CORROSION FAILURE OF NI-RESIST PUMPING SYSTEM COMPONENTS

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ABSTRACT

A new high pressure horizontal pumping system failed shortly after installation. The previous system lasted for more than five years.

The failed components were made from Ni-Resist type 1, which is a widely used material in corrosive environments. They were coated with a polytetrafluoroethylene (PTFE) based surface coating.

Our examination, which included visual examination, x-ray diffraction, optical microscopy examination, metallographic examination, and scanning electron microscopy (SEM) examination, did not reveal any indications of impingement corrosion, abrasive wear or cavitation.

The root cause of failure and design concepts to prevent similar future problems will be reviewed.

Keywords: coating, failure, blister, passivation, corrosion fatigue, Ni-Resist

INTRODUCTION

The high pressure horizontal pumping system was brand new and was installed in March 2008 as part of an oilfield water injection system. The pump impellers and diffusers failed after less than a year in service by corrosion and cracking of thin parts.

The old impellers and diffusers, which operated in similar conditions, were in service for about five years before they required replacement.

A mixture of the lake water blended with the produced water was re-injected in the field. There were no changes to the fluid composition, specifically with the amount of abrasive particles in water and/or increased oxygen content in water which could result in the accelerated failure.

The failed impellers and diffusers were manufactured with Ni-Resist type 1 material, which is a cast iron-based alloy containing 15% Ni 6% Cu, and 2% Cr. It was coated with a 1.5 mil (40 μm) thick PTFE coating.

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INVESTIGATION PROCEDURE

The failed components were examined visually and ultrasonically cleaned. Corrosion deposits were examined by X-Ray diffraction (XRD). Metallographic cross-sections were prepared from the areas of failure and examined using optical microscopy and scanning electron microscopy (SEM) techniques. Elemental compositions at different locations were determined by an energy-dispersive X-ray spectroscopy (EDS) technique.

RESULTS

Visual and Optical Microscopy Examination

Two modes of failure were observed: overall metal loss corrosion damage and cracking in guideways (Figure 1).

The examination after the cleaning (see Figure 2) showed that the coating failed by the growth and subsequent removal of blisters. The damage was distributed non-uniformly. The coating in the areas closest to centre of the impeller was damaged the least, and the coating in the areas close to the external surface of the impeller was damaged the most.

Corrosion Products

XRD examination determined two corrosion processes: H_2S corrosion was a major corrosion process, accounting for 83% of all corrosion products; aqueous corrosion was a minor corrosion process, accounting for 17% of all corrosion products. The presence of halite (NaCl) in the produced water could significantly accelerate corrosion processes.

Metallographic Examination

Metallographic examination revealed that the base metal exhibited microstructure of gray cast iron[1]. The microstructure contained randomly distributed elongated graphite flakes (type VII A size 3.5), and rosette-like graphite flakes (type VII B)[2]. This type of microstructure was expected for the Ni-Resist material.

The main crack (shown in Figure 3) was located in the thinnest part of the guideway, in the area of absent coating, and it penetrated the entire wall thickness. The metal surface in the crack initiation area and the fracture surface of the main crack was covered with corrosion products. This indicates the main crack was not created by abrasive wear, as it would result in the absence of corrosion product.

SEM / EDS Examination

Figures 4 and 5 show the results of SEM examination. The coating thickness varied from 25 to 50 μm (0.001 to 0.002 inches). The fluorocarbon coating was porous and contained pathways for corrosive media to transport to the metal surface. The blisters were filled with corrosion products, mainly iron sulfide.

There were two additional layers between the base metal (Ni-Resist) and the coating. They are indicated in Figure 5 as FeS-rich layer and Si-rich layer.

The Si-rich layer was adjacent to the base metal. It contained 30% oxygen and 20% silicon, which indicates that its major component is sand (SiO_2). This layer also contained a high percentage of chromium, nickel and copper. This layer was most likely formed at the time of sand casting.

The FeS-rich layer was adjacent to the coating layer. It contained 28% sulfur, and 57% iron. This indicates the layer is likely a corrosion product which formed in service.

DISCUSSION

Corrosion Failure

The massive amount of corrosion deposit on the surfaces of the impellers and diffusers was due to the coating failure. The impellers and diffusers were manufactured by casting. Casting resulted in formation of a surface scale of silicon based sands, ceramics, and inclusions. After casting, the surface scale was not completely removed by pickling. Pickling was probably performed for a short time, if performed at all.

The silicon rich surface scale after casting could have prevented passivation of the surface, which would not allow optimum corrosion resistance from Ni-Resist. The surfaces of the impellers and diffusers were covered with an additional layer of PTFE-based surface coating.

This coating was porous, which allowed corrosive liquid to contact the base metal resulting in its corrosion. When the corrosive media reached the surface of the cast Ni-Resist, which did not contain the passive film, it corroded, forming a corrosion deposit. As the density of corrosion deposit is considerably less compared to the density of metal, and the formation of corrosion deposit between the surface coating and the base metal will lift the coating, blisters will form.

