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Electrochemical Experimental Analysis of Different Coatings

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

Aims: This paper investigates four different metallic coatings of 17-4PH stainless steel and tests them in seawater as a means of preventing seawater corrosion of turbine upper stage blades..

Study Design: The self-corrosion current densities of the different specimens in the synthetic seawater solution were measured using open circuit, polarization curves, and electrochemical AC impedance spectra.

Place and Duration of Study: Department Between July 10, 2023, and August 10, 2023, the Laboratory of the School of Mechanics, North China University of Water Resources and Hydropower (NUWRH).

Methodology: For the working condition of turbine final blades, four different metal coatings based on 17-4PH stainless steel are investigated to simulate the working condition of turbine blades, and electrochemical tests are carried out on the four different specimens in the test solution of synthesized seawater solution. The self-corrosion current densities of the different specimens in the synthetic seawater solution were measured using open circuit, polarization curves, and electrochemical AC impedance spectra.

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Results: The results show that the AHP-coated 17- 4PH stainless steel specimens have the lowest self-corrosion current density (color) in the synthetic seawater solution.
Conclusion: Non-invasive This indicates that the corrosion rate of AHP coatings in synthetic seawater solutions is slower than that of TW-7 coatings, sprayed stainless steels, and other stainless steels in the same conditions.

Keywords: Metal coating; electrochemistry; synthetic seawater; corrosion resistance.

1. INTRODUCTION

With the continuous development of economic globalization, humanity's exploration and research in the marine field have reached an unprecedented level [1]. Our country also follows the trend of the times, and with it comes the development and utilization of marine resources, which not only brings abundant resources to our country, but also further gives full play to our marine development strategy, ensures the security of our marine territories [2], and pushes forward the construction and development of a strong country based on the sea. Most of the equipment currently in use is based on metal, so when metal equipment is exposed to harsh environments for an extended period, it will inevitably suffer from different degrees of wear and corrosion [3]. One of the most effective ways to improve the corrosion resistance of metals is to treat the substrate [4]. One of the most important and influential surface treatment methods is to protect the surface of the substrate with a coating layer [5]. In recent years, scientists at home and abroad have conducted a lot of research and experiments on the corrosion and protection of metals [6]. Up to now, the current methods of corrosion protection of metals include: coating protection, changing the structure of the metal, electrochemical protection, surface treatment of the metal, media treatment, corrosion inhibitor protection, temperature protection and maintenance [7]. Individually or in combination, these methods can provide adequate protection against corrosion and thus reduce the risk to the metal. However, in practice, the most suitable method of protection should be selected on a case-by-case basis. In the present review, the main focus of this paper is to analyze the feasibility of electrochemical protection of metal coatings used for the protection of turbine upper-stage blades by simulating electrochemical tests in a synthetic seawater environment [8].

2. MATERIALS AND METHODS

The material used in the experiment is steel [9]. 17-4PH stainless steel is a commonly used low carbon steel, the yield strength is generally between 725-1180MPa, with high strength and corrosion resistance, good welding performance and processing performance, widely used in construction, machinery manufacturing, highways and bridges, etc [10]. Moreover, its chemical composition contains carbon, silicon and manganese, Sulfur, phosphorus, etc [11]. The specific composition is shown in Table 1.

The TW-7 coatings, AHP coatings and sandblasted SERMETEL coatings are produced by applying a high temperature resistant topcoat consisting of silicone, high temperature resistant pigmented fillers, additives and organic solvents. Main Properties: Good heat resistance up to 200°C for a long period; good adhesion; moisture resistance, Oil-resistant performance; good weather resistance; can be directly constructed on high-temperature substrates at 200℃. Used in boilers [12]. It is used on steel surfaces where the temperature of engine casing, exhaust pipe, chimney, oven and other high-temperature equipments and pipelines is less than 200℃ [13]. According to the technical standard of the inorganic phosphate coating layer, the production process is based on 17-4PH stainless steel [13].

Material leakage in the ambient temperature of 20-40 ℃, its relative humidity control for 40% - 70%. Detailed operation is as follows:

(1) Sandblasting. Test forged samples with 40 mesh white corundum sand, sandblast the samples and then use compressed air to blow away the dust on the outside of the substrate and abrade the material simultaneously. When sandblasting a flat surface, ensure the spraying angle is about 65°~75°, and keep a distance of 250-280mm between the nozzle and the workpiece when spraying at right angles.

Distance. The process should keep the environment clean to avoid contamination [15].

(2) Bottom slurry mixing and spraying. Adopt mechanical mixer to mix the slurry for three hours, filter and remove impurities with 150-mesh filter to ensure that the slurry is uniform and non-layered, as well as precipitation and shelf-life slurry [16]. Spraying two times in total to ensure that the spraying is sufficient and the interval between each spraying is 20 minutes to ensure that the specimen is completely dry before proceeding Spraying.

