Study on the corrosion and wear resistance of SERMETEL coatings in harsh environments

Abstract:

Q235 steel with good toughness and castability, easy to stamp and weld as a substrate, SERMETEL water-based high-temperature coatings for the coating, using a part of the first coating primer coating coated with closed coatings shot blasting method coated in the surface after surface cleaning of 17-4PH stainless steel surfaces, and the other part of the coating primer coatings to be dry and then coated with closed coatings after the sandblasting process. The service performance of the coatings was tested in single condition tests such as dry hot air test, neutral salt spray test and sand abrasion test as well as heat/synthetic seawater salt spray/high humidity cycle test. The results of the dry hot air test show that the SERMETEL coating is less thermally aggressive than the sandblasted SERMETEL coating and that neither coating can withstand high temperatures for extended periods of time. After 3000 hours of neutral salt spray testing, the corrosion of the coatings became progressively worse. The coating is heavily corroded at the fork. The abrasion resistance of the SERMETEL coating and the sandblasted SERMETEL coating were 13.29 L/μm and 10.45 L/μm, respectively. The results of heat resistance/synthetic sea salt spray/high humidity cycling test for the two coatings under composite conditions show that after the compound alternating effects of sea salt spray, high temperature and high humidity, the two coatings did not show corrosion expansion or peeling off phenomenon at the scratching point. It shows that the two coatings have high corrosion resistance to seawater salt spray, high temperature and high humidity under composite cycling conditions.

Keywords:stainless steel; coatings; harsh environments; wear and corrosion resistance

1. Introduction

Metal materials are increasingly used in harsh environments on engineering equipment, applied in high temperature, high humidity, high corrosion environment of metal workpieces often occur serious corrosion, affecting the operation and use of the entire engineering equipment[10]. Compared with the ambient environment, high temperature oxidation environment will cause more rapid oxidation and corrosion of metal materials, so that the comprehensive mechanical properties of metal workpieces decline rapidly. Considering the corrosion hazards of metal materials in the ambient environment and high-temperature oxidizing environment, for the application of special areas of the workpiece should be from the ambient environment corrosion environment to high-temperature oxidizing corrosive environment in the overall corrosion protection[11]. In practical applications, if not for high strength steel workpiece surface protection treatment, high strength steel workpiece will be in service environment will be serious corrosion, fatigue performance has decreased significantly, shorten the fatigue resistance and reliability requirements of the workpiece of the service life of the workpiece is high, so high strength steel must be appropriate surface protection treatment to be able to play its performance in the actual environment better[7]. At present, the surface protection technology of the metal substrate is mainly electroplating, thermal spraying carbide, enamel coating, anti-corrosion coatings[9]. Water-based aluminum-containing phosphate anti-corrosion coatings also known as metal ceramic anti-corrosion coatings, where ceramic refers to the coating binder for the phosphate ceramics, metal refers to the aluminum powder filler[12]. Water-based aluminum-containing phosphate anti-corrosion coatings sprayed onto the surface of the metal substrate and cured to form a metal ceramic coating, the coating can be steel and titanium alloys and other metals in the high-temperature environment to provide corrosion protection, able to withstand the neutral salt spray test 1000h as well as in the high temperature oxidation of 600 ℃ environment for the complete antioxidant, can be applied to aerospace and other areas of metal corrosion protection[14]. Phosphate coatings because of its low cost of raw materials, high temperature performance and other characteristics of the coating field has attracted the attention of a wide range of scientific and technological workers, inorganic phosphate binder as the main component of the coating in a variety of fields of surface protection treatment has been in-depth research and wide range of applications, with a broad market outlook[15]. In this paper, the main anti-corrosion mechanism of waterborne aluminum-containing phosphate anticorrosion coatings for corrosive media shielding and chemical passivation, when chromium-containing primer coatings in the formation of porous aluminum-containing phosphate coatings sprayed onto the surface of the substrate, porous coatings can be avoided because of the coating and the metal substrate between the coefficient of expansion of the different coatings caused by the surface of the substrate from the shedding, and at the same time, chromium passivation of chromium in the primer paint will be the surface of the metal substrate passivated to form the passivation of the membrane; topcoat coatings after curing[16]. At the same time, the chromium passivator in the primer coating passivates the surface of the metal substrate, forming a passivation film; the topcoat will form a layer of continuous dense aluminum-containing coating on the surface of the primer after curing, and the topcoat effectively seals off the pores of the primer coating, forming a dense aluminum-containing phosphate protective coating on the surface of the high-strength steel together with the primer coating[17]. For SERMETEL water-based high-temperature coatings were dry hot air test, heat/synthetic seawater salt spray/high humidity cycling test, neutral salt spray test, wear resistance test, to make up for the SERMETEL water-based high-temperature coatings in the corrosion and abrasion performance of the relevant research, for the application of such a wide range of phosphate coatings, can be prepared for its application in industry, to provide certain guidance and reference, is of great significance. It is of great significance to provide some guidance and reference for the preparation and application of phosphate coatings in industry for such a wide range of applications[19].

