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Research Article

Investigation on erosion-corrosion behaviour of gate valve used in main water distribution line of Oman

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Abstract

Corrosion occurs as a result of the interaction of a metal with its environment. The extent of corrosion depends on the type of metal. This paper focuses on the investigation on erosion- corrosion behavior of gate valve used in main water distribution line of Oman. The hydrant valves are critically eroded and corroded because of the poor quality of coatings. Hence different types of metallic coatings are proposed to eradicate the erosion corrosion problem on the valves. Samples were cut from the actual valves and different coatings such as nickel-phosphorus, zinc, chromium and epoxy coatings were coated on the samples. Different nano materials such as nano Al_2O_3, nano ZnO and nano CuO (40~50 nm size) were mixed with the coatings and corresponding coatings have been done. Electroless technique was used to coat Ni-P on the samples. Zinc and Chromium were coated by spray technique. Epoxy coating was applied by brush. Different corrosion tests like atmospheric exposure test, wet corrosion test and erosion corrosion test were carried out on the different coated samples. The qualities of different coatings were compared and results were analyzed. Coated samples were characterized with help of scanning electron microscope and optical microscope. The surface roughness of coated samples was measured using stylus probe surface roughness meter. The hardness of samples was measured using Rockwell hardness tester. Among the different types of coatings used the electroless Ni-P coatings with nano Al2O3 resulted in superior corrosion resistance with negligible corrosion formed after a period of 12 weeks exposure.

Keywords: Metallic corrosion; Coatings; Hydrant valves; Chromium; Electroless nickel coatings; Powder coating.

Introduction

Corrosion is a chemical reaction between metal and environment. The gate valve (hydrant valve) used in water line of main water distribution lines undergoes severe erosion corrosion problem. Due to this problem the life time is reduced and resulted in high replacement cost every year (Elansezhian et al. 2008). To overcome the existing problem a different types of coatings were proposed and the quality of coatings were studied.

Erosion corrosion is the combined effect that occurs due to corrosion and erosion and is caused by the rapid turbulent flow of any fluid on a metal surface (Elansezhian et al., 2009). A bite, which is often located in the inner surfaces of pipes, valve door eta is the leading cause of turbulence. The erosion rate increases in turbulent conditions and may result in leaks in pipes and tubes (Fontana & Greene, 1978). To overcome the existing problem a new multilayer coating is proposed in the present study. The multilayer coating is most common anti-corrosion treatment the works do by providing Insulator of corrosion-resistant material between the damaging environment and the structural material (Rajendran et al., 2010). Typical areas of application include Pipe line, Gate valve, Flange and coupling (Dirjal et al. 1998).

Materials and methods

The experimental procedure adopted, relevant parameters and equipment employed during the course of the present investigation are reported. Preprocessing: the major steps in preprocessing are given below (Sudagar et al. 2012):

- Cut piece into fourteen numbers of sample by size of 30 mm x 30 mm.
- Use sandpaper to remove rust.
- Cleaning samples by Acetone, Methanol and dilute sulphuric Acid (10% v/v).

- Weight all sample before coating and after coating by using digital analytical balance. Also find surface roughness and hardness.
- Samples were coated with the following different types of coating:
  - ✓ Electroless Ni-P + Nano Al_2O_3
  - ✓ Electroless Ni-P + Nano CuO
  - ✓ Electroless Ni-P + Nano ZnO
  - ✓ Chrome coating
  - ✓ Zinc phosphate and Epoxy powder coating.
- All the samples were coated with uniform coating thickness of 15 – 20 µm. Samples were coated under static condition of water and running water.

Table 1. Compositions of plating bath used for electroless Ni- P coatings

EN Bath Compositions		Quantity (g/l)
Nickel source	$NiCl_2$	30
Reducing agent	$H_2NaO_2P{\cdot}H_2O$	40
Stabilizer	$Na_3C_6H_5O_7$	25
Comlexing agent	NH_4Cl	50
Anionic surfactant	$NaC_{12}H_{25}SO_4$	1.2
Cationic surfactant	$C_{19}H_{42}BrN$	1.5
	Temperature	85^0C (±1^0C)
	pH	9 – 10

Production of electroless Coatings

Plating bath and operating conditions

The basic composition of the plating bath for electroless Ni-P deposition had: Nickel chloride as the source of nickel, sodium hypo-phosphite as the reducing agent, sodium citrate as the stabilizer and ammonium chloride as the complexing agent (Arenas and Reddy, 2003). The specific bath compositions and plating conditions used are presented in Table 1.

The surfactant SDS was added to solution before electroless nickel deposition with concentrations of 1.2 g/l and CTAB with concentrations of 1.5 g/l. Temperature of the plating bath was maintained at 85^0C (±1^0C). The experimental set up used for electroless Ni-P plating is shown in Figure 1.