(3) Curing and shot peening of the substrate base. After spraying, the samples are cured in a heat treatment oven [17]. The performance parameters were: hold at 200°C for 70 minutes, then heat to 380°C and hold for 70 minutes. The air in the furnace was cooled to room temperature [18]. Spray the bottom Layer with granules after curing using a spray pressure of 0.4-0.5 MPa. At the same time, turn on the compressed air and release it for 10-15 minutes. Check the surface for compressed air [18]. External and shot peening can only be carried out without water.

(4) Coatings are sprayed and cured. Hold at 100°C for 50 min, then increase the temperature to 400°C for 50 min and cool to room temperature in a heat treatment oven. The curing procedure was repeated. In total, two coats were applied [19].

Make sure that the spraying is sufficient and that the interval between each spraying is 20 minutes to ensure that the specimen is dehydrated before spraying.

The instrument used in this experiment is an electrochemical workstation, as shown in Fig. 1.

In this experiment, four different coatings were tested on an electrochemical workstation with a synthetic seawater solution at 23±2°C as the electrolyte, using a three-electrode system with saturated calomel as the reference electrode, platinum sheet as the counter electrode, and the sample as the working electrode. The open-circuit potential was used as the measurement potential, and the impedance response characteristics were tested in the frequency range of 0.01-100 kHz. The polarization curves were measured in the potential range of ±0.5 V open-circuit potential, and the scanning rate of 0.5 mV was used to compare the electrochemical impedance response of the coatings before and after the experiments.

2.1 Electrochemical Experiment Results and Analysis

Fig. 2 shows the open-circuit potentials of the four samples in synthetic seawater, with values ranging from -0.77V to -0.67V. The sandblasted SERMETEL coating sample has the largest open-circuit potential, while the TW-7 sample has the smallest open-circuit potential. The composition of the synthesized seawater is shown in Table 2.

Table 1. Composition of experimental materials (%)

C	Si	Mn	S	P	(sth. or sb) else
≤0.22	≤0.35	≤1.40	≤0.045	≤0.045	Fe

Fig. 1. Electrochemical workstation

Table 2. Synthetic seawater components and their concentrations

individual parts making up a compound	common salt	magnesium chloride	magnesium sulfate	calcium chloride	dicalcium phosphate	sodium bicarbonate	sodium bromide
concentration	26.5g/L	2.4g/L	3.3 g/L	1.1 g/L	0.73 g/L	0.2 g/L	0.28 g/L