2. Experimental

2.1 Experimental materials

The material used in the experiment is Q235B steel.Q235B steel is a commonly used low carbon steel, the yield strength is generally between 235-245MPa, with high strength and corrosion resistance, good welding performance and processing performance, widely used in construction, machinery manufacturing, highways and bridges and other fields, its chemical composition contains carbon, silicon, manganese, sulfur, phosphorus, etc., the specific composition is shown in the table below:

Table 1. Composition of experimental materials (%)

C	Si	Mn	S	P	Other
≤0.22	≤0.35	≤1.40	≤0.045	≤0.045	Fe

SERMETEL coating is made of silicone, high temperature pigmented fillers, additives and organic solvents, etc. High temperature resistant top coat is applied. Main characteristics: good heat resistance, long-term resistance to high temperatures of 200 □; good adhesion; film with moisture, oil resistance; good weather resistance; can be directly constructed on the 200 □ high temperature substrates. Used for boilers, engine shells, exhaust pipes, chimneys, ovens and other high-temperature equipment, pipeline temperature less than 200 □ steel surface use.

The construction method is completed in two steps: spraying and brushing. High-pressure airless spraying is used. Adopt air spraying should pay attention to adjust the viscosity of the coating and air pressure. Diluent should not exceed 10%, otherwise it will affect the performance of the coating. It is used in pre-coating and small area coating, but the specified dry film thickness must be achieved. The method used in this test is to distribute the sandblasting and shot blasting treatment to the primer layer after drying of the sprayed primer, and then paint the top coat on the surface of the primer layer after sandblasting and shot blasting.

2.2 Pre-treatment of specimens

Pre-cleaning of the test piece: Immerse the test piece in petroleum ether, gently wipe the test piece with a pair of tweezers holding a piece of cotton wool or medical gauze, wipe clean and dry with hot air;

Test piece sanding: in dry condition, the test piece will be sanded step by step with 150-1000 grit sandpaper in the direction of parallel direction along the short side, parallel to the line of the two holes;

Cleaning of the test piece: the polished test piece repeatedly with water to rinse off the surface impurities and sand particles, and then alternately in anhydrous ethanol and acetone ultrasonic cleaning for 5 minutes each of 3 times, until the test piece of abrasive debris, sand and other pollutants on the wash. For inorganic coating specimens do not need to be polished, just repeatedly rinse with water, and then alternately in anhydrous ethanol and acetone ultrasonic cleaning for 5 minutes 3 times each;

Drying of specimens: cleaned specimens are dried with hot air and cooled to room temperature;

Preservation of test pieces: when the test cannot be done immediately, the test pieces should be put into a desiccator for preservation. However, the specimens kept for more than 24h should be re-polished.

