INFORMATION THESIS

Title: Research on fabricating magnetite electrode used as anode in the impressed current cathodic protection system to preventing corrosion of steel structure in seawater.

Major: Materials forming technology

Code: 62520405

PhD.student: Nguyen Trong Hiep

Advisors: PhD. Luu Phuong Minh

PhD. Nguyen Hong Du

University: University of Technology - Vietnam National University-HCMC.

Contents:

1. Overview of the cathodic protection method against corrosion in seawater.
2. Overview of the material system and method for fabricating the anode in the impressed current cathodic protection system (ICCPs).
3. Select process and technology to fabricate anode by magnetite powder.
4. Identify and optimize the impact of technological parameters to the compressive strength of magnetite anode.
5. Fabricate magnetite anodes meet the electrochemical properties and compressive strength.
6. Evaluate and test magnetite anode in laboratory and real condition.

Main results:

Identified, optimized component materials and technological parameters, fabricated anode by magnetite material with good electrochemical properties and mechanical properties which meets the requirements of fabricating anode in the ICCPs, against corrosion marine work. The results of testing in laboratory and marine environment showed that anode meets cathodic protection standards in seawater.

Sciential and practical contribution of the thesis:

1. Applicated powder metallurgy technology to fabricate successfully electrode by magnetite (Fe_3O_4) with electrical characteristics of the high anode current density and low material consumption that meet requirement of the inert anodes used in the ICCPs in Vietnam conditions.

2. Based on survey electrochemical properties of anode by material system of powder magnetite-lead, with ratio of lead powder from 1 to 5%, established relationships influence of 3 main technological parameters: the ratio of lead powder X_1 (%), the compressive pressure X_2 (ton/cm^2) and the sintered temperature X_3 ($^\circ$C) to compressive strength of the anode Y (MPa):

$$Y = -27{,}99925 + 0{,}5485X_1 + 6{,}98X_2 + 0{,}06354X_3 - 0{,}00118X_2X_3 - 0{,}06475X_1^2 - 0{,}865X_2^2 - 0{,}0000322X_3^2$$

Results of the optimization of parameters to achieve maximum compressive strength, with the cylinder samples with a diameter D = 20 x h (height) = 10 (mm):

- Ratio of lead powder : 4.2358%.
- Compressive pressure : 3.4043 ton/cm^2.
- Sintered temperature : 924.29°C.
- Compressive strength : 14.4072 MPa.

The test evaluated the results with the optimal parameters, average compressive strength: 13.70 MPa.

3. Experimental evaluation of the influence of lead to reliability shows that lead not affect the durability, proposed not use of lead in the ingredients, because lead is harmful elements for health and the environment. Experimental results show that the average compressive strength of anode not using lead that reaches 13.52 MPa and other electrochemical properties are still ensured: anodic current density reached 1000 A/m^2, rate of material consumption 0,4 x 10^{-3}kg/A.year in 3.5% NaCl environment. In the condition of using is not more stressed like the anode, this durability completely meets the requirements of practical use.

4. Determined parameters and process of technology suitable for manufacturing the magnetite anode used in the ICCPs, the technological parameters applied to the anode cylinder circle diameter D = 50 x h (height) = 10 (mm) as follows:

1. Composition of material : Fe_3O_4, PVA adhesive.
2. Method of mixing : Eccentricity.
3. Time of mixing : 3.5 hours.
4. Speed of mixing : 25 r/min.
5. Method of press : Hydraulic press, isotropic.
6. Compressive pressure : 3.4 ton/cm^2.
7. Press speed : 1 mm/s.
8. Sintered environmental : Argon gas, > 99.999%, 1 atm.
9. Sintered temperature : 950°C.
10. Sintered time : 4 hours.
11. Rate of heat : 200°C/h.
12. Rate of cool : 100°C/h.

5. Fabricated 30 anodes with simple structure, small size, convenient for transport, installation and operation. External dimensions of the magnetite anode is 45 mm (height) x 80 mm (diameter), the working surface area of anode is ~20 cm^2, current intensity reaches 2A. Magnetite anodes with high current density, low consumption rate that allow to limit number of necessary anodes. The properties of magnetite anode as follows:

- Composition of material : Fe_3O_4.
- Density : 4.35 ÷ 4.67 g/cm^3.
- Average compressive strength : 13.52 MPa.
- Current density : 1000 A/m^2.

- Consumption rate : $0.4x10^{-3}$ kg/A.year (in the 3.5% NaCl environment).

6. Tested anode in the ICCPs for a steel hull in seawater conditions, the good results at the first step of testing: The potential of the hull reduced from -156 mV to -259 mV, the *instant off potential* measured at the survey positions comparing to the Ag/AgCl electrode is relatively uniform from -913 mV to -920 mV to meet the requirements of cathodic protection. Maximum current density reaches 764 A/m^2.

7. Results of fabricating, testing in the lab and tested in seawater conditions show that magnetite anode meets technical requirements, using material with low price, high safety, suitable technology to match in Vietnam conditions; can replace imported products, economic value and contribute actively in providing supplies to preventing corrosion in marine environments.

New points:

1. Using the main material composition is magnetite powder (Fe_3O_4), not use of lead and other elements that may harmful to health and environment during manufacture and use process.

2. Calculated, controlled the sintered environment to ensure mixing magnetite after sintering, to ensure the product property is electrode used in the impressed current cathodic protection system (ICCPs).

3. Determine and optimize parameters of technology, ensure that anodic with the good electrochemical property that is high anodic current density, low material consumption and suitable mechanical properties, to meet requirements for use in reality.

Future developments:

1. Continue to improve on manufacturing technology process to apply for production, ensuring the stability of quality of anode product used in ICCP systems, against corrosion in seawater.

2. Continue to research on shaping technology to make the anode with many different dimensions and shapes that are suitable for various types of structures should to be protected against corrosion in marine environment.

3. Research on applicability magnetite anode in the other electrochemical fields, such as: industrial waste-water treatment, environment, desalination...

4. Research on using domestic materials or steel mill scale of the metallurgical plant... as raw materials to produce anode./.

Advisors		**PhD student**
PhD. Lưu Phương Minh	**PhD. Nguyen Hong Du**	**Nguyen Trong Hiep**