博士論文審査結果の要旨

博士論文審査委員会

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論文題目	Corrosion Protection of Zinc Rich Paint Coating on Steels

〔論文審査の要旨〕

塗装による鉄鋼材料の防食は環境遮断に優れた防食手法として用いられているが、樹脂塗料の中に粉末として亜鉛粒子を含有したジンクリッチペイントが、処理工程の低コスト化、メンテナンスなどにおいて有利な防食技術として注目されている。しかし、ジンクリッチペイントの耐食性の詳細や、防食メカニズムについては充分に理解されているとは言えない。そこで、本論文ではジンクリッチペイントにより塗装した鋼板の腐食挙動を海水模擬環境において調査し、環境因子による腐食挙動の相違を整理することで防食挙動を詳細に検討した。論文の構成は７章で、緒言（第１章）、研究背景、論文サーベイ（第２章）、実験方法（第３章）、ジンクリッチペイントの腐食挙動（第４章）、腐食挙動に及ぼす塩濃度の影響（第５章）、表面観察および電気化学インピーダンス法の適用（第６章）、結論（第７章）で構成されている。ジンクリッチペイントを単なる塗料として塗装鋼板の塗膜下腐食を調べるに留まらず、環境因子の系統的整理、亜鉛粒子の存在状態、亜鉛粒子含有量の違いによる防食効果を詳細に検討した点は、本論文の特徴であり、既存の論文では扱われていない新規性の高い成果である。本論文における亜鉛粒子による犠牲陽極作用、樹脂成分の環境遮断効果、腐食生成物の生成による欠陥防御の検討は、鋼材寿命予測や実用材料研究の観点においても重要な知見である。

平成 25 年 9 月 27 日に学位論文を提出し、平成 25 年 11 月 6 日 18 時から学外審査委員１名を含む５名の審査委員により予備審査が実施された。学位論文内容の発表と質疑応答および審査が行われた。さらなる参考文献の引用および文献との比較・検討、発表内容の論文への記載や表現方法の充実など、最終審査を想定した際の今後の計画への助言をいただいたうえで、「合格」の評価ならびに最終試験へ進むことが認められた。平成 25 年１月９日に学位論文を再提出し、平成 25 年２月 25 日 16 時から同審査委員で構成される博士論文審査委員会により最終試験が実施され、公聴会の形式で学位論文内容の発表と質疑応答および審査が行われた。審査委員からは塗料の構造や耐候性、機械的特性、電位やインピーダンス挙動解析など、基礎的、学術的、科学的助言をいただいた。さらに本博士論文研究の社会的貢献、実用課題まで議論が展開し、亜鉛粒子の適正化や環境安定性評価などへの挑戦的意義と新規性への高い評価がなされた。学位審査評価シートにおいてもすべての審査委員、すべての項目において高評価を受けた。博士論文として充分な価値があることが認められ、審査委員全員一致で「合格」の判定となった。

（様式第６号）

論　文　要　旨

2014年　01月　09日

※報告番号	甲　第　153　号	氏　名	Azizul Helmi Bin Sofian

主論文題名

Corrosion Protection of Zinc Rich Paint Coating on Steels

内容の要旨

Special attention has been paid since 1950s to improve and enhance the application of means of corrosion protection of metals as one of the methods for saving natural resources and increasing durability of machines, building structures and other equipment. Coating is one of the promising methods that can be applied. At the same time, insufficient attention has been given to the mechanism aspects of evaluating the efficiency of the protective coating. Recognizing the lack of information on corrosion mechanism, we are motivated to investigate the anti-corrosive behavior of zinc rich paints (ZRP) using the commercial paints in the market. The research work was structured by coating metallic substrate with two different kind of ZRP with zinc content of 74 wt. % and 96 wt.%. Based on this coated samples, three main studies; specifically on corrosion performance in corrosive agent, comparison in different concentration of corrosive agents and evaluation on protective coating using electrochemical impedance spectroscopy (EIS).

1. Zinc rich paints (ZRP) are one of the most effective coatings used to protect steel from corrosion and they have been studied under severe environment like sea water, marine and industrial environments. A major problem in classic solvent-based paint in the emission of volatile organic compounds (VOC), which contribute to atmospheric pollution. In this work, metal substrate was coated with various thicknesses of coatings of ZRP and the cross-section of the coating was observed by means of scanning electron microscopy (SEM), electrochemical behaviors were compared using potential corrosion measurement system and open circuit measurement. It was verified that both coatings with 74 wt.% and 96 wt.% showed good corrosion resistance mainly due to the cathodic protection and barrier effect, respectively. However, for single layer coating of 74 wt.% Zn, does not offer

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good corrosion protection.Based on results from morphology characteristics of ZRP at initial stage, a probable current density inhibition model was proposed.

2. The second study deals on the evaluation of coated samples in two different concentrations of corrosive agents, 0.5 and 1.0 M NaCl solution. The electrochemical behavior was investigated based on polarization measurement, open circuit potential and electrochemical impedance spectroscopy (EIS). To confirm our coating is stable in thickness, SEM observation on the cross-section was conducted. The performance of the coating with different coating thickness varied particularly in coating system of 74 wt.%-ZRP. Using Stean-Greary equation, the polarization resistance Rp was determined from the Tafel plots and we also calculate the corrosion rate V_{corr} in millimeter per year). In 0.5 M NaCl solution, coating system with 96%-5 shows the lowest corrosion rate. Coating systems with 74%-ZRP do performed well, and remarkably sample with 5 layers show the best performance in that system. There was a correlation between zinc content and corrosion resistance performance. Film thickness of the coated samples with 74% probably affected the electrochemical properties and the corrosion resistance performance.

3. The third study evaluates the corrosion performance of the coating systems by using electrochemical impedance spectroscopy (EIS). EIS was used to monitor, up to 7 weeks, the degradation kinetics of three different thicknesses under cathodic protection in NaCl solution were conducted. EIS in the 100kHz-1mHz frequency range was employed as the main electrochemical technique to study the corrosion behavior of ZRP. The EIS results obtained at the open circuit corrosion potential have been interpreted using a model associate the impedance of parcel to particle contact to account for increasing resistance between zinc particles with immersion time, in addition to the impedance due to zinc surface oxide layer and the resistivity of the binder. From the results, we conclude that the loss of cathodic protection is due to the decreases of the zinc and metallic substrate area ratio due to zinc corrosion and the loss of electric contact between Zn to Zn particles, and this can be confirmed from SEM observation. Coated sample with 74 wt.%-ZRP shows severe corroded zinc particles, while 96 wt.% sample relatively still maintain the spherical shape of zinc particle. Even when cathodic protection effect by Zn particle became weak, the metallic substrate is still protected against corrosion by the barrier effect and reinforced by zinc corrosion products.

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