3. Content of the experiment

3.1Dry hot air test

The specimens were kept at 600°C for 100h and 1000h, respectively, and then allowed to cool down to room temperature. After the test was completed, the damage, bubbles and discoloration were observed, and the structure, thickness and composition of the coatings were observed and analyzed by scanning electron microscopy, energy spectroscopy and X-ray diffraction to obtain the effects of the above exposure environments on the coatings.

3.2 Neutral salt spray resistance test

Neutral salt spray test according to GB/T1771 or GB/T10125, the cumulative duration of 3000h, and respectively at 500, 1000, 1500, 2000, 2500 and 3000h on the samples to observe whether the coating (scratching fork samples: the place of the cut) is broken or seriously corroded, and the use of scanning electron microscopy, energy spectroscopy, X-ray diffraction on the structure of the coating Scanning electron microscopy, energy spectroscopy, X-ray diffraction were used to observe and analyze the coating structure, thickness, composition, corrosion products, etc., and to obtain the effects of the above exposure environment on the coating.

3.3 Thermal/synthetic seawater salt spray/high humidity cycle resistance

The test piece was exposed to 35±2℃ synthetic seawater spray for 1h, then immediately heated in an air-circulating oven at a temperature of 450℃ for 2h, then cooled down to room temperature, and then exposed to a temperature of 45±3℃ and a humidity of more than 95% for 20h as a cycle, and the test was carried out for 10 consecutive cycles. After the completion of the test, the coating (crossed samples: the place of cutting) was observed to see whether there was any breakage or serious corrosion, and scanning electron microscopy, energy spectrum and X-ray diffraction were used to observe and analyze the structure, thickness, composition and corrosion products of the coating, and to obtain the effect of the exposure environment on the coating as described above.

4. Analysis of results

4.1 Physical and chemical characterization of SERMETEL coatings

Figure 1a shows the surface morphology of the shot peening specimen coated with SERMETEL coating. As can be seen in the figure, the surface of the inorganic phosphate coating is relatively flat and the overall corrugated shape can be seen locally in a small number of microcracks. In addition, the surface of the coating is relatively flat under high magnification, and no cellular protrusions are seen.