Figure 1. Electroless coating setup

Results and discussions

Results of laboratory experiments carried are shown in this part. The test results of corrosion and erosion at different conditions are presented.

Hardness Roughness Test

The Rockwell hardness values of different coatings are listed below and shown in Figure 2.

Table 2. Value of hardness test

Type of coating	Hardness (HRC)
Nano Al_2O_3	56.4
Nano ZnO	55
Nano CuO	55.3
Ni-P	53.6
Chrome	53.6
Zinc phosphate & Epoxy powder	52.6
Uncoated	52.4

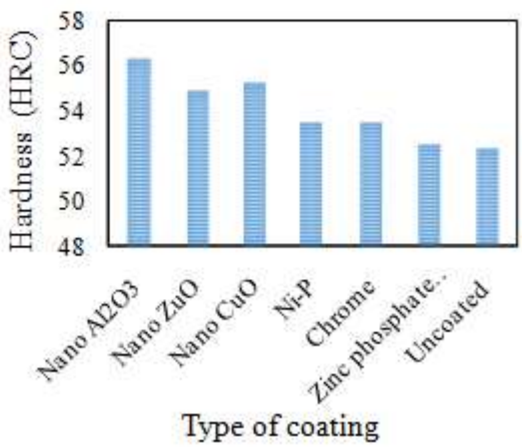

Figure 2. Hardness for samples

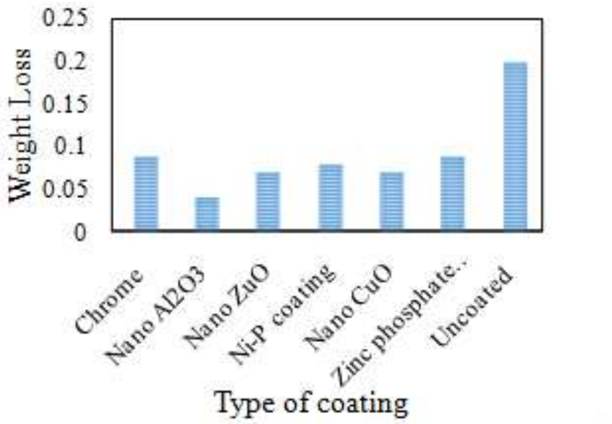

Figure 3. Weight loss of different coatings

Corrosion Test

The samples were tested under static water condition. The samples were exposed to wet condition and were monitored every day. Total period of exposure was for 12 weeks. Corrosion started on different coatings and they are shown in Table 3.

Table 3. Corrosion Test

Samples	**Exposure Period (Weeks)**								
Coated Samples	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Electroless Ni-P					x	x	x	x	x
Chrome		x	x	x	x	x	x	x	x
Nano CuO					x	x	x	x	x
Nano Al_2O_3							x	x	x
Nano ZnO					x	x	x	x	x
Zinc phosphate & epoxy powder		x	x	x	x	x	x	x	x
Uncoated	x	x	x	x	x	x	x	x	x

Erosion test

The coated samples tested for erosion test. A simulator test set up was designed and fabricated to carry out the test. The erosion test results on different coatings are shown in Figure 4.

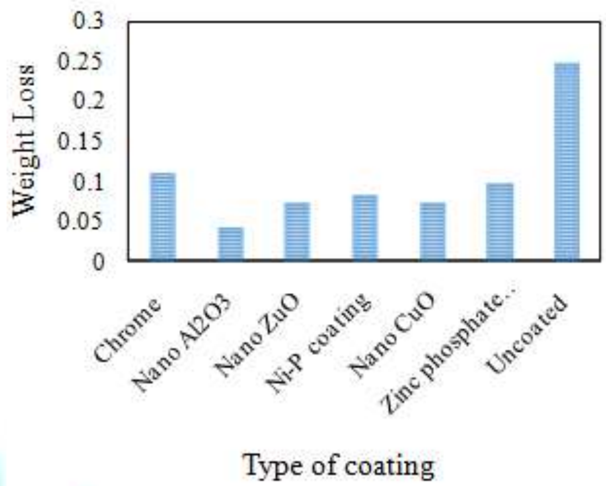

Figure 4. Weight loss in erosion test

Microstructure and surface morphology

The surface morphology of coated samples was examined under scanning electron microscope and optical microscopes to determine the coating structure. Corrosion formed on the coated samples varies from uniform corrosion and localized corrosion. The SEM micrographs and optical structures are presented in Figure 5 to Figure 14.

