0.31	0.10
Cl	10.19	0.07	0.05

Table 5. The weight percent ratio of O and Fe in the specimen No.2.

	Rust part (%)	Cleaning part 1 (%)	Cleaning part 2 (%)
O	15.58	4.83	5.62
Fe	52.3	88.0	74.6

3 CONCLUSION

Surface preparation using a laser has equal effect as blasting in the case of rust removal. Regarding the setting condition of laser in this study, in order to completely remove the rust, it is required a laser irradiation of about 5 times in the same range.

Based on the analysis result using the scanning electron microscope, when using a laser for surface preparation, not only the rust but also the salt is removable at the same time.

In this paper, the steel surface was in wet condition such as marine structures and steel structures under the rainy weather. In the case of blasting, it is difficult to perform the painting just after surface preparation because of difficulty of water removal. However, the construction time can be minimized because the laser cleaning is able to evaporate water.

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