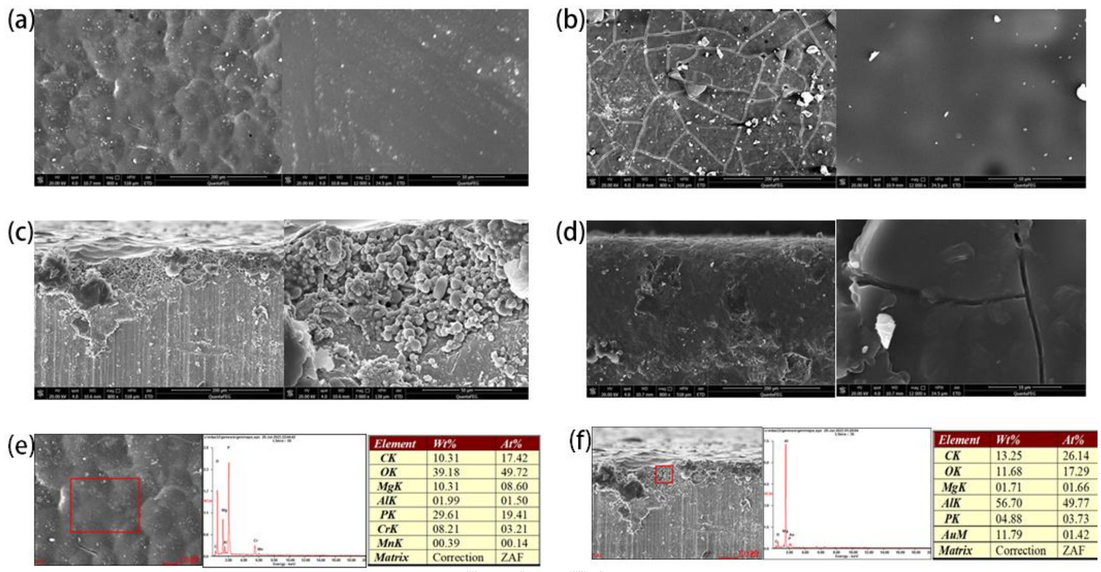

Figure 1: Analysis of physical and chemical properties of SERMETEL coatings. (a) SERMETEL coating shot peening treatment sample surface shape (b) The surface morphology of the sample was treated by sand blasting with SERMETEL coating (c) Section morphology of shot peening sample coated with SERMETEL coating (d) Section morphology of samples treated with SERMETEL coating by sandblasting (e) SERMETEL of EDX energy spectrum of coating sample surface (f) SERMETEL of EDX energy spectrum of coating sample cross section

Figure 1b shows the surface morphology of sandblasted specimens coated with SERMETEL coating. As can be seen in the figure, the surface of the inorganic phosphate coating is relatively flat as a whole, and more micro cracks can be seen in the whole field of view, which are considered to be caused by the drying and shrinkage of the coating as well as the temperature change during the coating preparation process, and the cracks can be seen in the local area as a sign of detachment. In addition, the surface of the coating is relatively flat under high magnification, and no cellular protrusions are seen.

Figure 1c shows the cross-sectional morphology of the shot peening specimen coated with SERMETEL. It can be seen in the figure that the coating is thin, and the bonding with the substrate can be seen obvious boundaries, the coating is relatively loose inside, in the form of stacked particles, more internal pores.

Fig. 1d Cross-sectional morphology of sandblasted specimen coated with SERMETEL coating. It can be seen in the figure that the coating and the substrate are tightly bonded, and the coating is relatively dense inside, but the coating can be seen cracks and localized fragments, which should be thermal cracks caused by the influence of temperature during the preparation of the coating.

Figures 1e and 1f show the EDX spectra of the surface and cross-section of the shot peening specimens coated with SERMETEL coatings, respectively. The spectra show that the chemical elements in the coating are mainly O, C, Cr, P, Mg and Al. From the content of metal elements, the content of Mg element is larger than that of Cr element and larger than that of Al element, and it is assumed that the original composition of the coating is a composite coating of Aluminum Chromium Phosphate and Magnesium Dihydrogen Phosphate. At a certain temperature, the coating decomposed into P_2O_5, Al_2O_3, Cr_2O_3 and MgO composite coating.

4.2 Hot air drying test

The muffle furnace was heated to 600°C, and after the temperature was stabilized, the shot-peened and sandblasted SERMETEL-coated 17-4PH stainless steel specimens were placed into the muffle furnace for 100h and 1000h, respectively, and then allowed to cool down to room temperature. Figures 2a and b show the photographs of the surface condition of the SERMETEL-coated Q235 stainless steel specimens before and after shot peening and sandblasting for 100h and 1000h, respectively, in a dry hot air experiment at 600℃.