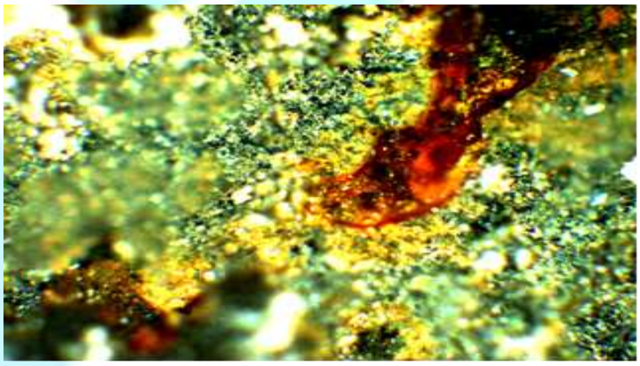

Figure 5. Optical microstructure (200X) of Nano CuO coated sample after exposed to erosion test

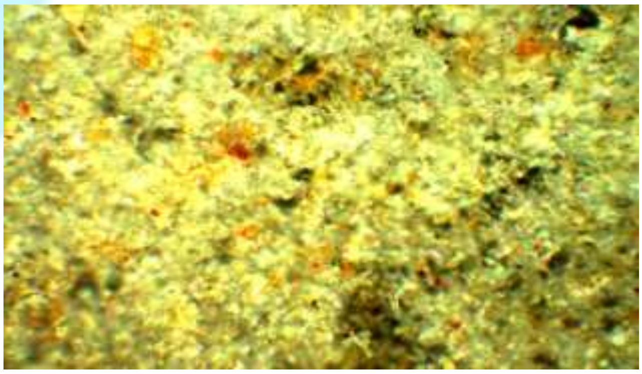

Figure 6. Optical microstructure (200X) of Electroless Ni-P nano ZnO coated sample after exposed to corrosion test

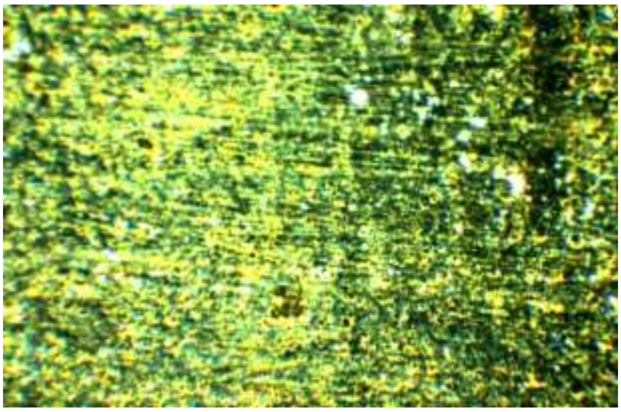

Figure 7. Optical microstructure (200X) of Electroless Ni-P nano Al_2O_3 coated sample after exposed to corrosion test

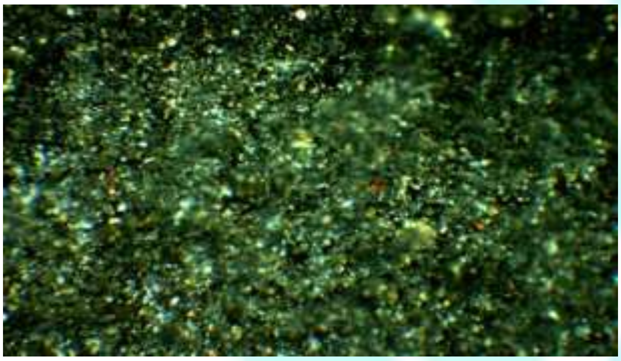

Figure 8. Optical microstructure (200X) of uncoated sample after exposed to corrosion test

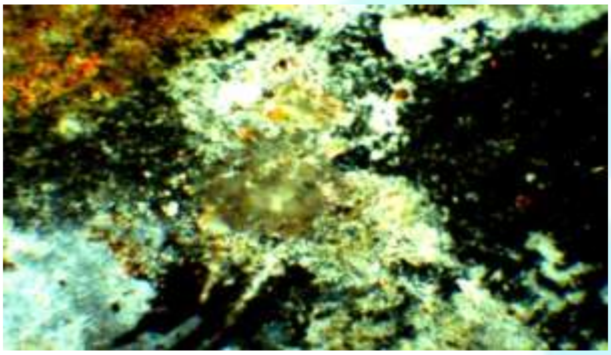

Figure 9. Optical microstructure (200X) of Zinc phosphate &Epoxy powder coated sample after exposed to erosion test

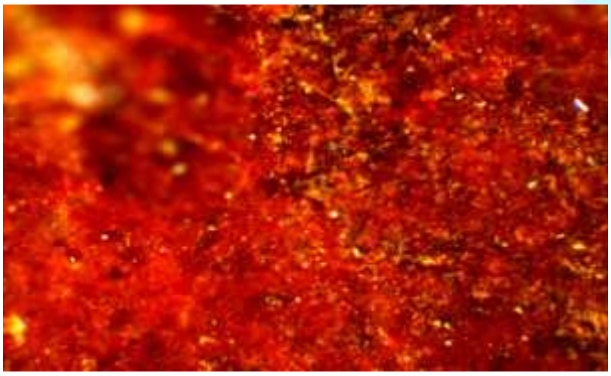

Figure 10. Optical microstructure (200X) of Electroless Ni-P Nano CuO coated sample after exposed to erosion test