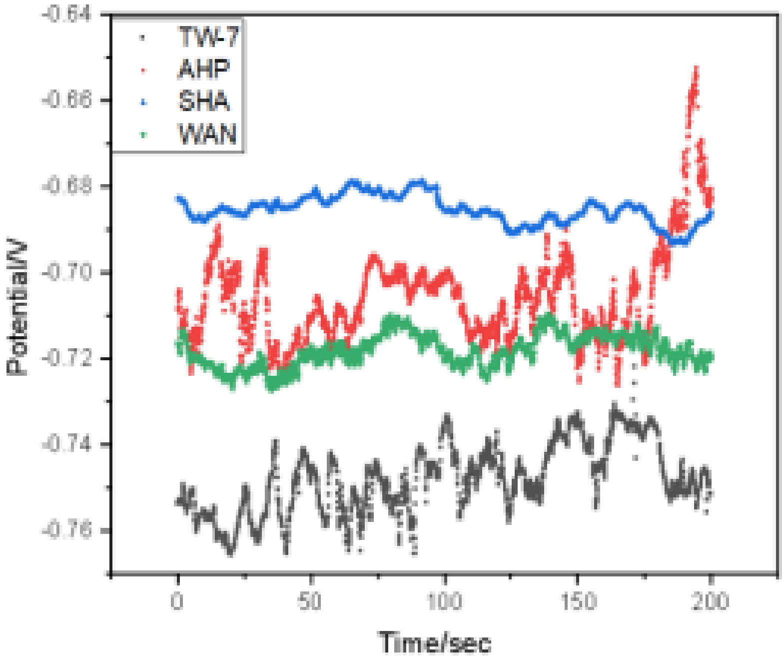

Fig. 2. Open-circuit potentials of four specimens in synthetic seawater

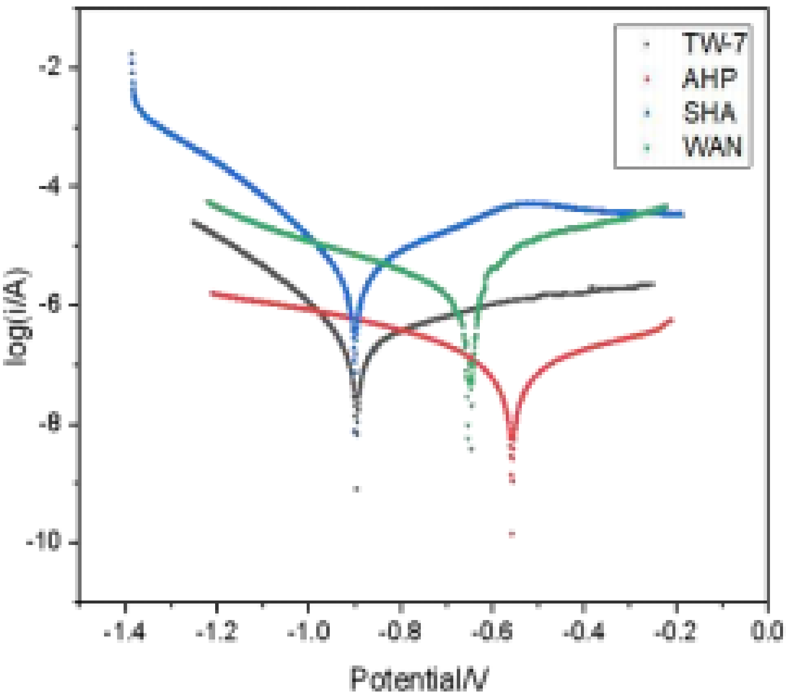

Fig. 3. Polarization curves of four specimens in synthetic seawater

Table 3. Polarization curve fit data

Specimen number	Self-corrosion potential score (V)	Self-corrosion current densityscore (A/cm2)
TW-7	-0.895	2.225 x 10-7
AHP	-0.557	5.961 x 10-8
Sandblasted SERMETEL coatings	-0.900	3.169 x 10-6
Shot Peening SERMETEL Coatings	-0.646	3.989 x 10-7

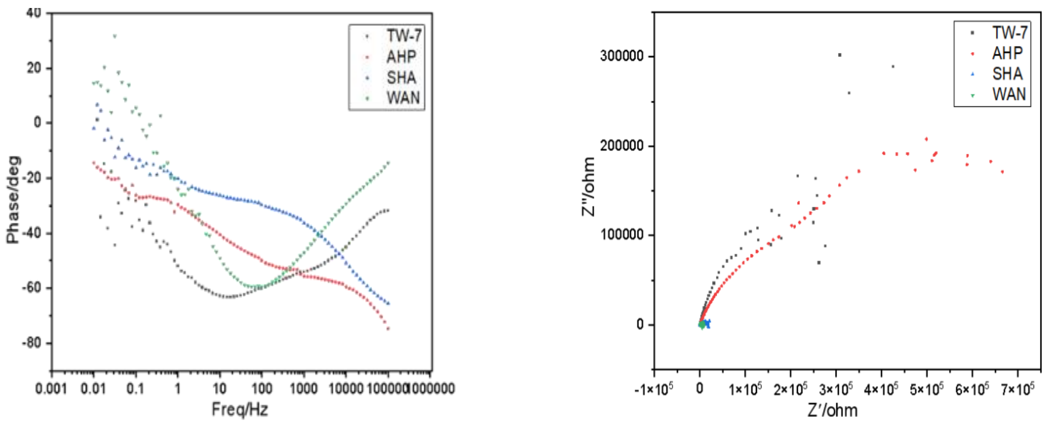

Fig. 4. AC impedance spectra (Bode plot) and AC impedance spectra (Nyquist plot) of four specimens in synthetic seawater solution

Table 4. AC impedance fitting data

Specimen number	Rs	C	Rp
TW-7	301.4	4.021 x 10-7	3.706×105
AHP	1424	2.941 x 10-8	4.536 x 105
Sandblasted SERMETEL coatings	1271	1.353 x 10-6	1.16 x 104
Shot Peening SERMETEL Coatings	56.89	2.362 x 10-6	6.646 x 103

Fig. 3 shows the polarization curves of the four specimens, in which it can be seen that the four specimens have more obvious passivation characteristics. Table 3 shows the self-corrosion potential and self-corrosion current density obtained by fitting the polarization curves. The level of self-corrosion potential represents the ease of corrosion, the higher the self-corrosion potential is, the less likely that galvanic corrosion will occur, and the lower it is, the more likely that galvanic corrosion will occur. The AHP coating has the highest self-corrosion potential and the lowest self-corrosion potential at the same time, which indicates that the AHP coating is the least prone to galvanic corrosion. Once corrosion occurs, the corrosion rate is lower than the rest of the specimens. The sandblasted specimens have the lowest self-corrosion potential and the highest self-corrosion potential of the self-corrosion current density, which indicates that the sandblasted specimen has the worst corrosion resistance among these four specimens.