Blisters will grow in size and eventually break, mechanically damaging the coating and allowing more corrosive media to reach the unprotected metal surface.

Cracking of Guideways

A metallographic examination confirmed the cracks in the diffuser guideways were not associated with either stress corrosion cracking or corrosion erosion, and they were most likely associated with corrosion fatigue. The fatigue cracks started in the corrosion pits, which in turn were created at the locations of the absent or damaged coating. When corrosion pits reached the interconnected network of graphite flakes, the corrosive media reached deeper areas of the base metal. The cyclic loading required for fatigue was due to shaft rotation.

CONCLUSIONS

The root cause of the corrosion failures was a combined result of the coating condition, which was permeable to corrosive media, and the unprotected surface of Ni-Resist, which did not contain a protective passive film. Instead, it contained an un-removed surface scale of sand, ceramics and possibly inclusions after casting.

Thorough cleaning of the surfaces, removing the casting scale and allowing the passive layer to form on the surface would have prevented the observed failure.

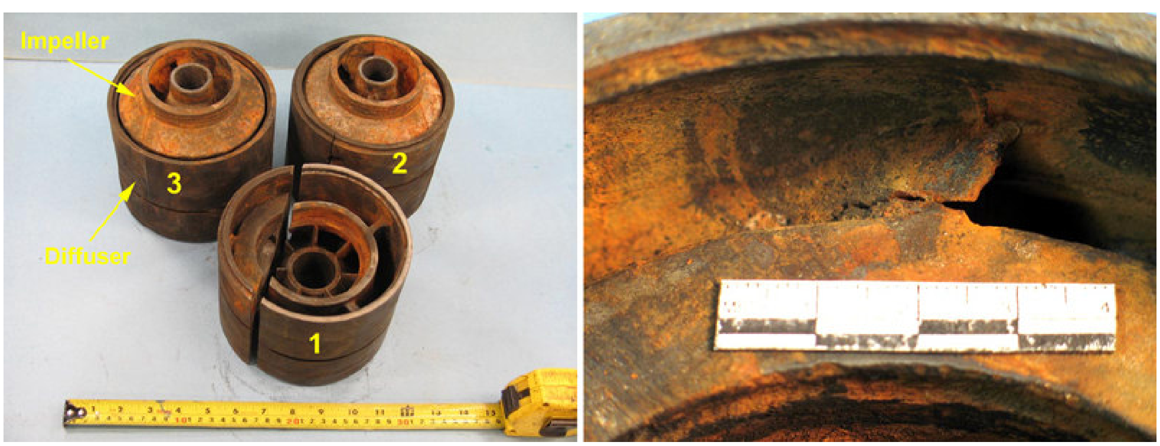

FIGURE 1 – Failed Parts Submitted for Examination

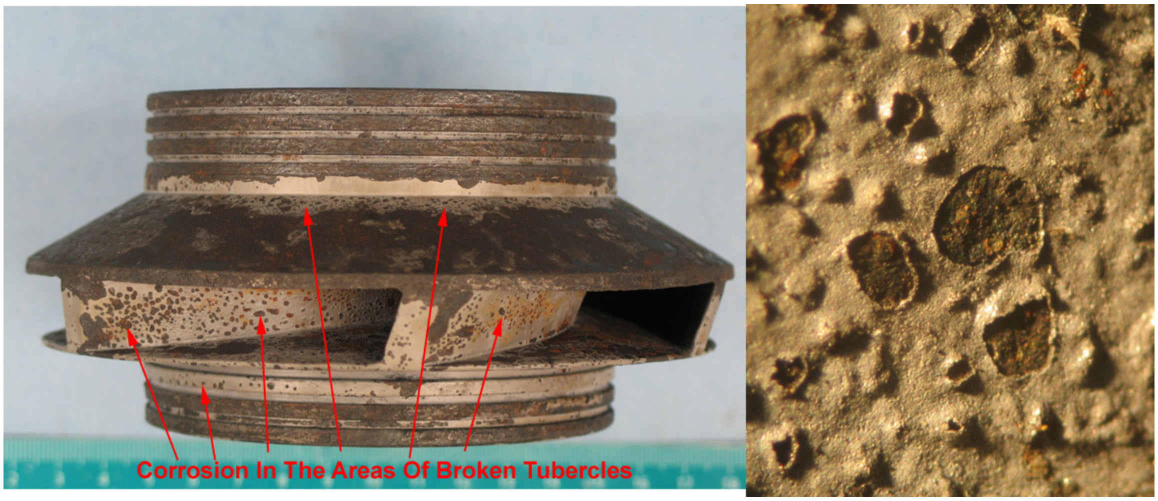

FIGURE 2 – Impeller: Coating Damage

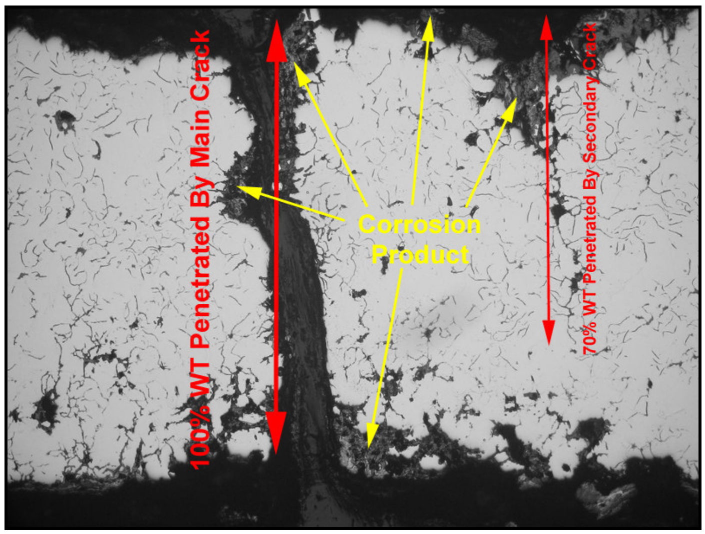

FIGURE 3 – Metallographic Cross–Section Of Crack. Mag. 75X

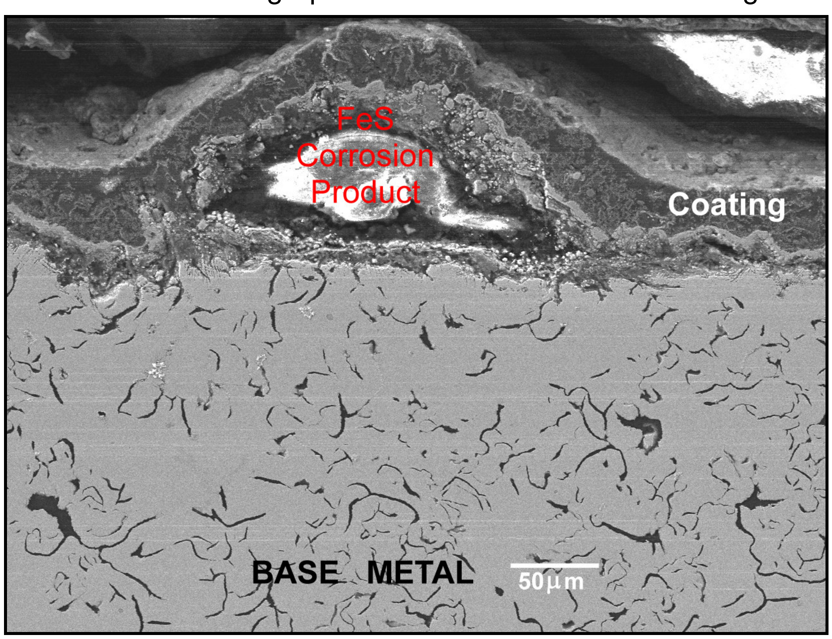

FIGURE 4 – SEM Image: Coating Blister

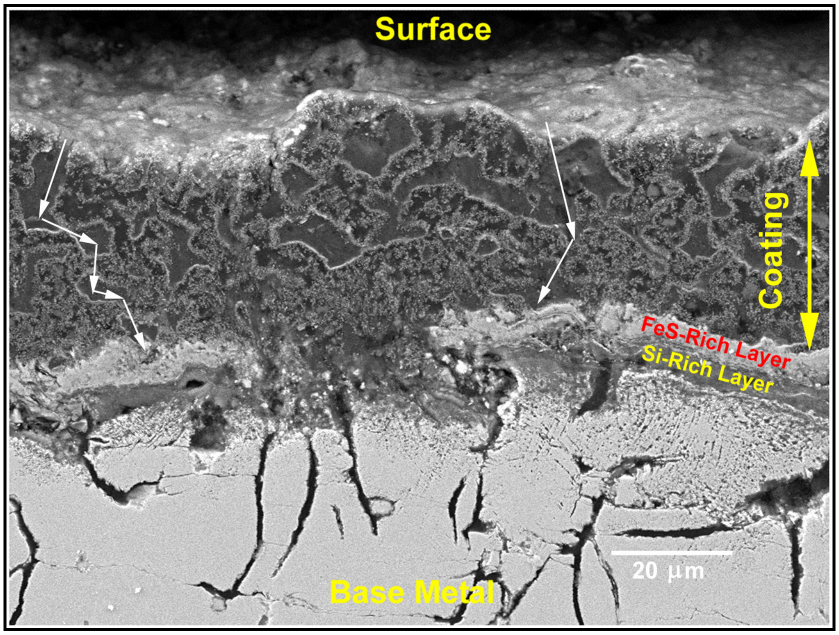

FIGURE 5 – SEM Image: Coating And Additional Layers

REFERENCES

1. ASTM A436 (2001) Standard Specification for Austenitic Gray Iron Castings.

2. ASTM A247 (98): Standard Test Method for Evaluating the Microstructure of Graphite in Iron Castings.