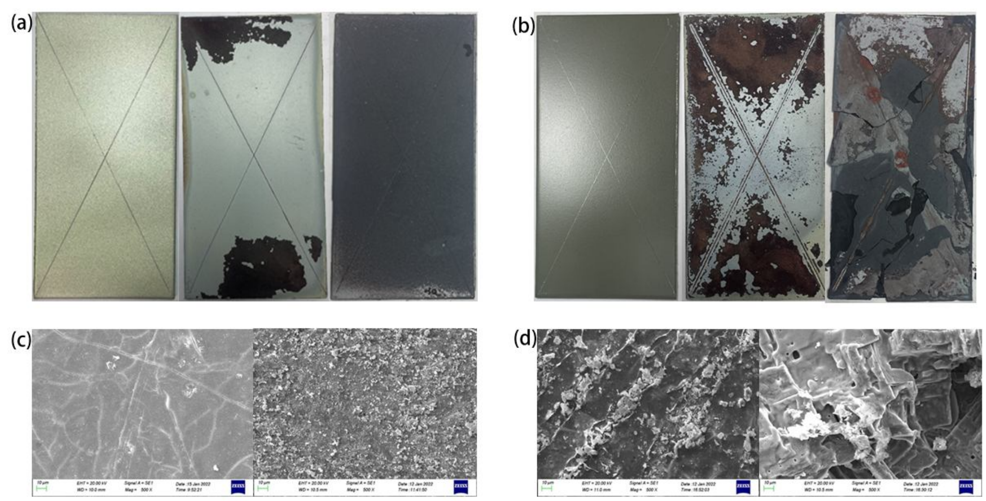

Figure 2:(a)(b) Photographs of surface state of SERMETEL-coated Q235 stainless steel specimens pre-and post-shot peening and sand blasting before and after 100h and 1000h 600 ° C hot air drying experiments (c)(d) Surface Sem photographs of specimens coated with SERMETEL coating after continuous heating for 100 hours and 1000 hours in 600 °C dry air by shot peening and sand blasting.

Coated with SERMETEL coating shot peening specimens in 600 ℃ dry air heating for 100 hours, the specimen on the lower part of the upper part of the obvious signs of ablation loss of coating luster. 600 ℃ dry air heating for 1000 hours, the coating did not appear a large area of the phenomenon of shedding, but the color of the coating loses its luster to black, which indicates that a long time to maintain a temperature of 600 ℃, the coating is still firmly bonded to the substrate, but not shedding. SERMETEL coating shot peening specimens, although more serious oxidative ablation phenomenon, but the coating and the substrate are still firmly combined, there is no phenomenon of shedding. Coated with SERMETEL coating sandblasted specimens at 600 □ in dry air continued to heat 100 hours, the coating appeared more serious oxidative ablation and accompanied by the phenomenon of coating shedding, to 1000 hours, the coating has been completely detached from the substrate and warped into fragments.

Fig. 2 c d shows the SEM photographs of the surface of the specimens coated with SERMETEL coatings by shot peening and sandblasting in dry air at 600°C for 100 h and 1000 h, respectively. Fig. c It can be seen that after 100 hours of continuous heating in dry air at 600°C, the surface of the specimen shows traces of coating fragmentation and detachment. When the time is extended to 1000 hours, the surface of the specimen is oxidized seriously, and the traces of coating are basically invisible, and the surface is covered with oxidized particles. Figure d can be seen in the 600 □ dry air in the continuous heating for 100 hours, the specimen surface has traces of coating cracking and peeling off as well as serious oxidation. When the time is extended to 1000 hours, the coating on the surface of the specimen has all peeled off.

4.3 Neutral salt spray resistance test

Neutral salt spray resistance test according to GB/T1771 or GB/T10125 neutral salt spray test, the cumulative duration of 3000h, and respectively in 500, 1000, 1500, 2000, 2500 and 3000h on the sample to observe the coating (scratch the fork sample: the place where the cut) whether there is a breakage or serious corrosion, to obtain the impact of the above exposure to the environment of the coating.

Figure 3a shows macroscopic photographs of the surface of the 17-4PH stainless steel specimens prior to the neutral salt spray test and after being kept shot peened with the SERMETEL coating for 1000 h, 2000 h and 3000 h, respectively. After 1000 hours of neutral salt spray test, there are more rust stains on the surface of the specimen, especially at the edge part of the specimen and at the scratching point, and the corrosion is serious and extends to both sides of the scratching point. The surface of the specimen is partly covered by reddish-brown rust. When the neutral salt spray test reaches 2000 hours, the surface of the specimen is completely covered by red-brown rust. When the neutral salt spray test reaches 3000 hours, a large area of the surface of the test specimen appears to be peeling off the coating.