Fig. 4 shows the Bode and Nyquist plots of the AC impedance of the four specimens, respectively. Because of the poor conductivity of the inorganic phosphate coatings, the impedance spectra are scattered at low frequencies, and the AC impedance was fitted to an R(CR) type circuit. The fitted data are shown in Table 4. The AHP coating has the most considerable polarization resistance value, consistent with the polarization curve results.

3. CONCLUSION

The AHP-coated 17-4PH stainless steel samples all have the lowest self-corrosion current density (icorr) in synthetic seawater solutions, which indicates that AHP coatings corrode slower in synthetic seawater solutions than TW-7, shot peened SERMETEL, and sandblasted SERMETEL in the same conditions Layer.

CONSENT

All authors declare that 'written informed consent was obtained from the patient (or other approved parties) for publication of this case report and accompanying images. A copy of the written consent is available for review by the Editorial office/Chief Editor/Editorial Board members of this journal.

ETHICAL APPROVAL

All authors at this moment declare that all experiments have been examined and approved by the appropriate ethics committee and have therefore been performed following the ethical standards laid down in the 1964 Declaration of Helsinki.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Zhang RG, Yang H, Liang DD, et al. Research progress on abrasive properties of nitride coatings in seawater environments, corrosion and protection.2024,45(03):53-60.
2. Tang Z, Gao J, Xu Z, et al. Effect of Laser Shock Peening on the Fatigue Life of 1Cr12Ni3Mo2VN Steel for Steam Turbine Blades. 2023;13(9).
3. Li Maomao, Wang Xiaolan, Qin Xiumin, et al. Research progress of laser cladding coatings for seawater pipelines of ships. Modern Coatings and Painting. 2023;26(10):29-34.
4. Zhu Xiangrong. Progress of Long-cycle seawater corrosion tests on metals and coating layer materials. Science, Technology and Engineering. 2003;(05):508-510.
5. AMP. Advances in anti-corrosion polymeric and paint coatings on metals: Preparation, adhesion, characterization and application. Metals. 2022;12(7):1216-1216.
6. Yang S, Gao S, Xue W, et al. Oxidation and hot corrosion behaviors of NiAlTa protective material for turbine single crystal blade tips. 2024;230:111899-.
7. Hui W, Junhuai X, Xiaosheng D et al. A self-healing polyurethane-based composite coating with high strength and anti-corrosion properties for metal protection. Composites Part B. 2021; 225
8. Wang Chuanbin, Li Xiuyi, Xu Zhigang, et al. Research progress on protective coatings for metal pipelines serving in marine environment. Surface Technology. 2023;52(12):225-248. DOI:10.16490/j.cnki.issn.1001-3660.2023.12.020.
9. Shi L, Chen D, Qi T. Analysis of seimens Class F Gas Turbine Protection System, F; 2016.
10. Hu P, Meng Q, Fan W, et al. Vibration characteristics and life prediction of last stage blade in steam turbine Based on wet steam model. 2024;159:108127-
11. Balaso FB, Jagtap HP. Failure analysis steam turbine in sugar factory thermal power plant: A Review. 2024; 1285(1).
12. Artyukhov DI, IAD, FSS et al. Use of photovoltaic converters in electrochemical protection systems for underground pipelines. 2020;1652(1):012030.
13. Liang Tianhao, Yang Shuo, Fan Keke. Intelligent "coat" for metal materials against acid rain corrosion: improvement of traditional metal coatings. China Science and Technology Education. 2021;(02):26-27.
14. Redondo FL, Villar MA, Ciolino AE, et al. Development and characterisation of block copolymer/bioactive glass and block copolymer/TCP composite coatings obtained by EPD. 2024;362:136159.
15. Bao P, Li H, Chen Y, et al. The GO composite coatings for enhancing interfacial interaction performance and desensitization of CL-20. 2024;316: 128968.
16. Hasan JA, Husein KSM, Kamil AS, et al. The effective and sustainable application of a green amino acid-based corrosion Inhibitor for Cu metal. 2023;7: 100316.
17. RAD, YAVM, AIG, et al. Guanidine-containing alkyl-substituted oligomer as a metal corrosion inhibitor. 2023;58(5):579-84.
18. Abou EA, MME, FSD et al. Recyclization of expired megavit zinc (MZ) drug as metallic corrosion inhibitor for copper

alloy C10100 in nitric acid solution. 2021;7(2).

19. Maria LM. Nanocomposite coatings for anti-corrosion properties of metallic substrates. Materials (Basel, Switzerland). 2023;16(14).

20. Li Wei, Li Taijiang, Wang Shaodong, et al. Experimental study on repairing and protecting water corrosion damage of turbine final stage dynamic blade. Chinese. 2011;40(01):40-4

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