Surface Preparation of Severe Corroded Steel Member by Laser Irradiation Combined with Pretreatment

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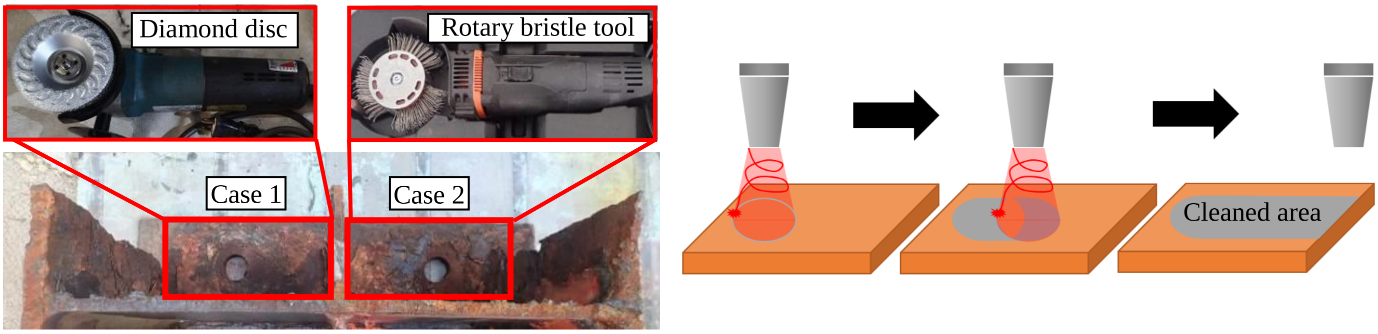
1. Introduction Traditional surface preparation for steel structure including abrasive blasting and chemical method, but both are difficult to reach desirable surface cleanliness. Laser cleaning has found successful applications in automotive, shipbuilding and artwork conservation, yet haven't applied in the construction field. The effects of laser beam including ablation and evaporation, have been expected to remove corrosion products and contaminations on the corroded surface completely.

A high power continuous wave (CW) laser was adopted in this study, to clean the surface of a steel member suffered from severe corrosion. Diamond disc grinder and rotary bristle tool were used as the pretreatment tools to remove layers of rust and painting on the surface before laser cleaning. The cleaning efficiency and surface conditions were analyzed after laser irradiation, to evaluate the effectiveness of different treatment combinations.

2. Specimen and surface treatment A severely corroded steel member removed from rock shed were used for surface treatment, the structure was exposed at coastal region of Kagoshima (Lat. 31°53′51″N, Long. 130°13′20″E) for 41 years. Fig.1 (a) shows two cleaning targets, surfaces with area of 0.03 m^2 and similar corrosion conditions were chosen. Before laser cleaning, diamond disc and rotary bristle tool were used as pretreatment to remove the outer rust layer for these two surfaces respectively, as shown in Fig.1 (a). CW laser beam with power of 3 kW is rotated by prism inside the laser machine and projected to the steel plate as a fixed diameter laser ring, then irradiate the whole steel plate surface with laser ring to remove corrosion products and contaminants on the surface, as shown in Fig.1 (b). The principle for laser irradiation is to remove any visible corrosion products on the surface in minimal treatment period. Diamond disc pretreatment combined with laser cleaning was defined as Case 1, and rotary bristle tool pretreatment combined with laser cleaning was defined as Case 2.

The processing period was logged by stopwatch to calculate efficiency of surface treatment cases. Salt residue was analyzed by SEM-EDX. Surface roughness and salinity also tested to verify the cleanliness.