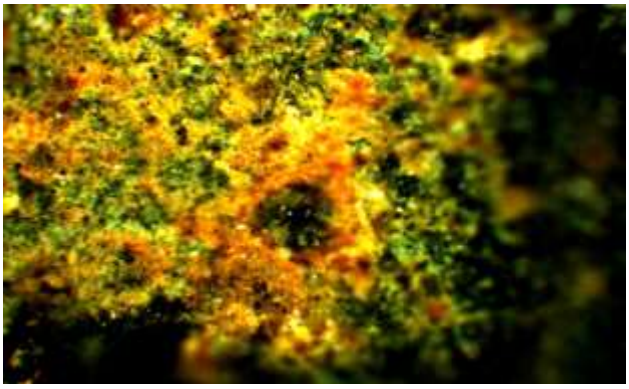

Figure 11. Optical microstructure (200X) of Electroless Ni-P nano ZnO coated sample after exposed to erosion test

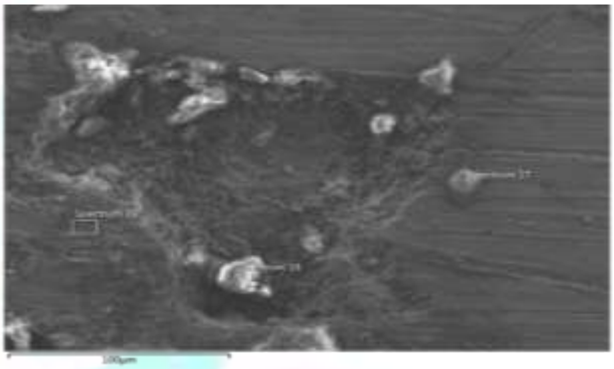

Figure 12. SEM microstructure (1000x) of Electroless Ni-P–Nano Al_2O_3 coated sample after exposed to 2184 hours of erosion test

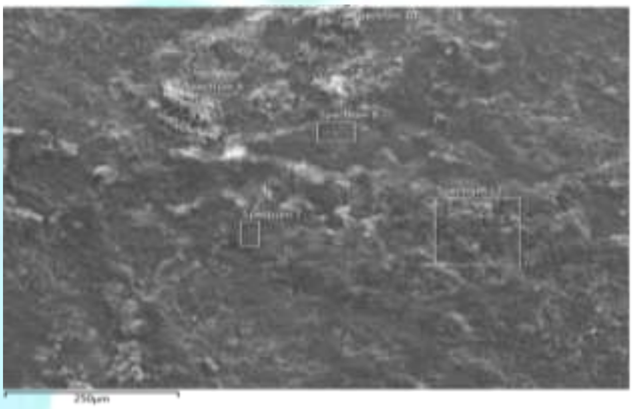

Figure 13. SEM microstructure (1000x) of Electroless Ni-P- nano CuO coated sample after exposed to 2184 hours of erosion test

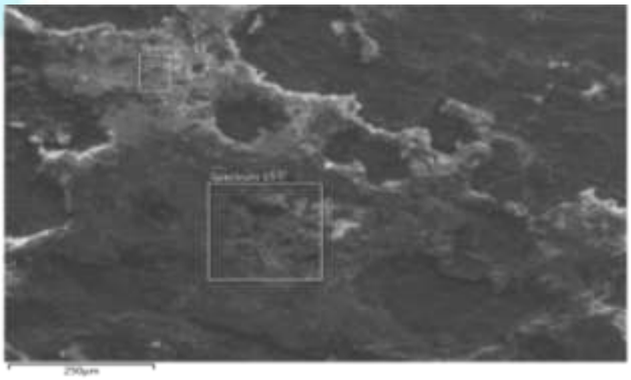

Figure 14. SEM microstructure (1000x) of Electroless Ni-P –nano ZnO coated sample after exposed to 2184 hours of erosion test

Conclusions

Corrosion is a major problem which leads to several million riyals loss to the society in Oman. The corrosion in water distribution line leads to economic loss and affects the quality of water distributed to the society. Hence to overcome the problem of erosion corrosion in the water line of main distribution system different coatings are proposed in this study. The corrosion rate and quality of coatings are investigated and reported. Among the different types of coatings used the electroless Ni-P coatings with Nano Al_2O_3 resulted in superior corrosion resistance with negligible corrosion formed after a period of 12 weeks exposure. After carrying out erosion–corrosion test, the Nanocoatings shows significant protection on the samples. In future, different types of Nanomaterials may be used in the coatings and their corresponding effect on corrosion behavior may be investigated.

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