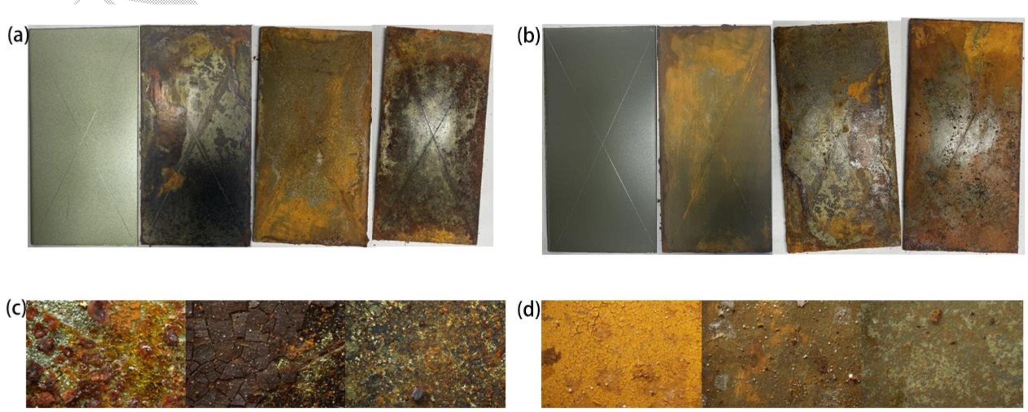

Figure 3: (a)(b) Macroscopic photographs of the surface of 17-4PH stainless steel specimens before neutral salt spray test and after 1000 hours, 2000 hours and 3000 hours, respectively, shot peening and sandblasting of SERMETEL coating (c)(d) Neutral salt spray test 1000h 2000h 3000h SERMETEL coating shot peening and sand blasting Q235 stainless steel samples surface metallographic photographs

Figure 3b shows the macroscopic photographs of the surface of 17-4PH stainless steel specimens before the neutral salt spray test and after keeping the SERMETEL coating sandblasted for 1000, 2000 and 3000 hours respectively. After 1000 hours of neutral salt spray test, there are more rust stains on the surface of the specimen, and the corrosion is more serious at the edge part of the specimen. When the neutral salt spray test reaches 2000 hours, the surface corrosion of the specimen is more serious, and the phenomenon of coating peeling and bulging appears. When the neutral salt spray test reaches 3000 hours, the phenomenon of coating peeling and bulging on the surface of the specimen is more serious.

Figure 3c shows the metallographic photographs of the surface of Q235 stainless steel specimens treated with shot peening of SERMETEL coating in neutral salt spray test 1000h 2000h 3000h respectively. After a long period of neutral salt spray test, the surface of the specimen was covered with reddish-brown rust stains after 1000 hours, and the coating was still visible underneath the rust stains, the surface of the specimen was covered with reddish-brown rust stains, and the coating was seriously puckered and cracked after 2000 hours, and the surface of the specimen was washed repeatedly after 3000 hours, and the coating was lost, and the metal substrate was exposed.

Figure 3d shows the metallographic photographs of the surface of Q235 stainless steel specimens treated with sandblasted SERMETEL coatings in the neutral salt spray test 1000h 2000h 3000h respectively. after 1000h the surface of the specimen is covered with reddish-brown rust stains, after 2000h the surface of the specimen is covered with reddish-brown rust stains, and white salt deposition particles can be seen. after 3000h, the coating is lost and the substrate is exposed.

4.4Heat/synthetic seawater salt spray/high humidity cycle resistance

SERMETEL coated shot and sandblasted Q235 stainless steel specimens in a 35 □ salt spray box synthetic seawater spray 1h, followed by the specimen is immediately transferred to the temperature of 450 □ in the air circulation oven heated for 2h, and then cooled to room temperature, and then in the temperature of 45 □, humidity 95% of humidity in the humidified hot box to maintain 20h, the above process for the heat-resistant / synthetic seawater spray / high humidity The above process is heat resistant/synthetic seawater salt spray/high humidity for 1 test cycle, and 10 consecutive cycles are carried out.