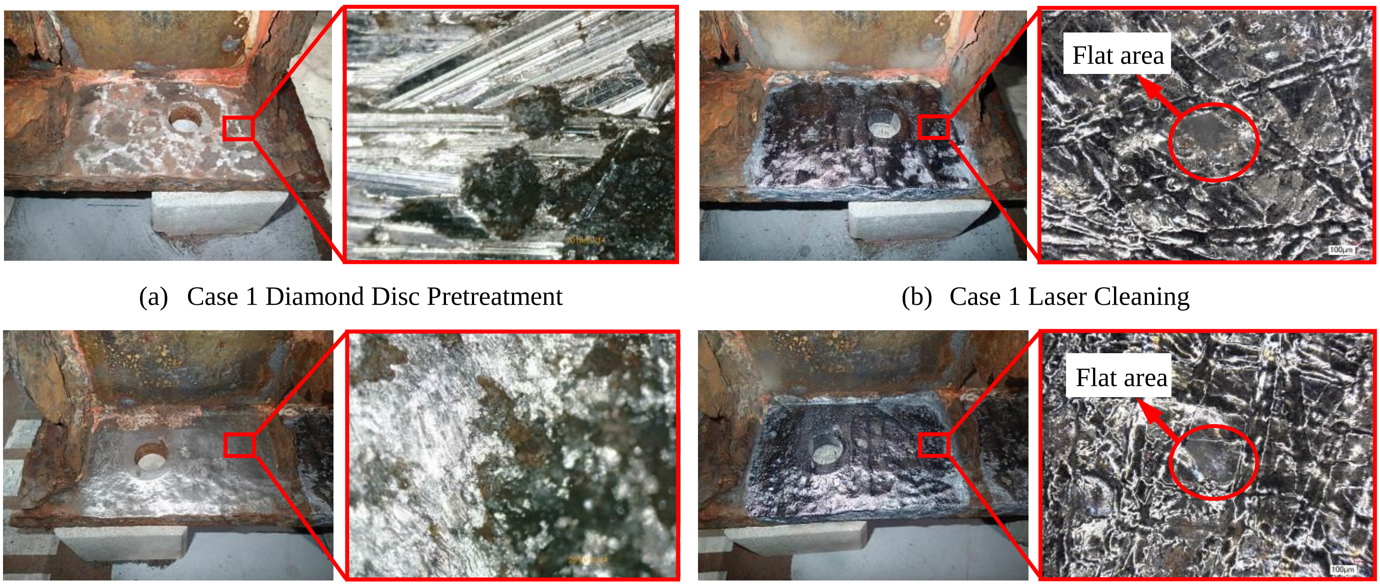


(a) Surface Treatment Specimen (b) Schematic Image of Laser Cleaning

Fig.1 Surface Treatment Specimen and Methods

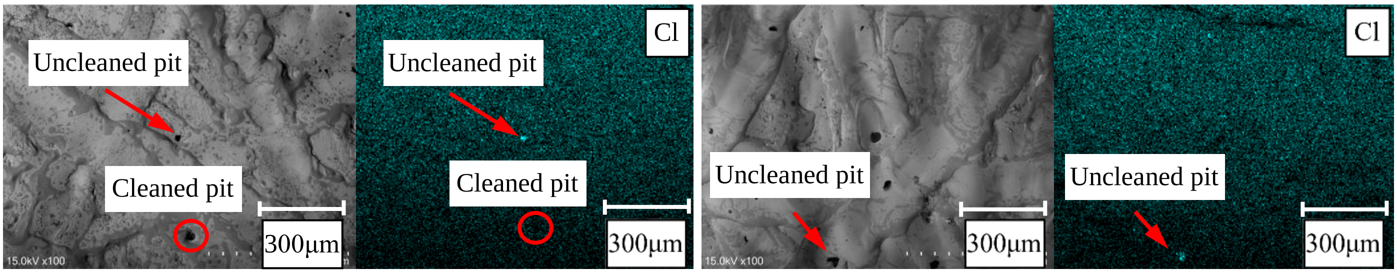
3. Test results Fig.2 shows the surface condition after treatments. For pretreatment using diamond disc grinder, there were corrosion products remained on the surface obviously. Large corrosion pits on the severely corroded surface causing irregularity appearance, and diamond disc grinder was managed to remove top rust layers only in consideration of avoiding damage on base metal. Therefore, corrosion products inside large pits still remained after Case 1 pretreatment. For area that had been ground, uncleaned small corrosion pits were observed in microscope photo, as shown in Fig.2 (a). The specimen surface after Case 1 laser irradiation presented in Fig.2 (b) showing a cleaning condition, corrosion products had been removed from the surface including some of the rust remained inside corrosion pits. Microscope photo presented clear intersected laser paths on the irradiated surface, while some areas showing flat appearance without laser path. The depths of corrosion pits on specimen surface were different according positions, hence the reason for flat area after laser cleaning could be unirradiated region or position under thick corrosion product. Fig.2 (c) shows the surface condition pretreated by rotary bristle tool. Most of corrosion products were removed from the surface, a relative cleaner surface appearance was achieved in comparison to Case 1. Rotary bristle tool has the advantage of clean corrosion products inside large corrosion pits, with little damage on the base metal. Therefore, pretreatment of Case 2 provided fewer corrosion products for laser cleaning, although untreated small corrosion pits still observed in the microscope photo. Surface condition after Case 2 laser irradiation shown in Fig.2 (d), a similar appearance with Case 1 was presented. From microscope photo taken in cleaned region, flat area without laser path was also observed. Although laser irradiation has the capability to remove most parts of corrosion products and contaminants on the surface, an area with thick rust layer or depth corrosion pits were suspected to remain contaminants after laser cleaning.

