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SURFACE AND MECHANICAL PROPERTIES OF CARBON STEEL AFFECTED BY ROTATING CONTINUOUS WAVE LASER TREATMENT

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論 文 名　：SURFACE AND MECHANICAL PROPERTIES OF CARBON STEEL AFFECTED BY ROTATING CONTINUOUS WAVE LASER TREATMENT
（回転連続波レーザーで素地調整した鋼材の表面と力学の特性に関する研究）

区　　分　：甲

論　文　内　容　の　要　旨

Laser surface treatment has found successful applications in various fields. Surface contaminants such as corrosion products, paint, and salt can be efficiently removed by laser cleaning. However, an appropriate laser-based cleaning technique for large size structures is still lacking. Although laser surface treatment has the potential to achieve better surface conditions, higher scanning speed and laser power are required to improve the treatment efficiency when targeting a large structure. A new method using high-power continuous-wave (CW) laser is proposed in this study as an alternative surface preparation technique for large steel structures. However, when using a high-power CW laser to clean a corroded structure, the laser beam will affect the base metal to a certain degree, owing to intense laser ablation effects and uncertainty in human operation. The major concerns of laser surface treatment are surface defects could result from laser irradiation, as long as oxide formation and microstructure modification on the steel surface. Thus, the durability and safety of steel structures could be affected by the high-power CW laser surface treatment.

The primary objective of this dissertation is to evaluate the influence of thermal effects result from rotating CW laser on the surface and mechanical properties of carbon steel. To confirm the feasibility of this CW laser treatment for steel structures, surface properties, including surface morphology, iron oxide formation, electrochemical properties of the laser-treated steel plate, and the mechanical properties of carbon steel after laser irradiation should be established. Any possible defects on the surface or mechanical properties could damage the durability of steel structures during service. The dissertation specially focused on three laser parameters, which were power density, interaction time and the exclusive feature of rotating CW laser: laser beam overlapping effects. The thermal effects of CW laser beam were established by modifying the temperature calculation method, and experimental analysis on surface and mechanical properties. Surface morphologies and defects induced by laser irradiation were evaluated, as well as the performance degradation of mechanical properties under various laser conditions was also investigated. Proper laser treatment conditions were proposed basing on the theoretical and experimental results.

In Chapter 1, background and purpose of this dissertation were proposed. Literature review relating surface treatment and laser technique were summarized. The organization of dissertation was illustrated at the end.

In Chapter 2, the newly developed rotating CW laser equipment for surface treatment of corroded steel structures was introduced, main laser processing parameters were selected for following test and application.

Then, a widely used temperature field calculation method for CW laser was adopted for modification, and the calculation method for peak temperature distribution along deepness direction in the steel material during laser irradiation was proposed. The modified peak temperature calculation method considered the overlapping effects of rotating CW laser beam, all the related parameters during laser processing were taken into the calculation. The surface morphologies and re-melted zone, heat-affected zone were observed in order to use as verification for the calculation method.

In Chapter 3, the surface properties and near-surface microstructure after laser irradiation were evaluated. The area suffered from more severe laser overlapping effects, and the average overlapping effects area were observed separately. Optical microscope and laser microscope were used for the surface morphologies and roughness inspection, SEM-EDX, XRD were adopted to observe the oxide layer on laser-treated steel surface. Relationship between laser processing parameters and the surface properties were established by comparing the test results referring to laser conditions. In addition, two cases that might be induced during the application of rotating CW laser in the construction field were also considered, to verify applicability of this new laser technique. Through the result, proper laser processing parameters were proposed.

In Chapter 4, the electrochemical properties of laser-treated steel plates were tested, including potential-time measurement, Potentiodynamic polarization test, and electrochemical impedance spectroscopy. The electrochemical test results were compared under different laser conditions, and associated with surface properties and modified microstructures. Changing corrosion properties and the iron oxide were further discussed in this chapter, to provide reference for following surface preparation procedure.

In Chapter 5, the tensile properties of steel coupon after laser irradiation were evaluated, together with the fractography after tensile test. The laser-treated steel coupon and unirradiated steel coupon were both tested under the identical monotonic tensile condition. The test results were evaluated in association with surface properties discussed in Chapter 3. The influence of laser thermal effects on mechanical properties of steel coupon was established.

Chapter 6 summarized the work presented in this dissertation, future research topics emerged from this work were also proposed.