Figure 4a is a macroscopic photo of the surface of Q235 stainless steel specimens coated with SERMETEL coating shot peening before and after the heat-resistant/synthetic seawater salt spray/high humidity cycle test. It can be seen that after the salt spray, high temperature, high humidity compound alternating action, although the metal at the cross has oxidized darker, but the coating at the cross did not see corrosion expansion or shedding phenomenon, corrosion did not extend to the coating and the coating and the metal substrate interface, the coating is only the edge of the corrosion traces, the color of the coating has not changed, but the loss of surface luster. This shows that SERMETEL coating shot peening for seawater salt spray, high temperature, high humidity compound cycle conditions of corrosion resistance is high.

Figure 4b is a macroscopic photograph of the surface of Q235 stainless steel specimens coated with SERMETEL coating sandblasted before and after the heat-resistant/synthetic seawater salt spray/high humidity cycling test, and the surface corrosion situation is the same as that of Q235 stainless steel specimens coated with SERMETEL coating shot peened and sandblasted.

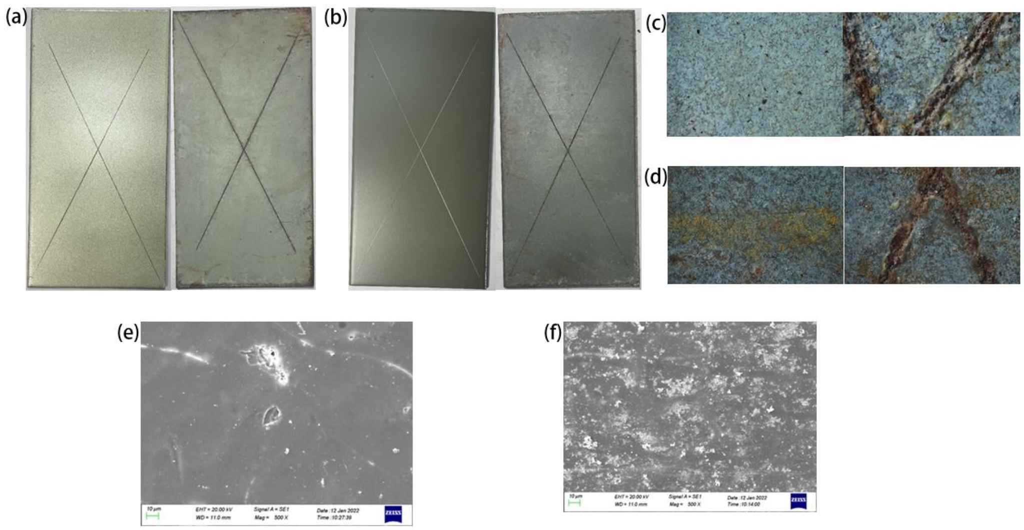

Figure 4: (a)(b) Macroscopic photographs of the surface of Q235 stainless steel specimens coated with SERMETEL coating shot peening and sand blasting before and after thermal/synthetic sea water salt spray/high humidity cycling tests (c)(d) Surface metallography of Q235 stainless steel coated with SERMETEL coating after 10 cycles of heat-resistant/synthetic seawater salt spray/high humidity cycling (e)(f) Scanning electron microscopy (SEM) of SERMETEL coating after thermal/synthetic seawater salt spray/high humidity cycling test.

Fig. 4c and Fig. 4d show the surface metallographic photographs of Q235 stainless steel specimens coated with SERMETEL coatings by shot peening and sandblasting after 10 cycles of 1h synthetic seawater spraying in a salt spray chamber at 35°C, 2h heating in an air-circulating oven at a temperature of 450°C, and 20h of heat-resistant/ synthetic seawater salt spraying/high-humidity cycling in a humid chamber with a temperature of 45°C and a humidity of 95%, respectively. In the picture, it can be seen that the surface of the specimen has more corrosion phenomenon, but no coating peeling off. There is obvious corrosion at the crossing but there is no shedding of coating based on the crossing area, which indicates that the coating and the substrate have a good bonding strength, and although there is corrosion on the surface after cycling under the three conditions, it is obvious that the corrosion fails to reduce the bonding strength between the coating and the substrate. Salt deposition on the surface of the coating was observed, especially at the scoring area, because the scoring area was rough and the salt in the synthetic seawater was easy to be precipitated and deposited in the grooves.