SEM-EDX analysis results shown in Fig.3 proved the existence of salt residue on the laser-cleaned surfaces of both cases. From results of Case 1 specimen shown in Fig.3 (a), a small pit located in flat area (marked with arrow) was found containing chlorine while another pit at laser path (circled in red) shows no evidence of chlorine. On the other hand, all of the pits observed in Case 2 specimen were located in laser path area, only one of the pits shown a few chlorine residues and the others present no evidence of chlorine. SEM-EDX analysis results indicated most of the salt residue can be cleaned under laser irradiation.



(a) Case 1 Diamond Disc Pretreatment
(b) Case 1 Laser Cleaning
(c) Case 2 Rotary Bristle Tool Pretreatment
(d) Case 2 Laser Cleaning

Fig.2 Microscope Photos of Treated Surfaces



(a) Case 1
(b) Case 2

Fig.3 SEM-EDX Analysis of Laser-cleaned Specimens

Table 1 Effectiveness of Different Treatment Combinations

Treatment combination	Speed (m^2/h)	Surface salinity (mg/m^2)	Surface roughness R_{ZJIS} (μm)
Case 1	0.136	92.0	23.7
Case 2	0.092	1.30	37.1

Table 1 shows the treatment speed, surface salinity and roughness after cleaning. Case 1 has higher treatment speed than Case 2 according to test results. Using rotary bristle tool cost more time during pretreatment, but a higher proportion of corrosion products were removed before laser irradiation. In consequence, surface salinity of Case 2 significantly lower than Case 1. Uncleaned large corrosion pits after diamond disc grinder treatment leaving thick corrosion products for laser irradiation, therefore salt below the corrosion products will remain. On the other hand, flat area as shown in Fig.2 (b) and (d) have probability to remain salt after laser irradiation. In case of recoating process, interval between surface preparation and coating have to be shortened to prevent surface corrosion, meanwhile salt residue will lead to coating failure. For the purpose of getting better surface cleanliness, additional laser irradiation is needed in Case 1 for further cleaning of salt residue. Surface roughness of Case 2 slightly higher than Case 1 due to cleaner surface conditions after rotary bristle tool pretreatment. Because thin rust layer allowing laser energy getting through and affect the base metal more significantly. Both cases result in a roughness satisfying the requirement for surface preparation.[1)]

4. Summary 1) Using rotary bristle tool to remove corrosion products previously result in better surface cleanliness after laser irradiation. 2) Pretreatment using diamond disc grinder improved treatment efficiency, but surface salinity is higher after laser irradiation. 3) Both treatment cases provide appropriate surface roughness for recoating. 4) Laser cleaning has the ability to remove contaminants inside corrosion pits.

Reference 1) Japan Road Association: Steel bridge anticorrosion manual, 2014.