EXPERIMENTAL STUDY ON THE CONTINUOUS WAVE LASER TREATMENT APPLIED TO CORRODED STEEL STRUCTURES

王, 啓迪

（様式２）

氏　　名　：王　啓迪

論 文 名： EXPERIMENTAL STUDY ON THE CONTINUOUS WAVE LASER TREATMENT APPLIED TO CORRODED STEEL STRUCTURES
（腐食した鋼構造物に対する高出力連続波レーザー処理の適用性に関する実験的研究）

区　　分　：甲

論 文 内 容 の 要 旨

Surface treatment is the necessary and key process in corrosion maintenance of steel structures before painting, and sufficient removal of rust and salt is important to ensure maintenance and coating quality. As the degree of corrosion increases, rust and salt removal of traditional surface treatment flow will be much less effective. Especially in cases of severe corrosion pits, the post-treatment will be repeated several times until the surface is visually cleaned. To obtain a sufficiently cleaned surface and carry out effective coating maintenance engineering, a new surface treatment flow is presented in this dissertation, which innovatively applies continuous wave laser (CWL) treatment technology as a pre-treatment method of abrasive blasting. CWL with high energy density can help efficiently remove the rust and salt that are difficult to remove in corrosion pits. On this basis, not only can raise the efficiency of the entire surface treatment process and improve the treatment effect of abrasive blasting, but also reduce the construction period and cost.

The primary objective of this dissertation is to evaluate the rust and salt removal capability of CWL as a pre-treatment method of abrasive blasting and to verify the feasibility and reliability of CWL in engineering applications. To evaluate the rust and salt removal capability, investigated and summarized various degrees of corrosion from common steel and weathering steel specimens and bridge components, summed up the shape of corrosion pits and surface treatment difficulties. Artificial pits specimens with different corrosion degrees were prepared for abrasive blasting and CWL surface treatment. A time-lapse-based test method named turning time test was proposed to evaluate the salt removal effect through the frequency and area rate of re-corrosion in corrosion pits. And a quantitative evaluation method based on photometric analysis was also verified by turning time test method. Through an engineering case attempt, the possibility of CWL treatment in wet conditions was also considered. The help of water vapor explosive effect on salt removal and the feasibility of CWL surface treatment in humid environments were verified. In addition, it is the first time to use CWL surface treatment to clean high-strength bolts and considered the axial force loss due to the thermal effects.

In Chapter 1, the background and purpose of this dissertation were proposed. Literature reviews relating to surface treatment and bolt cleaning were summarized. The organization of the dissertation was illustrated at the end.

In Chapter 2, the correlation between rust layer characteristics and corrosion depth after atmospheric exposure was discussed. The measurement was carried from the 4-year atmospheric exposed test specimens and severely corroded bridge components of ordinary steel bridges protected by coating in urban highways and weathering steel bridges in the mountain area. The study revealed the strong influence of the rain effects

on the rust layer thickness, also the relationship between the rust bud and the range of corrosion pit. The special shape of the corrosion pit after a long time of exposure was discussed and the difficulty of surface treatment was put forward.

In Chapter 3, the design and manufacture of artificial corrosion pits tests with different corrosion degrees were prepared for rust and salt removal evaluation. Electromagnetic film thickness meter, digital microscope and XRD were used to observe and count the rust layer in the artificial corrosion pit. The surface of the pre-treated specimens was cleaned by abrasive blasting and CWL. The turning time test method was proposed to measure the corrosion frequency and area of the cleaned surface. Through the result, the necessary cleaning rounds of blast and CWL under different corrosion degrees were proposed.

In Chapter 4, a quantitative evaluation method of CWL cleaning based on image analysis was introduced. Digital cameras were used to shoot the specimens cleaned by laser in different rounds. The color information of the corrosion pit area was captured by the software Photoshop 2022 to obtain the digital information based on the CIE LAB color space. The trend of color information in different cleaning stages was discussed and the corresponding relationship between color difference and cleanliness is determined. The quantitative evaluation standard based on image analysis and color analysis is proposed.

In Chapter 5, an engineering use of CWL cleaning was introduced. Treatment conditions of dry laser cleaning and wet laser cleaning of the drench, soak, and rinse methods are adopted, and SEM/EDX evaluates the cleanliness effect. The morphologies and chemical compositions of untreated and treated surfaces are analyzed using three-dimensional digital microscopy, laser confocal microscopy, and scanning electron microscopy–energy dispersive X-ray spectrometry. The feasibility of hand-held CWL for salt removal in engineering was verified and the mechanism of CWL surface treatment under wet and dry conditions was revealed.

In Chapter 6, the use of CWL treatment on high-strength bolts was attempted. Friction connection specimens with M22 high-strength bolts were prepared, and a fixed-angle CWL transmitter and rotating platform were used for high-strength bolt rotary cleaning. The change in the axial force and temperature of the bolts were real-time examined during the laser treatment based on the irradiation duration on the nut surface. The axial force loss of high-strength bolts after a different 3kW CWL treatment duration was fitted as calculation formulas. And the distribution of the bolt's temperature was stimulated by a FE model. The maximum irradiation duration of 3kW CWL on the M22 bolt was verified.

In Chapter 7, the work presented in this dissertation was summarized, and further research topics that emerged from this work were proposed.