Fig. 4e f shows the SEM morphology of shot peening and sandblasting coated SERMETEL coatings after heat/ synthetic seawater salt spray/ high humidity cycling tests, respectively. It can be seen that the surface of the shot peening specimen has the phenomenon of coating surface crack expansion and fragmentation. The sandblasted specimen has salt dissolution deposits on the surface.

5. Conclusion

This project mainly focuses on the dry hot air test, heat/synthetic seawater salt spray/high humidity cycling test, heat/synthetic seawater salt spray cycling test, synthetic seawater continuous spraying test, neutral salt spray test, electrochemical test and abrasion test for shot peening and sandblasting SERMETEL coatings, respectively, to make a detailed discussion on the problems of corrosion and wear resistance of SERMETEL coatings, and to make up for the problems of corrosion and wear resistance of phosphate coatings in the industry. The problems of the current research will be discussed in detail, to make up for the corrosion and wear resistance of SERMETEL coatings in the corrosion and abrasion performance of the relevant research, for the application of such a wide range of phosphate coatings, can be its preparation and application in the industry, to provide certain guidance and reference, is of great significance. Specific test conclusions are as follows:

(1) coated with SERMETEL coating shot peening specimens in 600 □ dry air heating 100 hours, the specimen on the lower part of the upper part of the obvious ablation traces of the loss of coating luster. 600 □ dry air heating 1000 hours, the coating did not appear to be a large area of the phenomenon of shedding, but the coating color loses its luster to black, which indicates that a long time to maintain the temperature at 600 □, the SERMETEL coating shot peening specimens, although more serious oxidative ablation phenomenon, but the coating and the substrate are still firmly combined, there is no phenomenon of shedding. Coated with SERMETEL coating sandblasted specimens in 600 □ dry air continued to heat 100 hours, the coating appeared more serious oxidative ablation and accompanied by the phenomenon of coating shedding, to 1000 hours, the coating has been completely detached from the substrate and warped into pieces. This indicates that the SERMETEL coated sandblasted specimen has poor resistance to long time high temperature environment, far less than the coated SERMETEL coated shotblasted specimen.

(2) After 1000 hours of neutral salt spray test, there are more rust stains on the surface of the SERMETEL coated shot peening specimen, especially on the edge of the specimen and at the fork, and the rust is serious, and the corrosion expands to both sides of the fork. The surface of the specimen was partially covered with reddish-brown rust. When the neutral salt spray test reaches 2000 hours, the surface of the specimen is completely covered by red-brown rust. When the neutral salt spray test reaches 3,000 hours, a large area of the surface of the specimen appears to be peeling off the coating. After 1000 hours of neutral salt spray test, the surface of

SERMETEL coated sandblasted specimen has more rust stains, and the corrosion is more serious at the edge of the specimen. When the neutral salt spray test reaches 2000 hours, the surface corrosion of the specimen is more serious, and the phenomenon of coating peeling and bulging occurs. When the neutral salt spray test reaches 3000 hours, the phenomenon of coating peeling and bulging on the specimen surface is more serious.

(3) After the salt spray, high temperature, high humidity compound alternating action, although the metal at the cross has oxidized darker, but the coating at the cross did not see corrosion expansion or shedding phenomenon, corrosion did not extend to the coating and the coating and the metal substrate interface, the coating is only the edge of the corrosion traces, the color of the coating has not changed, but the loss of surface luster. This shows that SERMETEL coating shot peening and sandblasting for seawater salt spray, high temperature, high humidity compound cycle conditions of corrosion resistance is higher.

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